White Heat Cold Logic

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White Heat Cold Logic: British Computer Art 1960–1980, edited by Paul Brown, Charlie Gere, Nicholas Lambert, and Catherine Mason, 2008

White Heat Cold Logic

British Computer Art 1960–1980

**Edited by Paul Brown, Charlie Gere,
Nicholas Lambert, and Catherine Mason**

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The arts, science, and technology are experiencing a period of profound change. Explosive challenges to the institutions and practices of engineering, art making, and scientific research raise urgent questions of ethics, craft, and care for the planet and its inhabitants. Unforeseen forms of beauty and understanding are possible, but so too are unexpected risks and threats. A newly global connectivity creates new arenas for interaction among science, art, and technology but also creates the preconditions for global crises. The Leonardo Book Series, published by the MIT Press, aims to consider these opportunities, changes, and challenges in books that are both timely and of enduring value.

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Leonardo, the International Society for the Arts, Sciences, and Technology, and the affiliated French organization Association Leonardo have two very simple goals:

1. to document and make known the work of artists, researchers, and scholars interested in the ways that the contemporary arts interact with science and technology and
2. to create a forum and meeting places where artists, scientists, and engineers can meet, exchange ideas, and, where appropriate, collaborate.

When the journal *Leonardo* was started some forty years ago, these creative disciplines existed in segregated institutional and social networks, a situation dramatized at that time by the "Two Cultures" debates initiated by C. P. Snow. Today we live in a different time of cross-disciplinary ferment, collaboration, and intellectual confrontation enabled by new hybrid organizations, new funding sponsors, and the shared tools of computers and the Internet. Above all, new generations of artist-researchers and researcher-artists are now at work individually and in collaborative teams bridging the art, science, and technology disciplines. Perhaps in our lifetimes we will see the emergence of "new Leonardos"—creative individuals or teams that will not only develop a meaningful art for our times but also drive new agendas in science and stimulate technological innovation that addresses today's human needs.

For more information on the activities of the Leonardo organizations and networks, please visit our Web sites at ⟨http://www.leonardo.info/⟩ and ⟨http://www.olats.org⟩.

Roger F. Malina
Chair, Leonardo/ISAST

Acknowledgments

This book is one of the outcomes of the CACHe (Computer Arts, Contexts, Histories etc) research project that was undertaken at Birkbeck, University of London, from 2002 to 2005.

That project, and this volume, would not have been possible without the help and assistance of many institutions and individuals. They are far too many to name individually, and so we hope they will not be offended by our blanket thank-you!

However, we would like to especially thank all of the individual contributors to this volume; the Arts and Humanities Research Council (or Board as it was then) for its generous financial support for the CACHe project; the School of History of Art, Film and Visual Media, Birkbeck, University of London, which hosted our project; George Mallen and System Simulation Ltd.; the committee and members of the Computer Arts Society; Doug Dodds and the Victoria and Albert Museum; Jasia Reichardt, curator of the seminal exhibition *Cybernetic Serendipity* for access to her archive; Dorothy Lansdown, the widow of R. John Lansdown, whose contribution to the field inspired our project; Olga Ihnatowicz; Patric Prince, whose donation to the Victoria and Albert Museum forms the foundation of their growing collection of early computer art; the Rutherford Atlas Laboratories, which gave us access to its archives; and Middlesex University, which gave us access to its Lansdown Archive.

This volume is dedicated to the memory of R. John Lansdown, one of the great pioneers of the computer arts.

1

Introduction

Charlie Gere

As its subtitle suggests, the aim of this book is to recount the history of the digital and computer-based arts in the United Kingdom from their origins to 1980. It also has a rather more polemical intention: to forcefully argue for the importance of such a history, which has otherwise been disregarded. It is our belief that the digital and computer-based arts, both in the United Kingdom and elsewhere, have been woefully neglected by contemporary art galleries and institutions involved in the history of art. This has been to the detriment of our understanding of not only this area of practice, but, more generally, art and culture in the post-war era in Britain. The post-war era was a time of technological optimism and even utopianism, in which Harold Wilson, speaking at the 1963 Labour Party conference, promised that a new Britain would be forged in the white heat of the scientific and technological revolution. The cold logic of computing was a vital component of this white heat, and artists played a central role in enabling cultural understanding and acceptance of new technologies. Even if our technological optimism and utopianism has somewhat abated, the highly technologized and mediated world we now live in owes much to such pioneers, not least for how their work expanded our sense of what we might be able to do with such technologies. We hope and intend that this collection of essays will be part of a process of redressing the marginalization of the pioneering work of these artists and their vital contributions to our contemporary technoculture.

The subtitle proposes a fairly concrete beginning and end to the historical period on which we are focusing. Computing started to become more ubiquitous and, with the emergence of personal computing and graphical user interfaces (GUIs), far more accessible around 1980. This marked the end of the early, heroic, pioneering period of computer art, which required artists to build their own machines, collaborate closely with computer scientists, or learn challenging computer languages. The question of origins or beginnings has deliberately been left vague. As any historian knows, it is difficult to pinpoint when something can be said to have started, and there are many possible points of origin for British computer art. It would be reasonable, for example, to go back to the early nineteenth century attempts by Charles Babbage to build calculating machines, and colleague Ada Lovelace's perception that such machines might be used for more than mere calculation. Numerous other points of origin could also be cited, including the history of avant-garde involvement with machinery and "new" media such as photography and film. But perhaps the strongest claim for moment of origin can be made for the 1956 exhibition, *This is Tomorrow*, at the Whitechapel Art Gallery in London's East End. This exhibition was a response to advances in technology and developments in communications and media, and took the form of a number of collaborations among artists, architects, and designers.

Many of those involved in *This is Tomorrow* were part of the loose group of artists, architects, designers and theorists known as the Independent Group, which coalesced around the recently founded Institute of Contemporary Arts (ICA). Some of them have since been called fathers of pop art, and are considered the first artists and theorists to celebrate popular culture, particularly as manifested in the United States. They are also known for critiquing the hierarchical understanding of art and culture represented by establishment figures such as Herbert Read.

In fact the Independent Group had a far broader range of interests, including science, non-Aristotelian logic, cybernetics, sociology, and new technologies. This eclecticism was demonstrated in the exhibition, which was divided into twelve sections, each put together by teams composed of various combinations of architect, artist, designer, and theorist. The twelfth and final section of the exhibition was the most directly concerned with theories of systems and communications. In the catalogue a text by Geoffrey Holroyd, Toni del Renzio, and Lawrence Alloway, describes its concerns as follows:

> This section of *This is Tomorrow* represents the basis of collaboration between architect and artist as part of a general human activity rather than as the reconciliation of specialised æsthetic systems. It is communications research which offers a means of talking about human activities (including art and architecture) without dividing them into compartments. Hitherto the conventional definition of the artist and architect has limited their efficacy to narrow mutually exclusive areas. It is this that has made collaboration difficult. Seeing art and architecture in the framework of communications, however, can reduce these difficulties by a new sense of what is important. (Alloway, Banham, and Lewis, 1956, n.p.)

At the bottom of the left-hand page there is a text that states:

> There has always been a variety of channels available for communications but modern technology has increased the scope of communication and the audience has increased in size. This

> chart suggests a way to organise this multiplicity of messages by reference to the characteristics of different channels. By its use the visual arts can be set in new relationships, free of the learned responses of composition, experiment and so on. (Ibid.)

This is accompanied by a table of three columns, showing the variety of different surfaces and means of making things on those surfaces, ranging from marks made by sticks on sand, through making colored painting by paints and brushes on cave or canvas. The final forms of operation are punched card machines producing punched card tapes by motor and input instructions, and, at the very bottom, magnetic surfaces, wire tape, and disk being produced on machinery by motor and input instructions. In this diagram, there is to be found one of the first statements, in the English language at least, about the computer and other computing machinery as potential means of making art—as good a point as any to mark the beginnings of computer art in Britain.

Though most members of the Independent Group did not, either then or later, use computers to make art, their interest in technology and technological discourses helped make British computer art possible. Their influence was both direct and diffuse. They created a general context in which such work might be taken seriously; and they directly fostered the careers of practitioners such as Roy Ascott (as described in "Creative Cybernetics: The Emergence of an Art Based on Interaction, Process, and System" (chapter 2). Ascott was taken on as a student and subsequently into the Basic Design course implemented by Richard Hamilton and Victor Pasmore at Kings College (in Newcastle upon Tyne, but then part of University of Durham). Ascott would in turn go on to teach and employ important figures such as Stephen Willats, which Adrian Glew describes in "Transmitting Art Triggers: The Early Interactive Work of Stephen Willats" (chapter 3).

Section Two of *This is Tomorrow* featured architect Cedric Price's cybernetics-influenced *Fun Palace*, as described in John Hamilton Frazer's "Interactive Architecture" (chapter 4), which also deals with Price's later work, the *Generator*. Though Price was an architect rather than an artist, as is true of Frazer himself, their experiences in trying to use computers in the period between the 1950s and the early 1980s are representative of the more general set of problems and promises that was typical of early computer art in the United Kingdom. As the chapter also makes clear, cybernetics was of great interest to members of the Independent Group, and at least a few of them had read Norbert Wiener's book *Cybernetics or Control and Communication in the Animal World* (1948) and *The Human Use of Human Beings* (1950). In these books, Wiener formulated the idea of information and feedback as the bases of a paradigm for understanding biological, machinic, and social processes. Cybernetics was extremely important for the development of British computer art, not just for the Independent Group but also for the work of British cyberneticians such as

Stafford Beer and Gordon Pask. As María Fernández's "'Aesthetically Potent Environments', or How Gordon Pask Detourned Instrumental Cybernetics" (chapter 5) shows, Pask was highly influential for those interested in applying cybernetics and computing to making art, and was involved in various computer art projects.

Pask was one of the exhibitors at *Cybernetic Serendipity*, the seminal exhibition of "the computer and the arts" held at the Institute of Contemporary Arts in 1968, which is examined in "In the Beginning . . ." (chapter 6) by Jasia Reichardt, then deputy director of the ICA, who curated the show, and in Brent MacGregor's "*Cybernetic Serendipity* Revisited" (chapter 7). *Cybernetic Serendipity* was a highly important factor in the development of British computer art, as well as an indication of the importance of cybernetics. Among the most notable exhibits was *Sound Activated Mobile* (*SAM*), a cybernetic sculpture by the polymath artist/engineer Edward Ihnatowicz, which moved in response to sounds made by the viewer. *SAM* and Ihnatowicz's later piece, *Senster*, made for the electronics company Phillips's *Evoluon* pavilion in the Netherlands, are among the most startling and, for the time, most technologically sophisticated works of art made in the area of cybernetic art. Ihnatowicz has been unjustifiably neglected, partly because he was and remains hard to categorize. It is hoped that the two chapters in this book about him, roboticist Aleksandar Zivanovic's "The Technologies of Edward Ihnatowicz" (chapter 8) and "Forty Is a Dangerous Age: A Memoir of Edward Ihnatowicz" (chapter 9) by his son Richard, might help to bring his work the recognition it richly deserves.

Along with its debt to cybernetics, computer art also owed much to the constructivist movement, the subject of Richard Wright's "From System to Software: Computer Programming and the Death of Constructivist Art" (chapter 10). Though neither the constructivists, nor the later Systems Group, founded in 1970 by artists Malcolm Hughes and Jeffrey Steele to explore the possibilition of geometric abstraction, were greatly interested in using computers, their procedural and logical sensibility made the application of computers to art possible, and artists with an interest in the possibilities of systems thinking, such as Harold Cohen and Tony Longson, investigated the possibilities of the computer for art practice. Cohen developed AARON, an artificial intelligence drawing program, the evolution of which he recounts in "Reconfiguring" (chapter 11); Longson also became a keen programmer, as he describes in "Reconstruction" (chapter 12).

While teaching at Ealing School of Art, Roy Ascott invited the artist Gustav Metzger to discuss his ideas about destruction in art (supposedly inspiring a young Pete Townshend to destroy his guitar on stage with his band, The Who). As Simon Ford's "Technological Kindergarten: Gustav Metzger and Early Computer Art" (chapter 13) shows, Metzger, increasingly regarded as a major figure of the postwar British avant-garde, was a pioneer of the use of computers in art, as well as an early member of the Computer Arts Society (CAS). CAS was founded in 1968 by

Alan Sutcliffe, an engineer at ICL and a composer, architect John Lansdown, and cybernetician and colleague of Gordon Pask, George Mallen. In "Patterns in Context" (chapter 14), Sutcliffe describes the formation of CAS and of the Electronic Music Studio, with which he was also involved, while, in "Bridging Computing in the Arts and Software Development" (chapter 15), Mallen gives an account of the relation among Gordon Pask's company, System Research Ltd., CAS, and his own firm, System Simulation Ltd., as well as describing CAS's extraordinary 1970 installation, *Ecogame*. In "Two Cultures: Computer Art and the Science Museum" (chapter 16), Doron D. Swade writes about another CAS display in the computing gallery of the Science Museum. Malcolm Le Grice, perhaps best known for his contribution to "structural film," was also an early member of CAS, and in "Never the Same Again" (chapter 17), he describes his early computer-based experiments as well as the relation between CAS and other, similar organizations, such as the London Filmmakers Coop, the Arts Laboratory, and the Institute for Research into Art and Technology. Le Grice's invocation of such organizations is a reminder that not all the pioneering work took place in art schools, and in "Which Art in Heaven" (chapter 18) Stan Hayward gives an account of his development of commercial computer animation in the late 1960s and early 1970s.

If the Independent Group made computer art thinkable and *Cybernetic Serendipity* had shown what could be done, it was the art school system that fostered its actual development as Catherine Mason's "The Routes toward British Computer Arts: The Role of Cultural Institutions in the Pioneering Period" (chapter 19) shows. According to Mason the emergence of computer art was also a product of the particular nature of British art schools, especially after the reforms that came about as a result of the Coldstream Report in 1963. Mason charts the role played by art schools from the early Basic Design course in the 1950s through the 1980s, when cuts in the educational sector led many artists to enter the world of commercial computer graphics. In "From Machine to Metaphor: Artists and Computers at Chelsea School of Art 1960–1980" (chapter 20) Stephen Bury traces the history of the use of computers in art at one such institution, Chelsea School of Art.

Paul Brown's "From Systems Art to Artificial Life: Early Generative Art at the Slade School of Fine Art" (chapter 21) describes the formation of the Experimental and Electronic Art Department at the Slade School of Fine Art in the 1970s by Malcolm Hughes. Also involved were Chris Briscoe, Julian Sullivan, Darrell Viner, Stephen Bell, and Stephen A. R. Scrivener. Scrivener and Bell both give accounts of their time at the Slade in this chapter, as well as in their own chapters, "Connections: A Personal History of Computer Art Making from 1971 to 1981" (chapter 22) and "My First Brush with Computer Graphics" (chapter 23), respectively.

In "Conceptual Art, Language, Diagrams, and Indexes" (chapter 24), Graham Howard describes how, at Coventry Polytechnic in the late 1960s and early 1970s, the Art & Language group, best known for their contribution to the development of conceptual art, made work that engaged with issues of information and database organization and clearly owed much to computing technology. Howard, an early member of A&L, is well placed to give an account of this work.

Ernest Edmonds's "Constructive Computation" (chapter 25) describes his combining mathematics, computing, and art at Leicester during the same period. In "PICASO at Middlesex Polytechnic" (chapter 26) John Vince describes the genesis of one of the first dedicated graphics programs, PICASO, which he developed at Middlesex Polytechnic in the early 1970s, while, in From "0 to 1: Art Made between the Times of Having and Not Having a Computer" (chapter 27) Brian Reffin Smith writes about using and not using computers in art at various institutions in the period. Jeremy Gardiner's "The Aftermath of Early Computer Art: A Painter's Odyssey" (chapter 28) describes Gardiner's attempts to make art using computers in the context of ebbing support and increasing resistance in the institutions where he was studying, particularly the Royal College of Art, despite the presence of important, pioneering figures such as Patrick Purcell and Brian Reffin Smith. To some extent Gardiner's experience at the RCA was part of a more general turn away from supporting computer art in the art schools. Gardiner does, however, pay tribute to the facilities offered by institutions that were less prestigious at this time which is a reminder that small enclaves remained to keep the practice of computer and new media art alive, particularly in the polytechnics, the technical and vocational higher education institutes that had subsumed many of the art schools in the United Kingdom. Many of the figures contributing to or featured in this book were involved in these activities, including John Vince, John Lansdown, and Paul Brown at Middlesex Polytechnic. It was courses such as these that, at least in part, enabled the computer arts to survive and even prosper in Britain as its reception improved with the advent of the World Wide Web and the ubiquity of computing in 1990s and 2000s. Such courses were a bridge between the early pioneers and current practice, and the effects of the pioneers' legacy is considered in the final essay in this volume, "The Ironic Heirs to Serendipity: British New Media Art, 1980s to Now" (chapter 29) by Beryl Graham.

As this brief introduction indicates, the early British computer art scene was extraordinarily lively and experimental. It was also a close-knit group of people and institutions. As a result, this book is far from just an account of how a number of artists at a certain period in a certain place used a particular technology. It is a story of a pioneering community, drawn together by a shared vision of how technologies can change the way things are done. This is especially admirable given the great difficulties of making such work at the time.

Of course one of the corollaries of being a pioneer of this sort is that you are not understood in your own time. This is almost a given for any form of avant-garde art practice. Hal Foster suggests: "The avant-garde work is never historically effective or fully significant in its initial moments. It cannot be because it is traumatic—a hole in the symbolic order of its time that is not prepared for it, that cannot receive it, at least immediately, at least without structural change" (1996, 29). But, unlike many more explicitly avant-garde movements, computer art has remained particularly resistant to recuperation and restitution by the institutions of canonical and orthodox art history. Perhaps this makes it more genuinely avant-garde. If so, maybe its moment has come, in that the structural changes required for it to be understood are taking place. I hope in particular that this book will help hasten the recognition this area so richly deserves.

This book is one of the main outcomes of a three-year project, funded by the Arts and Humanities Research Board (now Council) in the United Kingdom. Computer Arts, Contexts, Histories etc (CACHe), the membership of which is also the editorial team for this book, was started with the aim of investigating the history of early British computer art. Another outcome of CACHe has been the donation by California-based art historian Patric Prince of her unique collection of computer art to the Victoria and Albert Museum in London in 2005. That a major museum is willing to accept such a donation signals the increasing recognition of the importance of this area of artistic practice. Much of the credit for this must go to Douglas Dodds, head of Central Services at the Victoria and Albert, whose commitment and support has been invaluable. The acquisition of this collection by the Victoria and Albert has been the catalyst for the AHRC to fund a further large research project, the Computer Art and Technocultures project, which aims to celebrate the international impact of the digital aesthetic in the late twentieth century. This project involves Douglas Dodds; CACHe member Nick Lambert, one of this book's editors; Professor Jeremy Gardiner, one of its contributors; and Dr. Lanfranco Aceti.

The original impetus for starting the project was the sad death at an early age of Professor John Lansdown, one of the major pioneers of computer art and graphics. Given his important role in the history this book seeks to describe, it seems only right that it be dedicated to his memory.

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2

Creative Cybernetics: The Emergence of an Art Based on Interaction, Process, and System

Roy Ascott

This text does not seek to uncover the secret history of cybernetics in 1960s Britain! Nor is it intended to reflect the diversity of responses that artists had to the white heat of technology[1] and the nascent computerization of society that marked that era. Instead, it is no more than the personal memoir of an individual artist's awakening from the constructivist kiss of life that led eventually into the arms of a full telematic embrace.[2]

In early 1959 I had submitted my Fine Art dissertation to Kings College, University of Durham (in Newcastle upon Tyne and now part of Newcastle University) on *Cézanne and the Expression of Change* (a youthful challenge to Liliane Brion-Guerry's thesis on Paul Cézanne's expression of space[3]). I had looked principally at Cézanne's 1878–1906 work, focusing on how his paintings became autonomous visual organisms, in which clouds, bushes, hills, and bodies lay in fluctuating imprecision within a pulsating field of light. To contextualize his work, I looked at the writings of French philosopher Henri Bergson: his ideas of change and memory had made a significant impression on the minds of artists of his period, and perhaps too on Cézanne, although there seemed to be very little direct evidence of the painter's familiarity with his philosophy of change. I was alert also to the shifting viewpoint that was the feature of his painterly perception, recognizing that his work traced the behavior of his eye and the dynamics of his gaze, in conjunction with the flux and flow of the behavior of his "motif."

Cézanne was the first painter to take the viewer on an interactive journey into his perceived world. The fluctuating viewpoint of both artist and observer in Cézanne's late paintings ensured an always incomplete experience of open-ended perception. It can be argued that the aesthetic of process and emergence in computer-mediated art starts here, as though the technology were teleologically destined to realize the new understanding of constructivist consciousness that Cézanne intuited. By this I mean that the implicit engagement of the viewer in actively constructing a visual coherence and continuity out of the unstable flux of the painting field presages the ontology of radical constructivism[4] and the second-order cybernetics of Heinz von Foerster.[5]

Searching randomly in the stacks of Kings College library for insights that might amplify my thesis, alert to issues of perception and mental states, I came across the writings of F. H. George. He was yet to publish *The Brain as a Computer*,[6] which extended for me the behavioral approach to machines and organisms that I found in Ross Ashby's *Design for a Brain*,[7] but introduced me in his then recently published *Automation Cybernetics and Society*[8] to the seminal literature of what was quickly to become the central tenet of my aesthetic understanding, and the spur to my subsequent work as an artist. Of all the books emerging in the 1950s that addressed issues of cybernetics, it was perhaps Ross Ashby's introduction to the field[9] that most captured my imagination. The table of contents alone provided the foreplay to a kind of intellectual orgasm: Dealing with Change, Transformation, Coupling Systems, the Black Box ("isomorphic," "homomorphic," "very large," or "incompletely observable"), Inversion, System Transmission, Entropy, the Law of Requisite Variety, Error Controlled Regulation, The Markovian Machine, Amplification in the Brain, and so on . . . enough perhaps to say that Ashby was hugely inspirational to me and, as I later learned (obscure as he is now), inspirational to Norbert Wiener, Herbert Simon, Miller, Galanter and Pribram, Stuart Kauffman, and other notable scientists.

By another route entirely (I think initially from Samuel Butler's *Erewhon*, and More's *Utopia*) I happened on the behavioral psychology of B. F. Skinner.[10] This was a rather grim vision that, although based wholly in behavior, emphasized regimes of social control and conditioning that were both repugnant and reactionary, although trumpeted in the world of psychology as radical. These books did, however, alert me to seek out more socially responsible and spiritually satisfying utopian thought particularly of the nineteenth century where I discovered, to my lasting joy, the ideas of Charles Fourier and his system of passionate attraction.[11] In my view Fourier was a cybernetician *avant la lettre*, offering a proto systems theory that was at once practical and mystical. Equally one can understand how André Breton saw him as a precursor of surrealism, as recognized in his poem "Ode à Charles Fourier."[12]

In the biological context, my teachers at Newcastle, Victor Pasmore and Richard Hamilton, from their individual perspectives had both insisted on the beauty and truth to be found in D'Arcy Wentworth Thompson's *On Growth and Form*,[13] a book to which I return periodically even now, not simply as the bible of how event creates form but as a testament to self-organization in natural structures. As for Ross

Ashby, my reading from the start responded to the centrality of the biological model in his thought:

> Many have been prevented from taking up the subject (of cybernetics) by an impression that its use must be preceded by a long study of electronics and advanced pure mathematics; for they have formed the impression that cybernetics and these subjects are inseparable. . . . this impression is false. The basic idea of cybernetics can be treated without reference to electronics, and they are fundamentally simple; . . . a great deal can be done, especially in the biological sciences, by the use of quite simple techniques.[14]

This kind of intellectual generosity, exemplified also in the texts of Wiener[15] and George, encouraged me to forage deeper into the literature—a generosity that later was to be embodied in my friendship with Gordon Pask. In almost every respect, it was the epistemology of cybernetics cast in the frame of biology and psychology rather than of purely mathematics and engineering that attracted me. Later, in the 1960s, I would read Gregory Bateson's *Steps towards an Ecology of Mind*[16] and Stafford Beer's *Platform for Change*,[17] treating them as particularly valuable resources.

At the back of it all was the process philosophy of Whitehead[18] that had introduced me to the philosophy of organism, the principle of subjectivity, and the idea of *concrescence* (in which the observer creates the scene/seen) where the present arises from a consense of subjective forms. Whitehead argued that we are multiple individuals, but there are also multiple individual agents of consciousness at work in the construction of the given. For me, always alert to esoteric implications, this echoed Gurdjieff's doctrine of many selves. Gurdjieff, as Ouspensky reported it,[19] spoke of the human structure consisting of several minds. These minds, or *centers* of perception, are the real structural elements of human nature, and any attempts to bring man to unity that do not understand these centers are bound to fail. Decades later, I would find an echo of this in Marvin Minsky's *The Society of Mind*,[20] but a distorted and reductionist echo, perpetrating a sadly materialist view of the human condition.

So my love of Cézanne and my own rather particular analysis of his late work had led me to an understanding of behavior and cybernetics that I was beginning to see as the possible key to theorizing my own artwork. Since 1959 this had been concerned with constructs that I called *Change-Paintings* (figure 2.1) and *Analogue Structures*. This concerned assembling separate overlapping transparent panels within a routed frame, such that each could be rearranged by the viewer, sliding each panel over another, as a given set allowed. Each panel carried analogue images or signifying marks (the requisite variety). Applying the insight afforded by my reading in cybernetics, I could see that the artwork was a system arising from a process, the system including the artist, the artwork, and the observer, coupled in a semantic relationship, where the aesthetic experience emerged from the interaction of these

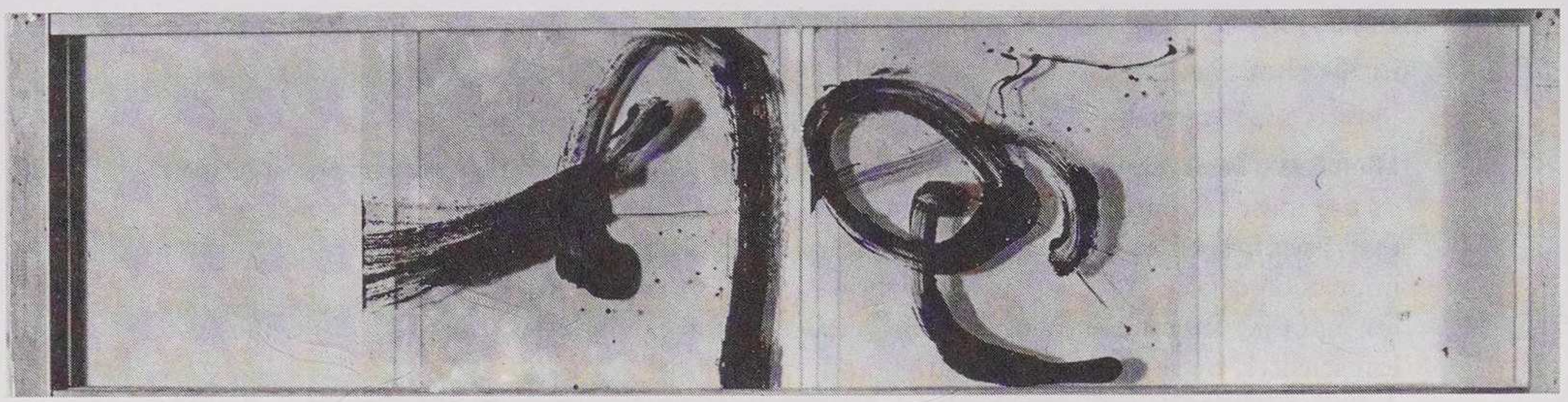

Figure 2.1 Roy Ascott, *Change-Painting*, 1959.

three elements. Just as I understood cybernetics to be the science of behavior, I saw art as essentially behaviorist. As I later wrote in my manifesto of 1967, cited by Lucy Lippard in the epigraph to her book *Six Years*:[21]

> To discuss what one is doing rather than the artwork that results, to attempt to unravel the loops of creative activity, is, in many ways, a behavioural problem. The fusion of art, science and personality is involved. It leads to considerations of our total relationship to a work of art, in which physical moves may lead to conceptual moves, in which Behaviour relates to Idea . . . "An organism is most efficient when it knows its own internal order."[22]

My change-paintings owed much to the sea change in aesthetic perception that I enjoyed in my first experience of Jackson Pollock's paintings, on show for the first time in London in a comprehensive exhibition at the Whitechapel,[23] in which an endless interweaving of actions and open-ended gestural flow seemed to manifest what now one might call the zero point energy field of the universe.[24] The conception of art as behavior, process, and system, came to me precisely between the time that I moved from teaching as an assistant to Pasmore and Hamilton at Newcastle to setting up a new foundation course at Ealing School of Art, London, in 1961. Equipped with an insight into how cybernetic theory could be applied both the eliciting and reinforcement of creative behavior, as well as to the structure of the institution designed to maintain that behavior (the art school), I proceeded to develop a staff and curriculum around the notion of a generative organism. I called this entity the Groundcourse, seen as a cybernetic seeding zone, a bottom-up space of artistic growth (figure 2.2). A full account was later published in *Cambridge Opinion*,[25] in an issue of the journal devoted to an overview of new art practice in London in the early 1960s.

Behavior was at the root of the process in art, but if I were a behaviorist in this, then it was not as a Skinnerian but as one more aligned to the "subjective behaviorism" of Miller, Galanter, and Pribram:

Figure 2.2 Roy Ascott, behavioral project, the Groundcourse, 1964.

> Our emphasis was upon processes lying immediately behind action, but not with action itself. On the other hand, we did not consider ourselves introspective psychologists, at least not in the sense Wilhelm Wundt defined the term, yet we were willing to pay attention to what people told us about their ideas and their Plans. How does one characterize a position that seems to be such a mixture of elements usually considered incompatible? Deep in the middle of this dilemma it suddenly occurred to us that we were *subjective behaviorists* (my italics).[26]

"The Construction of Change" outlined the development of the Groundcourse, identifying not only its pedagogical and creative features but also the artists involved in its emergence. Of these, Harold Cohen was perhaps most receptive to the cybernetic vision, a vision I defined in a two-part paper titled "Behaviourist Art and the Cybernetic Vision," published in *Cybernetica* 1966[27] and 1967.[28] But most faculty were exposed to cybernetics in some good sense, most dramatically at a dinner in the college at which Gordon Pask was the guest of honor. Pask gave a riveting address that excited the audience of artists even though most of them had very little comprehension of what he was talking about. Pask and I became good friends. When I gave my first one-man show in London (at the Molton Gallery, thanks to Annely Juda) in 1964, he came to the opening and later, after we had wined and dined (especially the former), he returned with me to my studio to discuss *Problems of*

Cybernetics, a set of papers by Russian cyberneticists that had just come into my hands. In this discussion, that which had been totally opaque to me became lucid; what had seemed impossibly complex to unravel was simplified beyond measure, by the interpretive skill of Pask and his wit and consummate ability to communicate. I had named a number of pieces in my show in homage to the authors of those papers: Lyapunov, Kamynin, Shura-Bura, and Lyubimskii. The works called for the physical participation of the viewer in sliding, folding, opening, or closing panels and other parts of the wall-mounted constructions. As I wrote in the catalogue:

> Cybernetics has provided me with a starting point from which observations of the world can be made. There are other points of departure: the need to find patterns of connection in events and sets of objects; the need to make ideas solid working in wood etc.) but interfusable (transparent panels, hinged sections), an awareness of change as fundamental to our experience of reality; the intention to make movement a subtle but essential part of an artefact. . . . my independent enquiry is regularly reinforced with close reference to scientific publications and search in to their methods of analysis and investigation.[29]

Pask not only helped me navigate through the rather dense undergrowth of cybernetic literature that was proliferating at that period, but also introduced me to the cybernetics community in London and proposed me for election to the Institute of Computer Sciences. His support for my membership was based on my exhibited work, on my embodiment of cybernetics principles in the design of the Ealing Groundcourse, and on the paper I was preparing on "Behaviourist Art and the Cybernetic Vision" (later to be published in the journal *Cybernetica*, described earlier).

In this context, I was invited to join the Cybernetics Committee he was setting up to assist in the design of the Fun Palace proposed by Joan Littlewood and Cedric Price. A detailed research and appraisal of the Fun Palace informs the thesis of Dr. Stanley Mathews of Hobart and William Smith Colleges, an abridged version of which has been published in *Technoetic Arts*.[30]

> The Fun Palace would challenge the very definition of architecture, for it was not even a conventional "building" at all, but rather a kind of scaffold or framework, enclosing a socially interactive machine—a virtual architecture merging art and technology. In a sense, it was the realization of the long-unfulfilled promise of Le Corbusier's claims of a technologically informed architecture and the "machine for living." It was not a museum, nor a school, theatre, or funfair, and yet it could be all of these things simultaneously or at different times. The Fun Palace was an environment continually interacting and responding to people. By the mid-1960s it had become a vast social experiment and a *cause célèbre* for scores of London intellectuals who saw in it the germ of a new way of building, thinking, and being. People as diverse as Buckminster Fuller, Yehudi Menuhin, and Tony Benn volunteered their services to the project.

The cybernetics committee included the scientist and journalist Ritchie Calder, the nuclear physicist and Nobel prize winner Joseph Rotblat, the historian Asa Briggs, the sculptor Reg Butler, psychologist John Clark, two members of Parliament (Ian Mikardo and Tom Driberg), Pask's partner Robin McKinnon-Wood, and sociologist Michael Young. Although I had been brought on board as an artist, such was my fascination with information/communication technology that my contribution was much more pragmatic than artistic. In the view of Stanley Matthews:[31]

> Certainly the most prescient proposal for the application of computer technologies was the "Pillar of Information," also proposed by Roy Ascott, a refinement of his earlier idea for a "Juke Box" Information system.[32] Ascott's "Pillar of Information" would be a kind of electronic kiosk which could display information of all sorts, based on the model of the *Encyclopedia Britannica*. His system was among the earliest proposals for public access to computers to store and retrieve information from a vast database. In addition, and even more innovative, it would also keep a memory of previous inquiries. As one person took information from the pillar, a trace would be recorded of the transaction, and subsequent users would be able to track the patterns of use, and the system would suggest multiple knowledge pathways, in much the same way that use patterns on the Internet of today are mapped through the use of tracking "cookies." Ascott envisioned that this would give users insight into the interests and queries of other Fun Palace users. Based on patterns of user interaction, the Pillar of Information would gradually develop an extensive network of cognitive associations and slippages as a kind of non-hierarchical information map, both allowing and provoking further inquiry beyond the user's initial query. The resultant web of information and free association to be produced by the Pillar of Information foreshadows in many ways the more recent prismatic theory of knowledge developed in the late 1980s by Gilles Deleuze and Felix Guattari.

I published a number of papers on cybernetics and art in the 1960s. "The Construction of Change" described the work of the Groundcourse, and "Behaviourist Art and the Cybernetic Vision" provided the ontological setting and a kind of instruction manual for a Cybernetic Art Matrix in which creativity and social coherence could reciprocally flourish. Then in 1967 I published as a fly poster the manifesto "Behaviourables and Futuribles,"[33] in which I argued that "when art is a form of behavior, software predominates over hardware in the creative sphere. Process replaces product in importance, just as system supersedes structure."

Then at the end of the decade I came out with a brief but, for me, important admission of my layering of *psi*bernetics over cybernetics, the paranormal and psychic over the technological and scientific in the *Studio International* essay "The Psibernetic Arch."[34] It was in many ways prescient for me, in that the 1970s would see me in North America, especially in San Francisco and the Bay Area where I experienced the transition in technology from the discrete stand-alone computer to an emergent telematics, from the ontology of noetic science (through Brendan

O'Reagan) and the quantum strangeness of the new physics (Jack Sarfatti and Fred Wolf) to the epistemology of computer conferencing and planetary networking of Jacques Vallee. It took a decade for me to mutate from plastician to telematician, where the all-at-onceness and indeterminacy of my cybernetically informed change-paintings, tabletop transactional works, and relief constructions led into the open-ended telematic interactivity of *Terminal Art*[35] and *La Plissure du Texte*.[36]

Notes

1. "The white heat of technology" was said to be the election address mantra that got Harold Wilson into 10 Downing Street in 1963.

2. R. Ascott, *Telematic Embrace: Visionary Theories of Art Technology and Consciousness*, ed. with an essay by Edward A. Shanken (Berkeley: University of California Press, 2003).

3. Liliane Brion-Guerry, *Cézanne et l'expression de l'espace* (Paris: Albin Michel, 1966).

4. P. Watzlawick, ed., *Invented Reality: How Do We Know What We Believe We Know?* (New York: Norton, 1984).

5. H. von Foerster, "On Constructing a Reality," in *Observing Systems* (Seaside, CA: Intersystems, 1981), 288–309.

6. F. H. George, *The Brain as a Computer* (Oxford: Pergamon, 1961).

7. R. W. Ashby, *Design for a Brain* (London: Chapman and Hall, 1952).

8. F. H. George, *Automation Cybernetics and Society* (London: Leonard Hill, 1959).

9. R. W. Ashby, *An Introduction to Cybernetics* (London: Chapman & Hall, 1956).

10. B. F. Skinner, *Science and Human Behaviour* (New York: Macmillan, 1953).

11. C. Fourier, *The Utopian Vision of Charles Fourier: Selected Texts on Work, Love, and Passionate Attraction*, ed. and trans. Jonathan Beecher and Richard Bienvenu (London: Jonathan Cape, 1972).

12. A. Breton, ed., "Ode à Charles Fourier." In *Anthologie de l'humour noir* (Paris: Fayard, 1939).

13. D. W. Thompson, *On Growth and Form* (New York: Dover, [1917] 1942).

14. R. W. Ashby, *An Introduction to Cybernetics* (London: Chapman & Hall, 1956), v.

15. N. Weiner, *Human Use of Human Beings* (Boston: Houghton Mifflin, 1950).

16. G. Bateson, *Steps to an Ecology of Mind* (New York: Ballantine Books, 1972).

17. S. Beer, *Platform for Change* (New York: Wiley, 1975).

18. A. N. Whitehead, *Process and Reality* (New York: Macmillan, 1929).

19. P. Ouspensky, *In Search of the Miraculous: Fragments of an Unknown Teaching* (London: Routledge, 1949).

20. M. Minsky, *The Society of Mind* (New York: Simon and Schuster, 1986).

21. L. R. Lippard, *Six Years: The Dematerialization of the Art Object*... (London: Studio Vista, 1973).

22. R. Ascott, "The Construction of Change," *Cambridge Opinion* 37 (1964): 37–42.

23. The first major show in Britain of the work of Jackson Pollock was at the Whitechapel Gallery London in 1958.

24. L. McTaggart, *The Field: The Quest for the Secret Force of the Universe* (New York: Quill, 2003).

25. *Cambridge Opinion* 37 (January 1964).

26. G. A. Miller, E. Galanter, and K. H. Pribram, *Plans and the Structure of Behavior* (New York: Holt, Rinehart & Winston, 1960), 211.

27. R. Ascott, "Behaviourist Art and the Cybernetic Vision," *Cybernetica, Journal of the International Association for Cybernetics* 9 (1966): 247–264.

28. R. Ascott, "Behaviourist Art and the Cybernetic Vision," *Cybernetica, Journal of the International Association for Cybernetics* 10 (1967): 25–56.

29. R. Ascott, *Diagram-Boxes and Analogue Structure* (London: Molton Gallery, 1964).

30. S. Mathews, "The Fun Palace: Cedric Price's experiment in architecture and technology," *Technoetic Arts* 3.2 (2005): 73–92.

31. Ibid.

32. See "Possible Activities," Appendix B: "Draft of a Fun Palace booklet," (1964?), Fun Palace document folio DR1995:0188:526, Cedric Price Archives.

33. R. Ascott, "Behaviourables and Futuribles," in *Theories and Documents of Contemporary Art*, ed. K. Styles and P. Selz (Berkeley: University of California Press, 1996), 489–491.

34. *Studio International*, London, April 1970.

35. E. A. Shanken, "From Cybernetics to Telematics," in *Telematic Embrace: Visionary Theories of Art Technology and Consciousness*, ed. Roy Ascott, with an essay by Edward A. Shanken (Berkeley: University of California Press), 62–63.

36. R. Ascott, "La Plissure du Texte," in *Electra: L'Electricité et l'electronique dans l'art au XX siecle* (Paris: Musée d'Art Moderne de la Ville de Paris), 398–399.

3

Transmitting Art Triggers: The Early Interactive Work of Stephen Willats

Adrian Glew

> The audience become not just an after-thought, but the prime reason for the provision of triggers. . . . The relationship that the observer has with most of these works is that of a receiver to a transmitter, the problem becoming one of transmitting the necessary conditions for trigger in via the shortest time; the feedback between the audience and the work being a result of this triggering.
>
> —Stephen Willats, Exhibition Catalogue, *Visual Automatics and Visual Transmitters*, Museum of Modern Art, Oxford, UK, October 22–November 16, 1968

Since the late 1950s, Stephen Willats has been an important art theorist and practitioner, focusing on the interface between art and society. From the outset Willats incorporated new research and utilized technology—including state-of-the-art computer components and programs—at every opportunity to create his innovative and increasingly interactive art works. By doing so, Willats's interventions and use of ready-to-hand technology have helped narrow the gulf in terms of psychosociological undercurrents in art. His recent work, for instance, continues to involve whole communities in determining the outcome of the final artwork, producing a multitude of views within a multichannel experience.[1]

Willats's earliest art experiences were at the Drian Galleries, London, where he worked from 1957 to 1960 under Polish émigré Halima Nalecz. At that time, the Drian was one of the few spaces in the capital that exhibited groundbreaking work by young artists from Britain and overseas.[2] It was here that Willats first began to articulate his ideas in the course of meeting more and more artists. He was particularly impressed by a group of constructivists from Cambridge, with whom he proposed the establishment of a center in Gloucester Place, London, where artists, philosophers, and mathematicians would be invited to research areas of mutual interest.[3] Willats took an active part in early discussions, deriving source material from his daily work at the gallery. For example, by examining the way in which the visitor to the Drian moved in relationship to the work on display, he soon realized that there was no right or wrong way to view a work and that the viewer was as important as the artwork itself. These musings led Willats to begin his first notebook, which he filled—when the gallery had no visitors—with writings and sketches.[4] Indeed the periodic lack of visitors caused him to question and reevaluate the whole notion and role of the art gallery in society. It dawned on him that visitors to the gallery looked for icons of certainty, and that instead a random variable could be set up in the space, such as moveable elements in a sculpture, that would cause visitors to organize their actual experience, which was infinitely better than the referential experience; this theme has remained crucial to Willats's working practice.

During this period, Willats's other key interest was rhythm and blues and jazz. One place that he frequently visited was the Ealing Jazz Club in London, a lively venue for these musical genres in the late 1950s. He produced many portraits of performers and visitors to Ealing, later showing these works in the foyer of the club, illustrating his growing interest in the contextualization of art practice and in the display of work outside the gallery environment to increase its meaning. These portraits formed the basis of the portfolio that he presented to the principal of the Ealing College of Art, James Drew, when he applied to join the Groundcourse there in 1962.[5] Significantly, during the first year at Ealing, there were an equal number of students to staff members (around twenty of each), with the influential Groundcourse led by Roy Ascott, who had enthusiastically taken up the tenets of the post-Bauhaus Chicago educational program, best exemplified in the U.K. by Victor Pasmore and Richard Hamilton at Kings College, Newcastle upon Tyne.[6] The first three or four months of the course focused on a Kings College–style basic design course with its emphasis on media dexterity and the handling of form and shape; there was little attention to meaning (this was to come later), but a celebration and encouragement of spontaneity.[7] Willats, having left the Drian by this time, was fortunate to be able to continue his empirical research at another avant-garde gallery in London, the New Vision Centre Gallery, run by South African–born Denis Bowen.[8] This continual access to a multitude of ideas was mirrored in some of the more forward-thinking art institutions of the time, such as the Institute of Contemporary Arts (ICA) where Willats had recently come across the art of Nicolas Schöffer.[9] With its visiting artists program, Ealing College of Art incorporated this cross-fertilization of ideas within its Groundcourse, posing questions about the nature of being an artist and the role of art in society.[10] However, it was the writings of Basil Bernstein[11] (with his theories surrounding restricted language codes) and the lectures of Gordon Pask (with his enthusiastic interest in cybernetics) that were turning points for Willats at Ealing.[12] It was the charismatic Pask who became the catalyst for change at Ealing, bringing a more conceptual, experimental, and cybernetic view to the course. Willats broadened his reading in these areas and in the fields of learning theory and alpha rhythms.[13] Around this time, he heard about Dr. Christopher Evans, who was working on similar theories at the National Physical Laboratory at Teddington and who had become interested in internal mechanisms and what happens within the brain.[14]

From all these stimuli Willats developed, in 1962–1963, a series of wall constructions created from planes of wood, which viewers could manipulate. These built upon work he had undertaken during the preceding year, namely constructed architectural models—including a speculative one for the Selfridges department store—using planes of Perspex, where light would create prismatic displays.[15] Again, there was no right or wrong position for the piece; people were able to walk through the façade any way they chose, as if in a maze. There were other attempts to initiate experimental pieces, reflecting the general cultural climate of the time in which many different areas of information were married together. Willats became interested in conceptualism in art—as many of his drawings show—and in interpreting semiology using conceptual diagrams of objects on tables. It was also at this time that he began to construct the first of his three-dimensional *Manual Variable Constructions*, a series made out of a complex set of wooden blocks.

In this series, Willats used increasing complexity to enable viewers to vary their experiences from the first in the series, which would set a normative benchmark, to the later works where viewers could bridge the gap and demonstrate, by their actions, the concept of the learning curve.[16] Their reasoning could be noted on response sheets or questionnaires. Willats developed these documents so that what was initially a concept became manifested in physical form; this was one of the first occasions that such direct feedback from the viewer had been used in art. These early tactile series were based on cognitive construction in time or sequencing, allied closely to computer programming, which was an area of increasing fascination to Willats.

During 1963–1964, Willats became a weekend assistant and "guinea pig" at System Research Ltd., which was founded by cybernetician Gordon Pask, and located in the London borough of Richmond.[17] It was while working there, administering the testing equipment, that he met Dr. George Mallen, a senior engineer and theoretician who later set up the firm System Simulation Ltd., and Peter Whittle, an electronic engineer, both of whom proved invaluable when Willats came to utilize computer technology for his artwork. With their help, Willats was able to construct his first machine works involving alpha rhythms. This was a world of cybernetics, modeling, learning theory, and responsible systems resonating with the work of Yaacov Agam, an early kinetic artist who was also very much concerned with viewer participation and who had previously exhibited at the Drian Galleries.[18]

By 1964, Willats had left Ealing College of Art, found a studio, and began the first works in his series, *Visual Automatics* (illuminated shift boxes marrying random variable theory and audience self-organization systems to determine their own sequence). In order for the shift boxes to work efficiently a simple on/off binary program was utilized. This was where his colleague Peter Whittle came to the fore, suggesting an independent program for truly random situations. For *Shift Box No. 1*, heat sensors created an analogue so that heat between two contacts within switches worked correctly.

Based on these works and further research, Willats produced his most ambitious conceptual drawing to date: *Virtual Reality Booth*, an analogue series of experimental works for a multichannel booth, that through touch, smell, and other variables would provide the participant with a multisensory experience. This was during a period when transistors were beginning to replace vacuum tubes in computers and Willats was one of the first artists to realize their potential. (This was only a year after Ivan Sutherland had developed his *Sketchpad* system, which allowed the user to draw directly on a screen.[19]) At more or less the same time, Douglas Engelbart was working with colleagues at the Augmentation Research Center (ARC), a development environment at the Stanford Research Institute, on the On-Line System (NLS), developing the world's first implementation of what was to be called hypertext.[20] Engelbart, mirroring Willats's interests, was particularly concerned with "asynchronous collaboration among teams geographically," with "Augmentation not automation" being the slogan.[21] The goal was to enhance human abilities through computer technology. Engelbart had, in turn, been influenced in the 1940s by Vannevar Bush's article, "As We May Think."[22]

Willats exhibited some of his random variable drawings and the drawings for his *Manual Constructions*, together with notes relating to these ideas, at the invitation of a group of doctors at the Chester Beatty Cancer Research Institute in London in 1964. Willats was seeking a wider audience for his ideas at this time, and a framework within which to operate. "In these drawings," he said, "the observer may view a single part, relate part to part, view the area as a whole, or wander at random over it. The drawings are connected with a way of looking at objects and relating oneself to an object."[23] Willats began to attend gallery openings, handing out personal manifestos[24] while kitted out in a white lab coat. Articles about his work began to appear,[25] and he started his own magazine, *Control*.[26] It was while handing out some of his manifestos at an exhibition of Roy Ascott's work at Hamilton Gallery in 1964 that Ascott invited him to teach at Ipswich School of Art, where Ascott was then running the fine art course. Willats was given complete control of the direction of the course for a year, working with approximately twenty students in a studio context. This appealed to his sensibilities and he duly joined the teaching staff in East Anglia from 1964–1965. This was the first time Willats was able to work collectively with others on the concept of feedback, which tied in neatly with Ascott's first year foundation strand on cybernetics and being. Each week, Willats presented a paper and asked students to solve a problem as a collective group for the following week or month. Typically, they were asked to create a work of art that involved the fabric of society and to make themselves an active part of the community and their future life in Ipswich. They were to assume nothing about the nature of art, but instead were to develop strategies about the situations they encountered. Willats was keen to exploit the potential for these kinds of interactions in the housing estates around Ipswich, which served as overflow from London. This environment tied in perfectly with Basil Bernstein's ideas about language and context-restrictive language codes: beyond the gallery, there was a freedom, which conversely through restrictive signs could only constrain you. The students could choose whom they operated with, uninhibited by artistic conventions, and create bonds of trust with the inhabitants and tap into their restrictive codes.[27]

It was while at Ipswich that Willats was able to develop "visual transmitters" in an eponymous series of three works. Throughout London, at this time, there were army surplus stores selling all manner of clothing and equipment. Cylloscopes, rotating uni-selectors, and photo-electric cells could be bought cheaply. Willats took advantage of the access to cheap materials to create *Visual Transmitter No. 1* and *Visual Transmitter No. 2*, which were very programmatic and used random variables based on alpha rhythms (figure 3.1).

The idea behind the series was to reduce the variables so that viewers' toleration levels became restricted and areas of information did not become overcrowded. This was achieved by using four or five rotors within the machinery. It was a cybernetic model that controlled the relationship between the work and the viewer. Some of these works were exhibited in kinetic exhibitions in the United Kingdom and abroad.[28] Willats, however, became dissatisfied with the fact that the exhibitions did not permit the viewer to manipulate them; his ultimate aim was interactive exchange.

Ipswich closed its doors for the summer, and the rest of 1965 was the period when Willats termed himself a conceptual designer, feeling that the traditional role of the artist was inadequate to intervene positively in society to give people what they would consider useful and familiar. Two manifestations of this new direction were conceptual designs for self-organizing furniture and for clothing that would express the concept of self-organization for the wearer and to onlookers—namely, the user could manipulate what they wore or sat on. The furniture, made cheaply from chipboard, was called *Coree Design* and could be manipulated by the prospective buyer into a myriad of shapes reflecting the many functions it might potentially fulfill. One dress, named *Variable Sheets*, would enable the wearer to construct her own personal garment from a kit of multi-colored PVC panels and

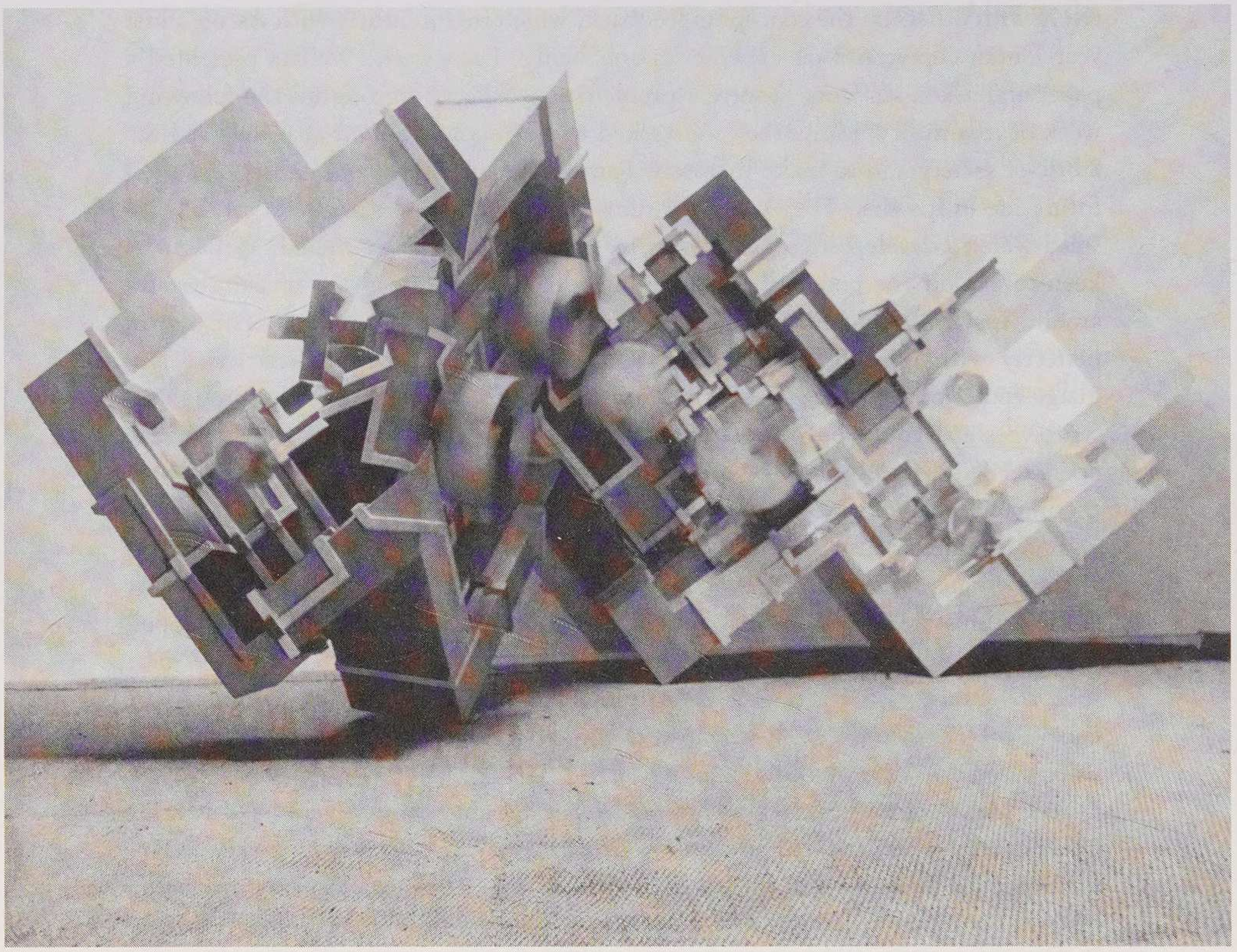

Figure 3.1 Stephen Willats, *Visual Transmitter No. 2*, 1965–1966 (wood, Perspex, electronics, stainless steel, and mixed media) as exhibited in *Visual Automatics and Transmitters*, Museum of Modern Art (MOMA), Oxford, 1968.

Perspex shapes, as its name suggests. A helmet would also have been supplied with a transparent visor, so that the wearer could literally alter her view of the world in a psychedelic mix of rainbow colors. In addition, a lamp attached to the top of the helmet would project a beam of light into the path of the wearer and passersby, reflecting past, present, and future reality.[29] Willats's conceptual design period lasted nine months.

Willats returned to teaching at Nottingham School of Art between 1968 and 1972,[30] where he devoted his energies to achieving his vision of interoperability, resulting, initially, in *Visual Homeostat*, developed with Peter Whittle and Chris Grimshaw, working in Oxford using transistor diode logic. The work comprised two units with two faces that interacted with two participants. By using an ultrasonic field and photo-electric cells between them, as each person got nearer to the unit, the program would run more quickly. The system worked by interrupting a beam that would trigger a simple program; people could only work successfully with the artwork by cooperatively developing their experience together (figure 3.2). This led to the building of Willats's most ambitious work of this period, the *Visual Homeostat Information Mesh, 1969–1971*, which had five component units of red and blue photo-electric cells turning on and off seemingly at random, driven by a binary program constructed with the help of Chris Grimshaw and Jack Shotbolt. This work used relays with lamps that required two people to self-organize to reach agreement. At that time, it was the most widely seen of the interactive works by Willats and was shown shown in two kinetic exhibitions at the Hayward on the South Bank and the ICA in London.[31] Looking back, Willats admits that there were deficiencies to the piece as the philosophical ideas underpinning the work were beyond the technology at the time.[32]

Realizing the limitations of working simply with light, Willats began to engage with encodings of language, which led to his next series, *Visual Meta Language Simulation*. This used the most advanced computer transistor-transistor logic (TTL) then available to explore the interpersonal relationships, and specifically mutuality, between people.[33] It was a dynamic simulation of a social concept based on a learning program of code recognition. It consisted of two decision boxes, an environment, and the "Problem Display," each of which was illuminated. The participants built a metalanguage to connect their separate decision-making processes. It proved very successful, relying again on two people in a mutual relationship with one person completing a colored shape before the other person. If the correct decision was made, the territory under the control of the first participant—indicated by illuminated Bernsteinian shapes—increased at the other's expense. In addition, the mark-space ratio between the nodes that made up the central environment altered in that participant's favor (that is the duration of pulses displayed within his or her territory increased while the other participant's decreased). However, this increase in speed meant that the "winning" participant could never achieve completion, as the time needed to make a decision about the next shape became too short. Like many of Willats's best pieces, it worked optimally when participants communicated cooperatively with one another, creating a more symbiotic relationship. Willats was again assisted on this project by Chris Grimshaw, but the technical aspects were only fully realized successfully through the advice of Derek Aulton, who took over the development of the electronic engineering in 1971 (figure 3.3).[34]

By 1972–1973, Willats recognized that there were two different directions he might take. On the one hand, there was *Visual Meta Language Simulation*, which represented a social ideal embodying cooperation and interaction between people

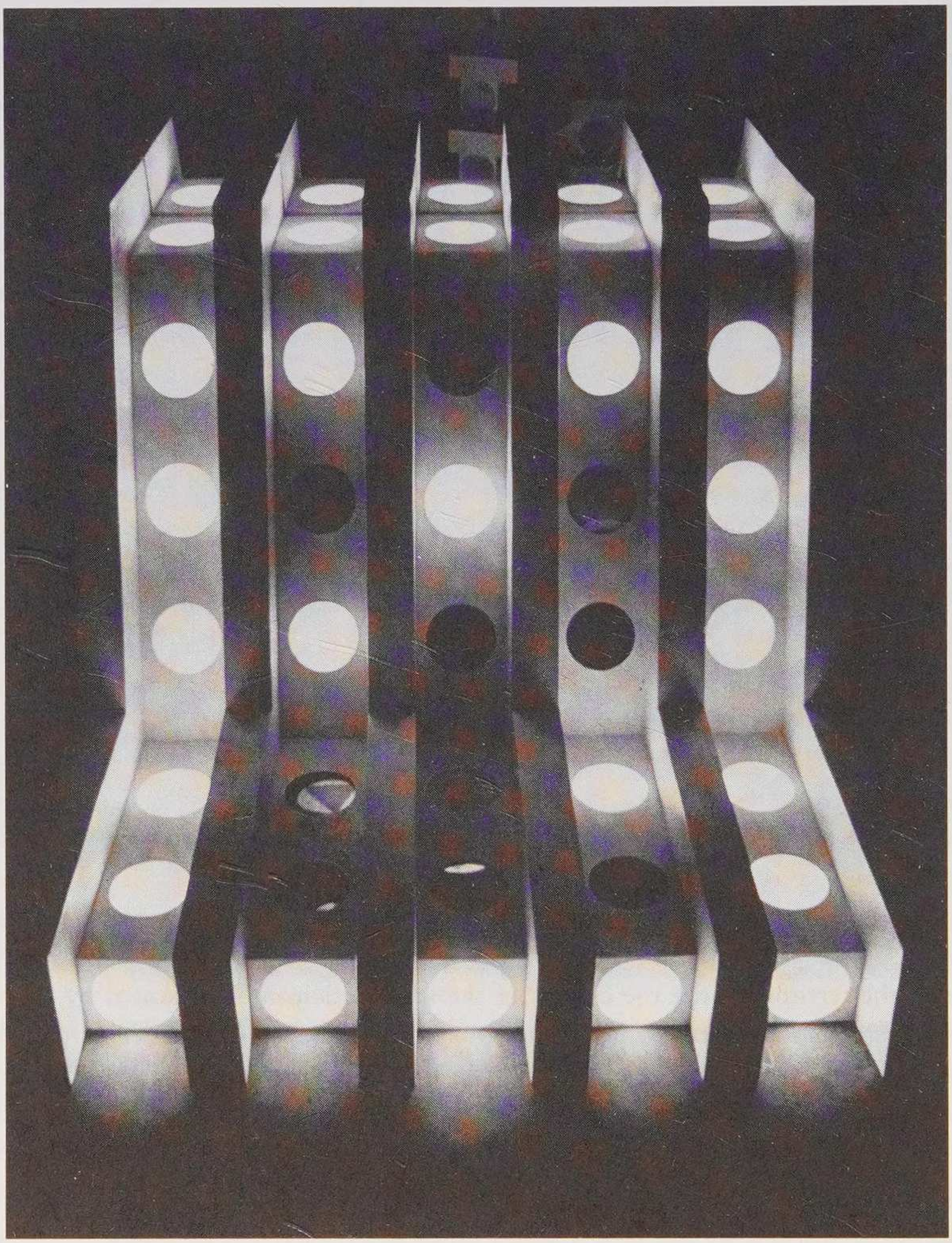

Figure 3.2 Stephen Willats, *Visual Homeostat,* 1968 (wood, Perspex, and electronics) photographed in the artist's studio, 1969.

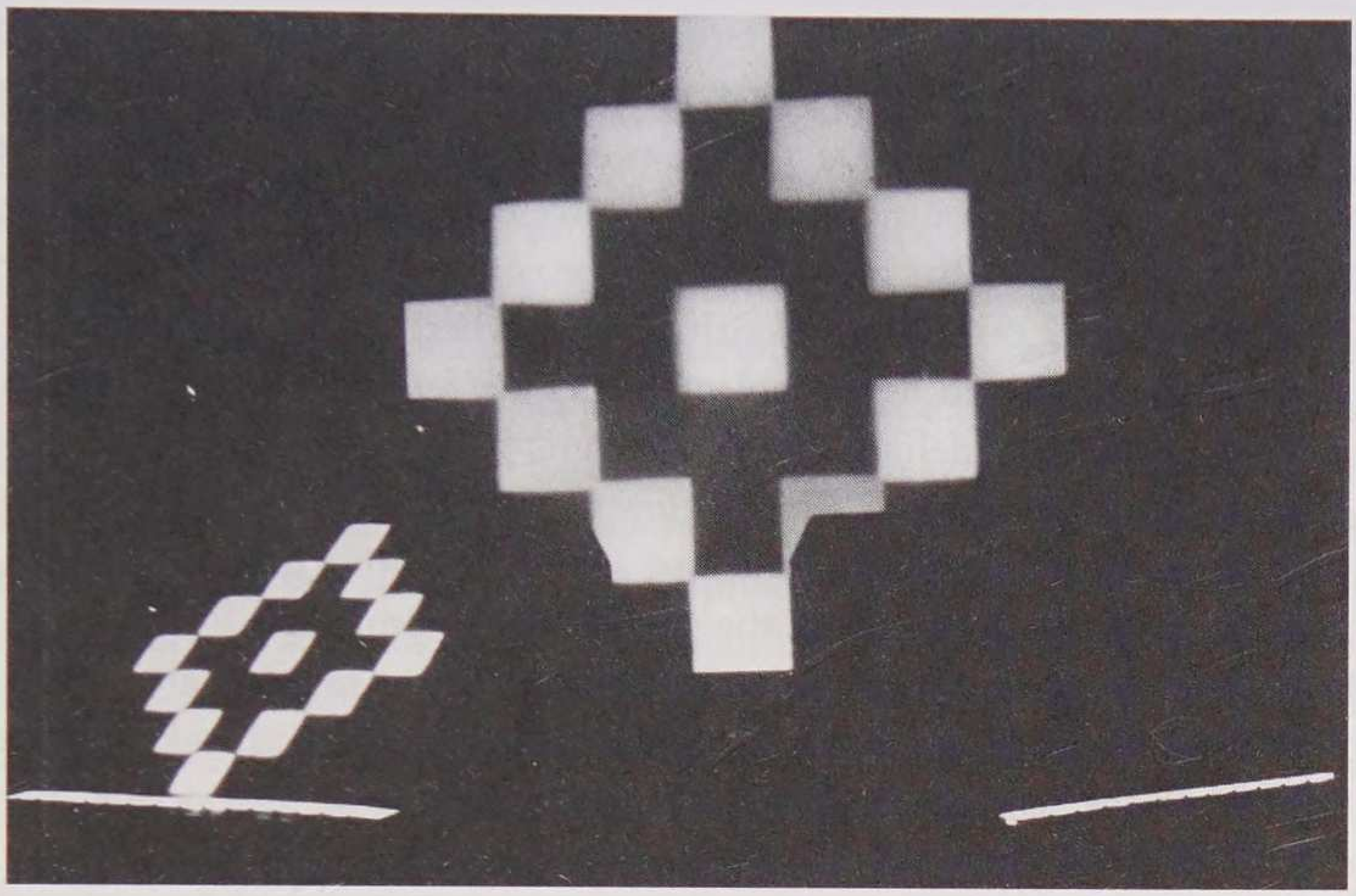

Figure 3.3 Stephen Willats, *Visual Meta Language Simulation*, 1971–1972 (wood, Perspex, stainless steel, electronics, and mixed media) as exhibited at *Cognition Control*, Museum of Modern Art (MOMA), Oxford, October 14–November 5, 1972.

through simulation, where the participants learned the language of the simulation.[35] On the other hand there was the simulation itself that could be enacted as part of the fabric of everyday life, using the very language of the participants. Willats was able to test the latter direction when invited to create a project for the Leith Festival in Scotland in the summer of 1973.[36] Here he was able to use the language of the neighborhood, create project groups, appoint administrators, and pose problems for mutual resolution using the latest computer technology. This developed into a five-day artwork, called *The Edinburgh Social Model Construction Project*.[37] The aim of the project was to enable residents in four locations in Edinburgh to construct a self-determined model of their own and other people's social behavior, achieved by participants "encoding and articulating their perceptions and understanding of social behaviour conventions, customs and rules."[38] The participants from four project groups provided responses, via tabulated sheets handed out by twenty administrators, to problems set by a computer program analysis of consensus tendencies made from the day before.[39] These responses were then fed into a main computer, programmed by Stuart Pound,[40] with four online terminals (teletype machines), significantly—considering their ubiquity today—housed in the street that would create additional consensus tendencies.[41] The terminals were interactive, so people could engage with the simulation in their own languages, suggesting directions for new problems to be set by the consensus tendencies program at the end of the day. Willats was able to tap into some new technology to enable this to happen, namely punched cards for a mainframe computer housed at ICL's (International Computers Limited's) center at Dalkeith, and Rank Xerox teletype machines connected to a central Xeroxing printer machine. Technologies were coalescing to such an extent that responses could be completed by 4pm to be delivered to the main computer center in Dalkeith at 5pm, where consensus tendencies were compiled by 9pm, prior to new problems being set for 8am the next day, with a printed Xerox tabulation delivered to participants by 9am. In addition, there was a fifth terminal in the Edinburgh Festival foyer, where casual visitors could participate, though their solutions were processed separately within a closed loop. At the time, Willats concisely summarized the purpose of the project:

> The project is conceived as an art work which attempts to relate art practice to a specific social context that is external from the traditional physical and social areas in which art functions. The concerns of the project attend to the distinctions between conventions, customs and rules of behaviour that govern relationships between people within different physical and social contexts. It enables people who take part to encode and comprehend its concerns in the context of their own physical and social environment. . . . The methodologies used in the project are related to the contextual environment of participants so as to increase its relevance and meaning to them, and they are operational within their existing routines of behaviour.[42]

When not working on the Leith project, Willats was establishing his Centre for Behavioural Art at Gallery House in London.[43] He had already exhibited a public monitor linked to his *West London Social Resource Project* in this space.[44] By developing his own centre, Willats could further explore themes relating to the artist as an instigator of change in social cognition and behavior by establishing relationships between art, cybernetics, and the behavioral social sciences.[45] To stimulate debate in this area he invited a number of experts including scientists such as Robert Bell, Jerry Brieske, George Mallen, and Stuart Pound to speak on topics of their choice.[46] Willats also gave illustrated talks at Gallery House.[47] The Centre saw the presentation of a more complete version of *Visual Meta Language Simulation*. When creating the *Edinburgh Social Model Construction Project*, Willats had realized that there was too much information to process manually and that any bias by the artist would always be present. A computer would be needed to create a structure beyond the artist and one that would not make assumptions or judgments. This formed the basis for *Metafilter*, another key work examining mutuality and cooperation in Willats's early oeuvre, which used the latest available technology.[48] Willats conceived *Metafilter* as "a dynamic Prescriptive Model of interpersonal structures, in that it functions as a mechanism over a period of time. The work is designed as a machine that functions between two people who may or may not know each other before operating it."[49] The work comprises a wooden unit to be used by two people seated opposite one another. There is a large upright panel, which houses a slide screen and from which neither participant can view the other. On the sloping desk panel sits a problem book with a keyboard and a number display. To the left of the keyboard, there is a slot for the deposit of completed problem books. Derek Aulton engineered the logical program in terms of engineering, which was a considerable feat, as the work dealt with problem situations that were complex, in loops, and with many subsidiary parts.[50] *Metafilter* presented the participant with a sequence of problems framed as questions concerning how two participants viewed a symbolic group of eight people represented in a series of everyday situations. These appear as neutral photographic images on the slide screen; each photo was chosen with great care to in order to minimize the distortion inherent in photography. The participants were asked to provide a solution to each problem and, in order to do this, were asked to search through a thesaurus of person perception words for a word that both participants could agree upon.[51] Rather than compile the thesaurus himself, Willats took two groups of philosophers—one working from a behaviorist standpoint and the other from a humanist perspective—to create the lexicon. So, in response to the problem, operators selected what they considered to be the most appropriate word from the thesaurus, and entered it into the machine, while at the same time communicating their choice with the other participant by typing the unique number of the word on the keyboard. Like his earlier works, *Metafilter* was designed for two people to carefully and systematically cooperate, with no right or wrong way to engage with the piece, and no correct or incorrect view favored by the work. The level of agreement was allowed to fluctuate and direct itself to whatever field of investigation was decided upon between operators.

Once agreement was achieved, the programming within *Metafilter* provided a basis for progression by presenting the operators with a new problem to cooperatively solve. The program could also assist if no agreement was reached by positing another problem that provided an alternative way of looking at the kind of behavior being considered.[52] The computer, in this instance, becomes subservient to the exchange of people consciously trying to develop two strategies. In response to a question posed by John A. Walker about whether participants could gain much by looking at the physical exterior or indeed by examining the electronic circuitry within, Willats replied, "The physical machine is not seen as important except as a means of achieving a set of re-orderings."[53] As both participants progress through the system, perceptions are conjoined with results made manifest in the problem book. The operators receive carbon copies and the originals are shown on walls surrounding the machine so that past responses can be compared with those of current participants. Whereas photographic encoding of reality in the locale was the medium favored in the *Edinburgh Social Model Construction Project*, making it very site specific, *Metafilter*'s use of language meant that it could be located anywhere."[54]

From this brief survey of Willats's early work, one can see a natural evolution from concerns with single participants, through involvement with groups of people (often in binary pairs), to working with entire social clusters. Cybernetic concepts such as self-regulating systems and homeostasis are used to illustrate complex systems of input and output as heuristic or problem-solving apparatus for the participant. One can perceive an increasing sophistication in the way electronic hardware and software is used to process the ever-increasing amounts of data generated. The figure of Stephen Willats, as artist, is ever present both as investigator and observer of the system. As time has progressed, Willats has shifted from objective outsider to internal agent and back to interested onlooker. The role technology and computers have played in Willats's work contrasts sharply with the way in which such machines were used by artists in exhibitions like *Cybernetic Serendipity* at the ICA,[55] and is best summed up by the artist himself:

> The use of task-orientated or participatory techniques and the references to learning theory means that one is entering the world of engineering—that is, the engineering of human response. One could argue that this is what artists have been concerned with all along. However, although sophisticated technology is pertinent to the artist he is not concerned with extending the behavioral sciences but with furthering the realm of art.[56]

Notes

1. For instance, his work with residents on a Peckham housing estate and citizens of Sheffield, the results of which were exhibited respectively in *Changing Everything*, South London Art Gallery, July 1–August 2, 1998, and *Creative Force*, Mappin Art Gallery, Sheffield, July 10–August 30, 1998.

2. Solo and group exhibitions during this period included those devoted to Yaacov Agam, Jack Clemente, William Crozier, Erich Kahn, Kosice, Stephen Gilbert, Cecil Stephenson, Edgar Pillett, Brian Wall, and Herbert Zangs; of major significance was the exhibition on English Constructivism in 1960.

3. The principal people involved were Brian Elliott, David Elliot, Constantin Mouches, and the art theorist Andrew Hudson.

4. Willats completed four of these early notebooks at the Drian—three of philosophical writings and one of conceptual models and propositions about the nature of art.

5. Staff included Roy Ascott, Anthony Benjamin, Adrian Berg, Denis Bowen, William Brooker, Bernard and Harold Cohen, Noel Foster, William Green, Derek Hirst, R. B. Kitaj, Brian Perrin, George Poperwell, Robin Ray, Larry Rivers, Peter Startup, and Brian Wall.

6. For a survey of the teaching methods employed at the Institute of Design, Chicago, see *Taken by Design: Photographs from the Institute of Design, 1937–1971*, edited by David Travis and Elizabeth Siegel (Chicago: University of Chicago Press, 2002). Roy Ascott studied under Victor Pasmore and Richard Hamilton at Kings College, University of Durham, and is the

founding president of the *Planetary Collegium*; professor of technoetic arts, University of Plymouth, England; and visiting professor in design/media arts at the University of California, Los Angeles.

7. This echoed the ideas of Harry Thubron (1918–1986), who studied at the Royal College of Art, London, before becoming an influential teacher at art colleges in Sunderland (where he had a direct influence on Victor Pasmore and the course at Newcastle), Leeds, Lancaster, Leicester, and Goldsmiths in London.

8. The New Vision Centre Gallery was another of the small number of avant-garde galleries in London showing, among other artists at this time: Keith Arnatt, Peter Blake, Stuart Brisley, William Green, Gordon House, Heinz Mack, Piero Manzoni, and Ralph Rumney.

9. Nicolas Schöffer (1912–1992), who is often termed the father of cybernetic art, created his first outdoor, interactive light sculpture in 1956. His solo exhibition, *Spatiodynamic Cybernetic Luminodynmaic Sculpture*. . . , Institute of Contemporary Arts, London, July 8–30, 1960, was a great success. The term *cybernetics* was coined by the American mathematician and early computer developer, Norbert Wiener (1894–1964), who defined it, as "the science of control and communication in the animal and machine," which was the subtitle to his book *Cybernetics* (Cambridge, MA: MIT Press, 1961). The discipline embraced information, feedback, identity, and purpose.

10. There were talks by artists such as Anthony Benjamin, Richard Hamilton, Robin Page, Brian Wall, and Group Zero (Heinz Mack, Otto Piene, Gunther Uecker), as well as by the architect Norman Foster.

11. Basil Bernstein (1924–2000) was a preeminent sociolinguist, particularly known for his series *Class, Codes and Control*, which became required reading in sociology courses worldwide. Willats remembers hearing him talk at the ICA around this time.

12. Gordon Pask developed a unique theory of learning within a cybernetic framework based on research into biological computing, artificial intelligence, cognitive science, logic, linguistics, psychology, and artificial life. As early as the 1950s, Pask had reproduced intelligent behavior with his own electromechanical machines.

13. Such as the *New Scientist*, *Scientific American*, and the seminal text by W. Grey Walter, *The Living Brain* (New York: W. W. Norton & Company, 1963). In the 1940s, Dr. Walter had carried out pioneering research on mobile autonomous robots with his robot "tortoises" Elsie and Elmer, which proved influential in the development of cybernetics.

14. Dr. Christopher Evans joined the National Physical Laboratory in the mid-1950s. He published both academic and science fiction texts, including a number on the subject of sleep, dreams, and computers; see, for instance, his eponymous text in *The Disappearing Future*, edited by George Hay (London: Panther, 1970).

15. The Drian Galleries was close to Selfridges. Willats often took lunch there, though he did not contact the store about his idea.

16. This series was initially shown to visitors at Willats's studio first at Redesdale Street, Chelsea, and then at 5 London Mews, Paddington, before being publicly shown for the first time in Willats's solo exhibition, *Concerning Our Present Way of Living*, Whitechapel Art Gallery, London, January 12–February 25, 1979.

17. System Research Ltd. was Pask's empirical baby where cybernetics could be simulated and alpha rhythms examined in a laboratory setting. It was here that Willats became aware of Ross Ashby (1903–1972) and his *Homeostatic Machine* or *Homeostatic Model*, homeostasis being an important facet of Willats's work to this day. Ashby wrote two classic texts concerning the study of organizations and the control of complex systems, *Design for a Brain* (New York: John Wiley & Sons, 1952) and *Introduction to Cybernetics* (London: Chapman & Hall, 1956).

18. Yaacov Agam is best known for his role in the development of kinetic art. His work is typically characterised with abstraction, movement and viewer participation, especially in his transformable pieces first made in 1952, and which were shown at the Drian Gallery, April–May 1959.

19. Dr. Ivan E. Sutherland developed *Sketchpad* to create highly precise drawings. He also introduced important innovations such as memory structures to store objects and the ability to zoom in and out. He currently teaches, undertakes research on advanced hardware technology and is a vice president and fellow of Sun Microsystems, Inc.

20. Douglas Engelbart (b. 1925) later had a hand in inventing or contributing to several interactive, user-friendly devices: the computer mouse, windows, teleconferencing, email, and the Internet.

21. As quoted in Douglas Engelbart and Harvey Lehtman, "Working Together," *BYTE* 13, no. 13, (December 1988): 245–252.

22. Vannevar Bush's article, "As We May Think," published in the *Atlantic Monthly* in 1945, outlined—among other innovations—his concept of a machine that would aid human cognition.

23. Statement in catalogue of exhibition, Chester Beatty Research Centre, London, January 1964.

24. Manifestos included, "Society's Aesthetics," "The Artist as a Philosopher," and "The Random Event." A later one entitled, "Totalism" includes the lines: "Computerised centralism sweeps our decision-power into the margin: open control dies" and, "Totalism deals with the 100%. Artists, with intense visual and environmental originality, persuade the mass but, with openness technologically assured, they are controlled by the mass, who learn from them till the two but merge," signed Logie Barrow (aka Stephen Willats), June 19, 1965.

25. For example, John Newell, "Alpha Rhythm Applied to Art," *New Scientist* 25, no. 436, (January 14, 1965): 75–76.

26. *Control* magazine, which was first published in 1965, was established for artists concerned with the social function of art in contemporary society allied closely to cybernetic or behaviorist ideas. It is still published at periodic intervals today.

27. In collaboration with Willats, one group of students developed a questionnaire, which they used when going from house to house looking at color and shape associations. From this empirical research, students realized that the community would find it useful to have signposts indicating areas that were particularly important to them such as directional ones to the local supermarket or warning signs alerting children to the existence of a dangerous pit. In all, seven signposts were created and positioned in the neighborhood, remaining in place for many weeks. Other students attempted to develop the ideal picture for an audience. Again,

they used the methodology of the questionnaire and constructed paintings using new techniques based on the responses to the questionnaires, such as images of galloping horses with the sun setting behind. The paintings were later given to respondents.

28. For instance, *KunstlichKunst*, Stedelijk van Abbemuseum Eindhoven, Netherlands, September 25–December 4, 1966; *Light in Movement*, Herbert Art Gallery, Coventry, December 7–31, 1967; and, most notably, his solo exhibition, *Visual Automatics and Visual Transmitters*, Museum of Modern Art, Oxford, October 22–November 16, 1968.

29. A drawing of *Variable Sheets* and the actual clothing and helmet is in the collection of the Victoria and Albert Museum, London.

30. Here Willats created *The Man from the Twenty First Century*, 1969–1971, and he would later return to Nottingham to organize *Cognition Control Project*, an umbrella title for six projects by nine individual artists in and around the city in 1973. These ranged from Mick Burrows's radio artwork, *Mass Media People*, to an interactive piece, *Mind Rover*, by Stroud Cornock and Ernest Edmonds. For this project, Willats also initiated *Social Resource Project for Tennis Clubs*, a cooperative effort with four city tennis clubs. In 1974, Willats visited the city again with his solo exhibition, *Life Codes and Behaviour Parameters*, housed at the Midland Group Gallery.

31. *Kinetic Art*, Hayward Gallery, London, September 25–November 22, 1970 and *Electric Theatre*, Institute of Contemporary Arts, London, March 18–April 18, 1971.

32. In a conversation with the author, November 2004.

33. TTL 74 series logic supplied by Motorola Semiconductors Ltd.

34. Derek Aulton was a senior engineer at Ferranti Space; he collaborated with Willats over the next seven years.

35. To address this aspect, Willats gave a paper on symbolic language at a Computer Art Society symposium, *Interact*, as part of the Edinburgh Festival in August 1973. *Visual Language Simulation* was also presented in Edinburgh during this time, having toured the United Kingdom previously at Gallery House, London, and in Willats's solo exhibitions at Nottingham and Oxford, op cit.

36. This was part of a group of projects for the Edinburgh Festival, also organized by the Computer Arts Society under their collective title, *Interact*, August 1973.

37. *The Edinburgh Social Model Construction Project*, sponsored by the Computer Arts Society, International Computers Ltd., and the Leith Festival, August 25–31, 1973.

38. See Stephen Willats, *Project Operators Manual Social Model Construction Project*, 1973, 3.

39. Interestingly, Hans Haacke used questionnaires with ten demographic questions for his *Visitor Profile* series for visitors to the exhibitions, *Software, Information Technology: Its New Meaning for Art*, Jewish Museum of Art, New York, September 16–November 8, 1970; *Directions 3: Eight Artists at the Milwaukee Art Center*, June 19–August 8, 1971, and later at *Documenta 5*, Kassel, June 30–October 8, 1972. For *Software*, the installation comprised a teletype terminal with a monitor that was connected to a time-sharing computer. The computer was programmed to cross-tabulate demographic information about the museum audience and to provide a profile of all the visitors to the exhibition. Ironically, the software did

not operate in *Software*, though answers to the questionnaire for *Visitor Profile* were processed by computer at Milwaukee, confirming the viability of the real-time display of a feedback loop between audience and artwork. Haacke, however, felt discouraged from using such technology again.

40. Stuart Pound later became Director of the British Society for Social Responsibility in Science.

41. The consensus tendencies, comparisons made by the computing system, were used by participants as the foundation for their solutions to the project's problems. Participants could compare their solutions with others by accessing the public monitors or terminals.

42. Press release titled, "*The Edinburgh Social Model Construction Project* August 25th–31st" (1973).

43. Gallery House was a temporary alternative exhibition space in South Kensington managed by Rosetta Brooks and Sigi Krauss between spring 1972 and summer 1973.

44. Shown as part of the *Survey of the Avant-Garde I*, Gallery House, August 18–September 8, 1972. The *West London Social Resource Project*, March 1972.

45. Willats set up the Centre for Behavioural Art on the second floor of Gallery House between 1972 and 1973 as a members-only research forum. While resident, he also curated a solo exhibition, *The Artist As An Instigator of Changes in Social Cognition and Behaviour.*

46. Dr. Jerry Brieske, for instance, gave a talk about his interest in man-machine interaction and its relationship to education. He had already designed an adaptive teaching machine for use in psychological research as well as undertaking research into the formulation of a model of a goal-seeking adaptive organism.

47. For example, *The Use of Interactive Learning Systems by the Artist*, October 28, 1972, in which Willats examined past and future applications of learning theory models to structured interaction through the use of machines by himself, Don Mason, and George Mallen.

48. Work on *Metafilter* began in March 1973, with work first shown at The Gallery, Lisson Street, London, later that year.

49. Stephen Willats, "Metafilter," *Art & Artists* 9, no. 104 (November 1974): 28.

50. Some of the original components from *Metafilter* are housed in the records of the project now in the Tate Archive (TGA 999).

51. The words were grouped into sections—associated with a form of behavior within a group—such as "basic relationships," "social provision," "survival behavior," "projectional behavior," and "formal behavior"; these were further divided into twenty subsections.

52. The machine automatically resets if: participants cannot agree for five problems; twelve problems are completed; or a word from the thesaurus is not entered into the system within four minutes.

53. Stephen Willats in an interview with John A. Walker, *Studio International* 190, no. 977 (September 1974): 151.

54. *Metafilter* was subsequently exhibited in venues such as the Midland Group Gallery, Southampton Art Gallery, Tramway, Glasgow, the Tate Gallery, the Whitechapel Art Gal-

lery and at galleries in Paris and Berlin. The work is now in the collection of the Musée Nationale de La Ville de Paris, France, and is currently on tour in that country.

55. *Cybernetic Serendipity*, ICA, London, August 2–October 20, 1968. The exhibition involved 130 contributors, of whom 43 were composers, artists, and poets, and 87 were engineers, computer scientists, and philosophers. See Jasia Reichardt's account in "Cybernetic Serendipity," *Studio International* 176, no. 905 (1969): 176–177.

56. Stephen Willats in an interview with John A. Walker, op cit.

4

Interactive Architecture

John Hamilton Frazer

This chapter explores the development of concepts of interactive environments by comparing two major projects that frame the period of this book. The *Fun Palace* of 1960 and the *Generator* of 1980 both proposed interactive environments responsive to the needs and behavior of their users, but the contrast in terms of the available technology and what it enabled could not be more marked. The *Fun Palace* broke new architectural, organizational, and social ground and was arguably the first proposition for cybernetic architecture; the *Generator* demonstrated how it could be achieved. Both projects are now acknowledged as seminal architectural propositions of the twentieth century, and both were designed by Cedric Price.

Significantly, both projects were driven by a social idealism for which the developing technology almost incidentally provided the solution. As Price himself put it: "Technology is the answer—but what was the problem?"[1] This was a rhetorical question for a slide presentation, but the question, or at least the issues, was very clear to him—Price placed architecture in an entirely new perspective, generating models for future architecture. His commitment was not to architecture as then known, but to some value or effect outside of architecture that architecture was to serve. Price's projects explored his generic ideas about new ways of making environments responsive to the needs and desires of their users, and became the fundamental archetypes of a new deal for users—or a new "menu," in Price's terminology, for consumers of architecture.

At a time when architects were beginning to acquire a social conscience, Price went far further and centered his thinking on social and ethical concerns from which architecture might be a byproduct. He continually challenged the preconceptions of the profession and society about the limits and social usefulness of architecture. For most of his associates, these fundamental social and ethical concerns were the driving inspiration of the period. Technology was seen as the primary force to enable this change.

The Context of the Sixties

Throughout this chapter, there is an ironic leitmotif. Although we are celebrating computer creations of the 1960s and 1970s, there were in fact no computers; or, more accurately, there were no computers that most people could get their hands on, let alone program if they did gain access. So the period is also framed by the arrival of mainframe computers to some leading universities by the 1960s and the first personal computers appearing on the market at the end of the 1970s.

The sixties and seventies were rich in ideas but strangely (yet perhaps advantageously) impoverished of actual technology. From the perspective of my twenty-first century work environment (my Sussex garden where I use a wireless broadband battery-powered laptop), it is hard to remember how little we had of the technology we talked so much about. And now, although the performance of the technology has exceeded the wildest dreams of the seventies, the vision and direction seem drained and tired. Perhaps this is because the politics have changed more dramatically than the technology, and mainly for the worse.

In a recent article in *Architectural Design*,[2] I described how, while I was writing the article in my garden, a student had logged in from China for a tutorial in one window; my son was chatting in another; in a third window an urgent email query from Frank Gehry's office was being answered; and then Cristiano Ceccato came online from the first class cabin on a plane at 35,000 feet over India. It was 4pm British Summer Time—that magical time of the day when Los Angeles is waking up and Shanghai is not yet asleep. The text and images for the article were then assembled and sent to the editor and transmitted online by wireless link. But more significantly, I reflected that I had just been connecting to the Peoples Republic of China, the United States of America, and the air space over India simultaneously from my garden in the European Union with an international network of agreed protocols. The politics of this seemed more wondrous than the technology and were quite impossible to conceive during the sixties and seventies. In the mid-1960s, revolutions were plotted from communes in North London, and with the 1968 Paris student riots we saw a real chance of a quick fix to social injustice. But with the sobering 1973 oil crisis came new strategies to effect social change and hope was seen in the new technologies and the emergence of cybernetics in particular.

By 1960, the computer age had supposedly arrived, but, as I wrote above, there were no computers, or at least no computers to which most of us had access, so the sixties and early seventies fostered a prolonged thought experiment. Most of us could not access or afford computers, so we just imagined we had them and we also imagined all the rest of the technology and social and political change necessary to realize our dreams. So it became a challenge of computing without computers—like an athlete prepares mentally by rehearsing in the imagination the achievement of some difficult feat. In architecture, we spent the sixties and seventies going through a mental rehearsal of what it would be like at the beginning of the twenty-first century—except that we were thinking it would all happen in the eighties!

First Interactive Environment: The *Fun Palace*

Joan Littlewood, the legendary producer of radical and political theater, approached Cedric Price in 1958 with a project to regenerate what she described as the "tired formalism" of theater and amusement facilities and reincorporate them into the everyday life of the city.[3] This initiated the notion of a fun palace, which would be a flexible and indeterminate space. This concept reverberated through two generations; inspiring in particular Piano and Rogers's Pompidou Center in Paris. Gordon Pask, who was the cybernetics consultant to the *Fun Palace* project, cites Gaudi's Parc Guell as the first interactive building because it provoked a reaction from the observer.[4] That comment, which could be applied to many buildings, discribes a passive type of interaction. Pask was also fond of saying that if it did not kick you back it was not interactive. The *Fun Palace* however, stands at least as the acknowledged first actively interactive environment—it would literally move and change in response to the desires of the users.[5]

Price's concept was not a static monument, but an ever-changing environment responsive to the appetites of its users. There was no façade or even formal enclosure but cranes redeploying an expendable kit-of-parts as needed, and all under cybernetic controls developed by Pask.[6] A different configuration is shown in every drawing; the conventional labels such as Elevation were replaced with titles such as "Selection," "Assembly," "Movement," and "Control," and the whole proposition is only grasped from a helicopter view at night with the roof retracted.

Writing in the *New Statesman* in 1964, Reyner Banham ignited a public debate about the social potential of architecture by comparing the traditional frozen monumentality of the then recently completed Crystal Palace Sports Centre with the flexibility and new set of choices proposed in Price's *Fun Palace*. Banham talked not in terms of precedent, but by showing how as both a concept and a program, it had far greater social relevance and conceptual significance than the Sports Centre, the other contemporary "people's palace." Banham recalled that Cedric drove the press mad for months by refusing to show drawings of what the *Fun Palace* would *look like* and Banham suspected that even Cedric might not know but "that was not the point. Seven nights of the week it will probably look like nothing on earth from the outside: the kit of service towers, lifting gantries and building components exist solely to produce the kind of interior environments that are necessary and fitting to whatever is going on. What matters is that the various activity-spaces inside the *Fun Palace* will not be fossilised in a single architectural schema that may be functionally out of date in five years . . ."[7]

The real difficulty with the *Fun Palace* was not that nobody knew what it might look like, but that it was never clear how it would be controlled and who would have the fun of controlling all the gantries and moving parts. There was a notion that it would all be dictated by some cybernetic system to be devised by Pask. However, because the cybernetic systems never got to the point of being a testable, questions of how decisions were made and how conflicts of interest would be resolved were never addressed. But that was to change with the design of the *Generator*, which will be described later in this chapter.

The In-between Years

We are now operating under a legacy clearly derived from the fertile thinking of the late fifties, sixties, and early seventies, when many of the leading practitioners of today were developing their own thinking and even beginning to teach it in the more progressive art colleges of the world. I believe my own experience was typical of that generation; perhaps I can shed some light on how things evolved by relating a series of personal anecdotes and experiences that are representative of the period and the whole post-war generation of artists and designers.

My first lesson in interaction was from Grey Walter. He built a series of tortoises that returned to their boxes to recharge, guided by a light, and with wheels steered by a photo-electric cell.[8] When I was six years old I was taken to the 1951 Festival of Britain in London and saw one of the tortoises performing. I clearly remember thinking that the tortoise was looking for its home. My Father patiently reproached me and explained that this was only my interpretation, that the machine had only apparent intentionality and I should avoid the temptation of attributing meaningful behavior to a machine. This did not deter me, however, from building my own tortoise when I got home. (It worked, but not as well as Walter's.)

My second lesson was inspired by Donald Michie's 1961 essay, "Trial and Error,"[9] in which he describes MENACE (Matchbox Educable Noughts and Crosses Engine). MENACE was essentially a computer that learned to play noughts and crosses (tic-tac-toe); it was constructed from more than three hundred matchboxes, each containing colored beads. Each box corresponded to a possible position in the game (symmetrical situations were eliminated) and each color of bead (there were several of each color at the start) in the box corresponded to a possible move. MEN-

ACE was played by humans who selected a color at random from the box corresponding to the current state of play. At the end of each game, MENACE was rewarded for a win by having extra beads of the appropriate color added to the appropriate boxes, or punished for losing by having beads taken away. Since a good strategy could be spoiled by a losing move at the end of the game, which would result in all boxes involved being punished, the rewarding system was very crude; yet it still resulted in MENACE learning to play to the extent that it generally won or tied if a human opponent made a mistake. As a fifteen-year-old schoolboy, I was wildly excited by this concept and immediately built my own copy—and like the tortoise it also worked. So my personal involvement with computers from this humble beginning ties in closely with the developments that began in 1960.

To pursue my interests, I enrolled at the independent Architectural Association (AA) in 1963. My own experience was a typical struggle against both the lack of computers and some hostile staff attitudes to computing. For example, in 1964, I was ridiculed for designing a church based on a series of Boolean diagrams representing the relationship between theological propositions. Boolean descriptions of relationships are now commonplace in computer programs for design applications.

Lesson three on interaction came in 1965 when Gustav Metzger lectured at the AA on autodestructive art.[10] He contrived for his slides to burn in the projector during the lecture, and afterwards there was a demonstration in the courtyard outside. His choreographed destruction of fluorescent tubes inspired an orgy of desolation, with models, drawings, drawing-boards, and furniture being hurled from the studio windows overlooking the yard; I was inspired to hurl myself from the rooftop onto this participatory event—not from depression but a sense of elation. Others admitted feeling this impulse too: the mystic urge to martyrdom inspired by art.

Lesson four was Gordon Pask's *Musicolour* system and his *Colloquy of Mobiles* in the *Cybernetic Serendipity* exhibition in 1968 at the Institute of Contemporary Arts. Jasia Reichardt brought together Norbert Wiener, Stafford Beer, Karlheinz Stockhausen, John Cage, Edward Ihnatowicz, Gustav Metzger, Gordon Pask, and others, combining poetry, music, art, sculpture, dance, film, even architecture. For page after page, the catalogue[11] documents the seminal experiments that set the agenda for the next forty years. But for me it was Pask's *Colloquy of Mobiles*, the first demonstration of a working interactive environment (well it worked some days), that stole the show. Male sculptures went into states of sexual excitement and rounded female figures used their reflectors to attempt to satisfy them (issues of sexual stereotyping were just beginning to emerge in the 1960s!). Visitors to the exhibition could also use mirrors to attempt to intercept the light beams and thus satisfy the Gordon Pask look-alikes. The result was a spill of orgasmic light around the whole exhibition space.

The more progressive magazines of that time such as *Architectural Design* gave one to imagine that computer-aided design was already a reality and that the construction of buildings by computer-controlled machinery was about to happen. The reality was that the AA only acquired a teletype terminal to a time-sharing mainframe in 1967, and no computing instruction was available. So I went to the London School of Economics to learn programming, discovering how to program FORTRAN using punched cards for the data analysis of social surveys. Later I had to cross a vast gap from writing code to count single-parent families to programming the instructions for drawing buildings.

Lesson five came about in 1967–1968 through the pain of generating my first computer drawings plotted in black ink on cartridge paper.[12] Creating drawings of a geometrical complexity that was virtually impossible by hand was inspirational, but the agony of writing the software (there was no AutoCad) and entering all that data started me on a lifelong project to improve the situation. With the encouragement and help of my tutor, John Starling (who wrote the perspective routine for me), I produced my final-year drawings using paper tape as the input and outputting from a flat-bed plotter that I had to hire by the hour. With no screen preview there was every chance that the drawing would be blank . . . but there was great joy whenever the pen began its painstaking plotting. The cost of hiring this goliath was astronomic; however, I was saved by the BBC coming to film "the first student project to be produced by computer." Seeing my desperation at the extra time the filming was taking, the BBC generously picked up the whole bill (figure 4.1). At last I

Figure 4.1 Pen plotting student project at Glen computing. John Frazer, 1967–1968.

finished what was possibly the first student project to be fully drawn by computer, and won the year prize for it, only to have all the original drawings stolen from the end-of-year exhibition.

Screen graphics finally arrived for me in 1969 when I graduated from the AA and moved to Cambridge University to be an assistant lecturer. I finally had access to a graphics display device—a circular cathode ray tube with refresh vector graphics. The first lines faded before the last ones were drawn and had to be refreshed by overwriting with the electron beam again and again; but this was at that time the only graphics device at one of Britain's most prestigious Universities.

The mainframe at Cambridge at that time was an Atlas Titan. Housed in the new tower of the Mathematics Laboratory in Lion Yard in the center of the town, this system allowed me to start developing generative programs based on a kind of digital DNA concept that enabled me to design structural forms automatically, without the tedium of entering all of the data. I was helped in this venture by Charles Lang, the director of the lab, and Richard Parkins, who wrote subroutines in Atlas Titan machine code that packed into one word all the location, orientation, and unit type data of the structural elements I was using. I then wrote the manipulative program in FORTRAN, assisted by research student Francesco Guerra. And thus I successfully embarked on a long series of experiments with generative and evolutionary design (figure 4.2).

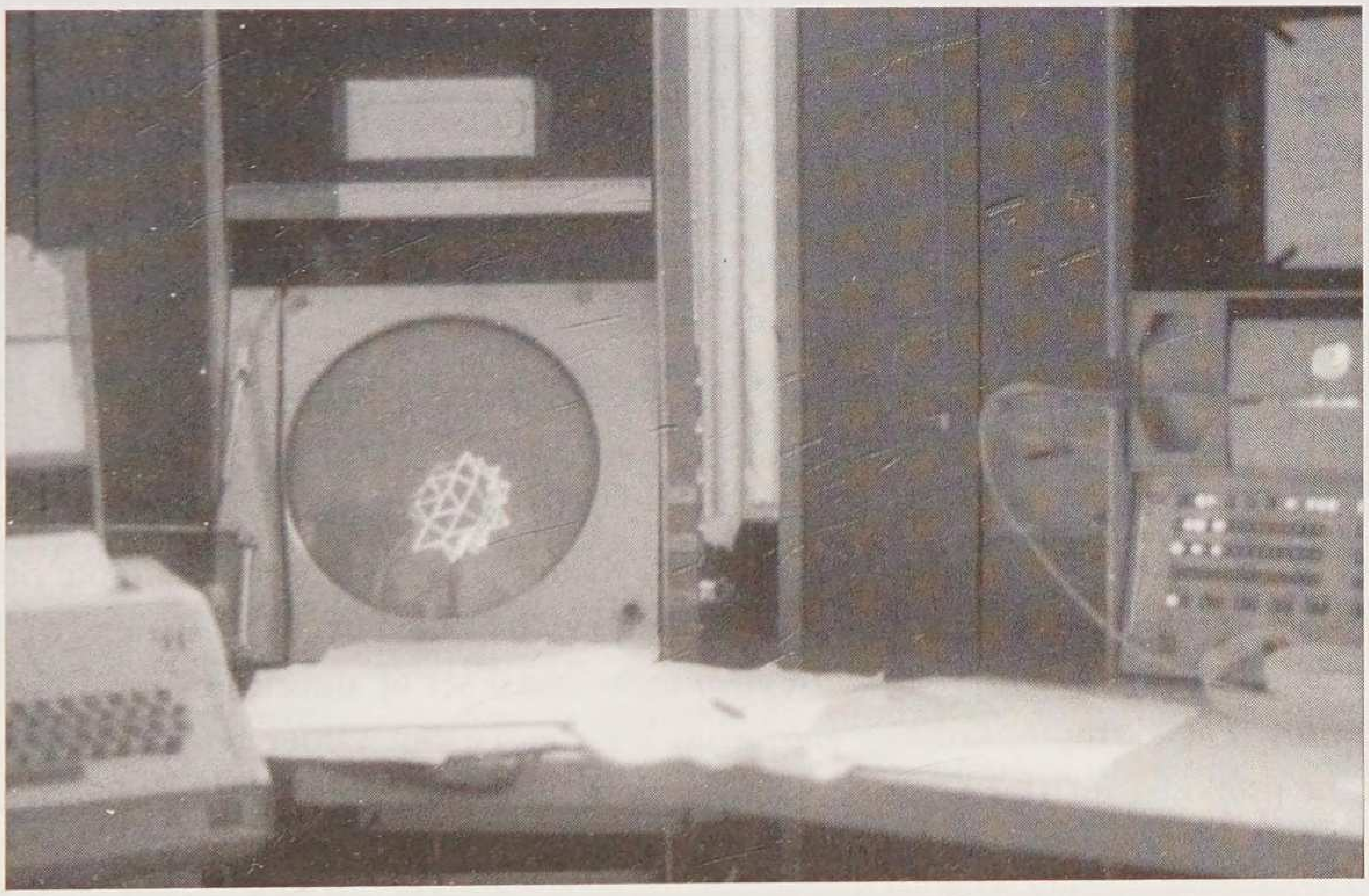

Figure 4.2 Generative design on Cambridge University Atlas Titan. John Frazer, 1970.

Lesson six came from John Horton Conway, who at that time was the only other user of the graphics system at Cambridge. He was developing rules for his *Game of Life*; a two-dimensional cellular automata in which the behavior of individual cells was dependent on the number of neighbors. If there were too few neighbors, the cell died of loneliness; too many and they died of suffocation. A reasonable density of neighbors resulted in continuing life, and perfect conditions resulted in the birth of a new cell. This anthropomorphosis of behavior recreated the fallacy of interpreting the behavior of the Grey Walter tortoises as lifelike. We naturally associate certain patterns with living organisms and this led to the term "artificial life." Watching these little dots fighting for life on the screen inspired me, and I began modifying my generative program to have *Game of Life*–like rules. I started thinking of architecture as a form of artificial life (a theme I was to revisit with a group of AA diploma students in the late eighties, outside this book's time-frame).

By the mid-1970s, I was back at the AA again and we repeated the matchbox computer experiment with a group of students, but this time we built two machines to play against each other. The learning was slower but it still worked; we soon witnessed the astonishing sight of two piles of matchboxes playing each other and gradually improving their apparent strategies. I say "apparent" because they actually improved through learned response patterns rather than any kind of strategy. One machine was always X and the other always O. Eventually the O machine would run out of matches; we interpreted that as the machine giving up or getting bored. This response refreshed yet again Grey Walter's lesson about the ease with which we tend to see behavior in machines as purposeful when it is not purposeful at all; or we attribute to machines human characteristics such as boredom or a feeling of failure or an urge to win. The inspiration for the project was of course Donald Michie's MENACE, described previously, and Michie, who as a young man was a close colleague of the legendary Alan Turing at Bletchley Park, is now widely regarded as the father of British artificial intelligence research.

At the AA in the mid-seventies, I was able to introduce computing as an algorithmic, generative process. We began by generating classical columns using proportional rules based on James Gibbs's 1732 treatise, *Rules for Drawing the Several Parts of Architecture* "in a more exact and easy manner than has been heretofore practised, by which all fractions, in dividing the principal members and their parts are avoided."[13] Gibbs provided us with an integer-based set of algorithms for drawing columns. For example, Gibbs's algorithm for the Tuscan Order reads, "take any height proposed for this Order upon a straight line, and divide it into five equal parts; one of those shall be the height of the pedestal, according to the outer division of the scale. Then divide the other four parts above into five parts according to the inner division of the scale; the upper fifth part shall be the height of the entablature . . ."[14] We rendered this directly in about thirty lines of code and thus generated a

Tuscan column according to Gibbs's rules. We then substituted a random number generator for each of Gibbs's carefully considered proportional ratios. This generated a grotesque series of Tuscan aberrants. The intention was to adjust the randomly generated variables so that it was possible for the program to learn to emulate our matchbox experiments. This failed at the time because our method of control was too closely based on the matchbox process. Later, having discovered genetic algorithms, I reran the exercise with a PhD student, Peter Graham, and succeeded in controlling the proportions to either learn exactly Gibbs's preferred proportions (it converged surprisingly quickly) or to learn proportions preferred by the user in a user-selection system analogous to Richard Dawkins's *The Blind Watchmaker* biomorph software.[15] But in the mid-1970s, the AA, arguably the most advanced school of architecture in the world, still only had one teletype terminal. Everything I did with my students was with the aid of my old friends in the Cambridge Mathematical Laboratory.

Late 1970s: At Last We Got the Computers, But No Software

Christmas 1977 was spent sitting in bed, snowbound in a remote farmhouse in Killyleagh County Down, reading a stack of manuals for a Tektronix 4051 that had just been delivered. I had taken a post as head of School of Art and Design Research, History and Criticism at the University of Ulster (then Polytechnic) and at last had access to enough resources to introduce computing into the curriculum as the first microprocessor-based graphics systems became available. Our excitement grew as we realized that here was the potential for every architect to have a graphics computer on their desk. Famously, John Lansdown (to whom this book is dedicated) was one of the first architects to acquire a Tektronix 4051.

At last we had computers but still there was no software, so we embarked on a twenty-year task to write useful software that really assisted design rather than obstructing it. Working with my wife, Julia Frazer, we developed a series of graphics programs for the 4051, including the general purpose pattern program (GPPP), an animation program (not much more than in-betweening and some automatic functions), and a 3D wireframe visualizer, GPPP3. We also purchased a hidden line program, BIBLE (buildings with invisible back lines eliminated), from the ABACUS group in Strathclyde.

There were many obstacles to introducing digital tools, including outright hostility from many staff. There was also the burgeoning authorship problem: Should the artist or the programmer be accredited with the creation? We were teaching students to use graphics programs and even to write simple generative routines, however the few staff who did show interest expected their doodles to be programmed for them, and that they would then get all the credit as the artist.

However an even bigger problem was that we only had one graphics terminal and it was obvious we wouldn't get the funding for more, particularly in the face of a strong anti-computer lobby from the department heads of Fine Art and 3D Design. At the time it seemed understandable incomprehension, but in hindsight it was clearly self-interest.

The arrival of the Commodore Personal Electronic Transactor, affectionately known as the PET, allowed us to improvise by attaching small pens on plotters, and even passing light via fiber optics into the plotters to record animations on film. A new generation of students was introduced to the potential of computer graphics and produced some remarkably creative and inventive work. (Some was shown in the *Young Blood* exhibition at the Barbican in 1983.)

This part of the seventies was a fruitful period for all kinds of other collaborations and, again, I believe my experience was typical. We invited a series of visiting lecturers to Ulster, including Edward Ihnatowicz, Cedric Price, Gordon Pask, Chris Jones, Richard Gregory, and Tony Pritchard. The political situation in Northern Ireland at that time was highly unstable and work in the Belfast city center was interrupted by frequent explosions, gunfire, bomb scare evacuations of our offices, and endless bodysearches just to go shopping. We tried to protect our visitors from this; however, Ihnatowictz in particular was very upset to learn that he had just missed the sight from my office window of a remote-controlled army robot getting blown up while investigating a suspicious device. Because of the dangers, most visitors stayed in our remote farmhouse in Killyleagh, where we could see only the Toye lakes, masses of wild geese, and the Mourne mountains beyond. In the sprawling outbuildings to the farm we built studios, laboratories, workshops, and offices, and established our software company, Autographics.

When it became obvious that all architects and designers would soon be able to have their own microprocessors, we set to writing graphics packages. We established Autographics with Paul Coates and other colleagues and launched AutoPlan in 1979 and AutoView as the first commercially available 3D program (which soon included hidden line removal). Only a few years later AutoCad appeared, eclipsing our pioneering little company. But in the meantime, we had demonstrated to a skeptical profession that a useful drafting package was possible on a low-cost microprocessor. We developed an interpreted graphics language known as SPL (Shape Processor Language), which accessed a special-purpose ROM with machine code matrix transformations for high speed graphic transformations. We based the interface on the idea of user-defined commands, which enabled users to extend and customize the functionality of the program.[16] We went on to develop the first microprocessor-based solid modelling program. It had an ingenious 3D cursor and replaced the complex use of Boolean expressions with the simple metaphor of a workbench; this is still employed in many CAD systems to this day.[17] We later won many major design and innovation awards for this interface, including a British Design Award in 1988, Design Council and Shorts Aircraft special award for best technical innovation in 1988, and the British Computer Society IT award for Technical Achievement in 1989.

Birth of Intelligent Building: The *Generator*

In our optimism, we hadn't reckoned for the despondency and lack of vision of three decades of politicians, culminating in the greed and destruction of the Thatcher era, which utterly drained creative spirit and imagination. But not quite! In fact the era ended with the creation in 1979 of the world's first intelligent building in the form of Cedric Price's *Generator* project.

The *Generator* was proposed as a kit of parts that enabled enclosures, gangways, screens, and services to be arranged (in a forest clearing in Florida) to fulfill the requirements of users (employees of the Gilman Paper Corporation). It was intended to be part recreational, part social, and part think-tank. The forest floor was gridded with foundation pads and a mobile crane was to be permanently on site to move around parts of the structure, providing endless reconfigurations in response to a self-organization strategy.

As architect for the project, Price was unequivocal in seeing architecture serving the user. He described the *Generator* as "a forest facility . . . Architecture is used as an aid to the extension of one's own interests. A series of structures, fittings and components that respond to the appetites that they themselves may generate. A 'menu' of items for individual and group demands of space, control, containment and delight. A place to work, create, think and stare."[18] The *Generator* moved further than previous projects by offering a clear program for how and why change could be effected and what the variation in resulting environments might be like. It posed the notion of an intelligent building that could learn from its own experience. It was the logical conclusion to Price's thoughts about interactive buildings following the *Fun Palace*.

Price appointed my wife Julia and me systems design consultants to the project, and we developed a suite of computer programs in 1979 to suggest new arrangements on the site in response to changing needs (figure 4.3).

We proposed embedding microelectronics into every part of the structure and connecting them through the foundation grid so that the whole structure would "know" where all the parts were. Thus all parts of the structure would cooperate to compute new configurations to meet changing user needs and responses. In the event that the users did not suggest many changes, the building would get "bored" and start suggesting alterations. This would trigger a learning cycle by which the building would discover how best to configure itself to meet the users' needs and

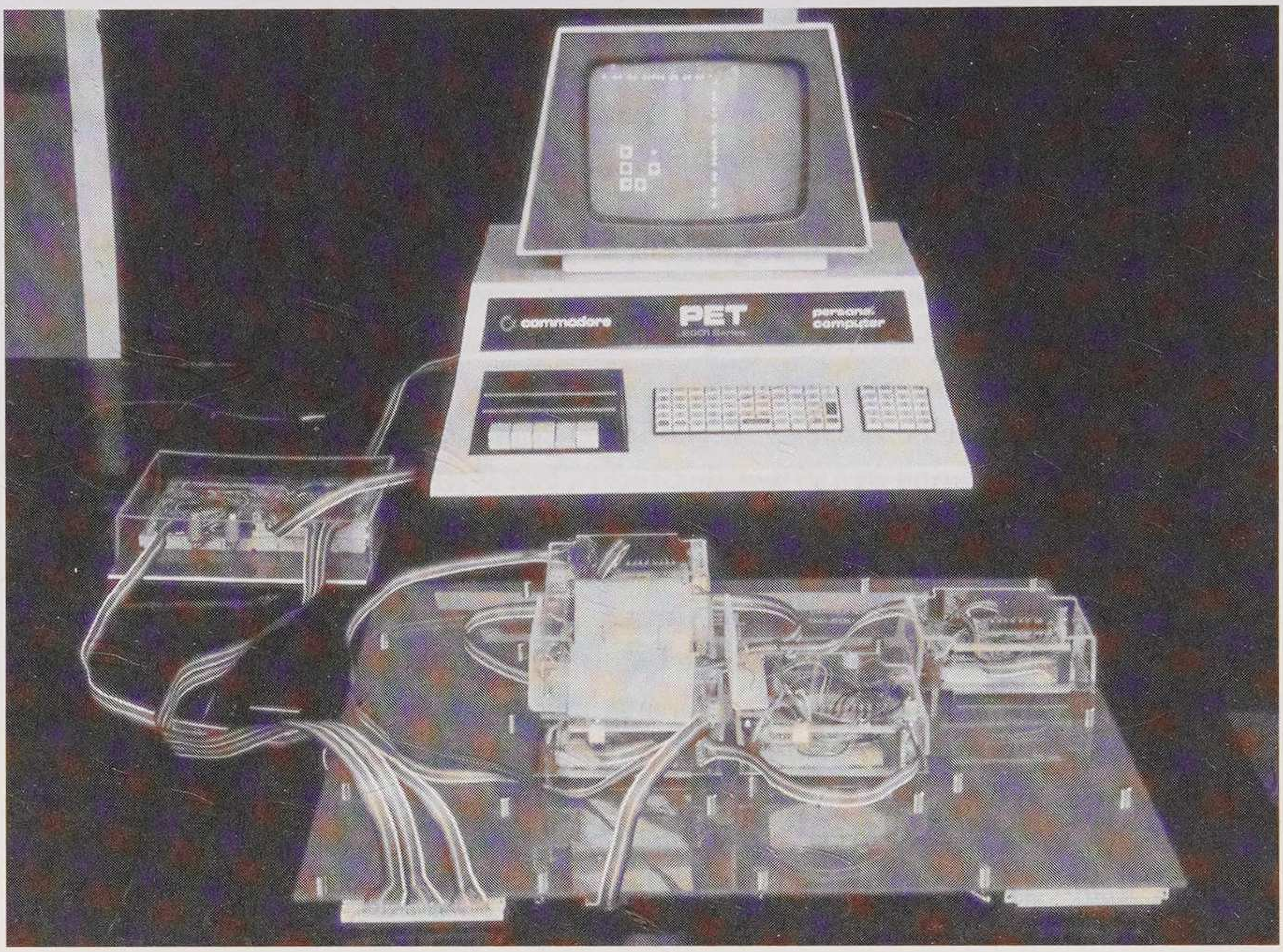

Figure 4.3 Working model of the *Generator* project. Architect Cedric Price, Cybernetics consultants John and Julia Frazer, 1979.

perhaps stimulate new appetites.[19] Our working model of this proposal is now in the permanent collection of the Museum of Modern Art in New York, along with many of our drawings.[20]

In *Building Design*, Price wrote:

> Just to add to the computer in architecture debate I include this proposal from my consultant on our latest project in which this friendly machine is widely used. "The site and the elements on it should have a life and intelligence of their own and the program would start to generate unsolicited plans, improvements and modifications in response to users, comments, records of activities, or even by building in a boredom concept so that the site starts to make proposals about changes of itself if no changes are made." Now such a proposal can only work if the initial design allows for layouts and structures that can alter and decay and disappear. Mine can.[21]

The press were quick to pick up on this; the June 1980 *RIBA Journal* contains the headline: "World's First Intelligent Building." The article described how microprocessor chips would be incorporated into the building fabric and how the different computer programs would organize the site. It latched onto the concept of boredom as the logical conclusion to Cedric's ideas about interactive buildings over a twenty-year period. The article concluded: "The computer program is not merely a passive computer-aided design program nor is it just being used to assist with the organization of the site, but is being used actively to encourage continual change and adaptation to changing requirements."[22]

In the January 1981 issue of *Design*, Deyan Sudjic heralded the "Birth of the Intelligent Building" and noted that "long before he began the project, Price was determined to create environments which could instantly respond to their inhabitants' immediate needs. Labelling a room on a plan has a paralysing effect on the way it is used. Today it appears he's set off on a course that could rid us of those paralysing effects once and for all." And on March 19, 1981, *New Scientist* commented on "a building that moves in the night . . . But to call it a building is an understatement; for, by means of a few instructions from a central computer, the building can change its shape and layout to meet the needs of people inside it."[23]

Although Price generously credited us as his consultants for adding this idea of intelligence to the building, the idea was actually intrinsic to his building concept. The *Generator* as a proposition was an intelligent building to which the consultants just added the electronics and the software. Neil Spiller recently revisited this issue in his *Cyber Reader* and reflects my own view that "important new ideas emerged from the *Generator* project. These included embedded intelligence and learning from experience during use, the isomorphism of processor configuration and structure, and the question of consciousness [of intelligent buildings]." Spiller continues, "This important symbiosis, examined in Price's architectural thesis of 'enabling' and the use of the computer, sets a benchmark against which most contemporary 'intelligent' buildings (and their designers) can be measured."[24]

Price's work espouses flexibility, not indeterminacy. It was driven not by a technological imperative, but a concern for the varying needs and appetites of the users. I contend that there is nothing "formless" or "indeterminate" about Cedric's projects. They certainly have form and it is determined (at least the enabling structure and systems, and indeed the form itself at any one moment) by the preferences and needs of the users rather than imposed by the artistic whim of the architect. Conceptually, Price freed architecture from traditional inflexible and overly determined form.

In *New Directions in British Architecture*, Roy Landau saw indeterminacy as being the basis of the *New Directions* of his title and suggested that Price approached indeterminacy "as an ideal which can be shown to have a very special appropriateness to a range of architectural questions" producing work "possessing almost no arbitrary formal allegiances."[25] However, the *Generator* offered a clear program for how and why change was to be effected and what the variation in resulting environments might be like. The proposition was fully detailed in both physical and system terms so that it could be tested (in an abstract sense) and evaluated (in some sense at least). The *Generator* unfortunately never got to the point where it would face the ultimate test: Would it bring delight to the users?

Relevance Now

Projects in which functions and spaces continuously move about are understood by some to be the architectural equivalent of the preoccupations of John Cage or are dismissed by many critics as formless or like permanent construction sites; for others they represent anonymous design. But certainly Price's work was provocative, and he distanced himself from the formal preoccupations of shape-making that obsess architects and industrial designers. Formal architectural systems of arbitrary static order were replaced by a new cybernetic order, restlessly changing to meet the real needs of the users. Architecture as we previously knew it had been undermined.

So What Went Wrong?

Digital culture suffered from two contrary tides between 1960 and 1980. On one hand we witnessed the development of important new technologies; on the other, these technologies were exploitated and trivialized. Technology moved fast—in many ways faster than expected—but the social and political and economic systems did not. When the problem becomes disconnected from the solution, we do not have a solution at all but a new problem. The fundamental concepts of the *Fun Palace* and the *Generator* are models for a future architecture as yet unrealized. These are not so much projects but generic ideas about new ways of making environments that are responsive to the needs and desires of their users. They represent fundamental archetypes of a new interaction for users—or, in Cedric Price's terminology, a new menu.

Notes

1. Cedric Price, "Technology is the Answer but what was the Question?" tape/slide presentation, Pidgeon Audio Visual, PAV 798, 1979.

2. John Frazer, "Computing Without Computers," in "The 1970s is Here and Now," ed. Samantha Hardingham, special issue, *Architectural Design* 75, no. 2 (March/April, 2005): 34–43.

3. Cedric Price, *Re:CP* (Basel: Birkhäuser, 2003).

4. Gordon Pask, "The Architectural Relevance of Cybernetics," *Architectural Design* (September 1968): 494–496.

5. Reyner Banham, "Peoples' Palaces," *New Statesman*, 68 (August 7, 1964): 191–192.

6. Cedric Price, *The Square Book* (Chichester, West Sussex: Wiley-Academy, 2003), 56–61.

7. Reyner Banham, "People's Palaces," *New Statesman*, 68 (August 7, 1964): 191–192. (Reprinted in *A Critic Writes* [Berkeley: University of California Press, 1996].)

8. http://en.wikipedia.org/wiki/Grey_Walter.

9. Donald Michie, "Trial and Error," in *Penguin Science Survey*, vol. 2 (London: Penguin, 1961), 129–145.

10. Gustav Metzger, *Auto-Destructive Art* (London: Destruction/Creation, 1965).

11. Gordon Pask, "The Colloquy of Mobiles," *Cybernetic Serendipity: The Computer and The arts*, ed. Jasia Reichardt, *Studio International* special edition (July 1968): 34–35.

12. John Frazer, "Reptiles," *Architectural Design* 49 (April 1974): 231–239.

13. James Gibbs, *Rules for Drawing the Several Parts of Architecture, etc* (London: W. Bonyer, 1732).

14. Ibid.

15. Richard Dawkins, *The Blind Watchmaker* (New York: W. W. Norton, 1986).

16. P. S. Coates, J. H. Frazer, J. M. Frazer, and A. E. Scott, "Commercial and Educational Impact of Shape Processors," *Computer Graphics* 81, conference proceedings, Online Publ. (1981), 383–395.

17. Alan Pipes, *Drawing for 3-Dimensional Design* (London: Thames and Hudson, 1990), 74, 86–87.

18. Cedric Price, "Generator Project," in *Cyber Reader*, ed. Neil Spiller (London: Phaidon 2002), 84–89.

19. John Frazer, in *Cedric Price Opera*, ed. Samantha Hardingham (Chichester, West Sussex: Wiley-Academy, 2003), 46–48.

20. Terence Riley et al., *The Changing of the Avant-Garde* (New York: Museum of Modern Art, 2002), 185.

21. Cedric Price, "Week by Week," *Building Design* (1979).

22. "World's First Intelligent Building," *RIBA Journal* (June 1980): 63.

23. Deyan Sudjic, "Birth of the Intelligent Building," *Design* (January 1981): 56.

24. Neil Spiller, ed., *Cyber Reader* (London: Phaidon, 2002), 85.

25. Royston Landau, *New Directions in British Architecture* (London: Studio Vista, 1968), 74–79.

5

"Aesthetically Potent Environments," or How Gordon Pask Detourned Instrumental Cybernetics

María Fernández

Gordon Pask is rarely acknowledged in histories of digital culture and is virtually unknown in the history of art. Pask was a cybernetician, not an artist, yet he was influential in various art-related disciplines including art installation, theater, architecture, and art theory. He participated in the groundbreaking exhibition *Cybernetic Serendipity*, curated by Jasia Reichardt in 1968, and appeared prominently in the exhibition catalog and texts associated with that exhibition.[1] His theoretical writings contributed to a diversity of fields including cybernetics, cognitive science, psychology, education, ethics, and sociology. He built a number of machines for sociocultural purposes as diverse as teaching and "sensing." He wrote plays and musicals, drew cartoons, and created works of cybernetic art.

Pask's education was as eclectic as his professional production. After completing his secondary education at Rydal School in North Wales, he obtained degrees in geology and mining engineering from Bangor and Liverpool Technical Colleges. He obtained his BA from Downing College, Cambridge, in 1952 and his MA in 1954. He completed his degree in psychology from University College London in 1964 and was awarded the first doctorate of science in cybernetics by the Open University in 1974. Pask published over two hundred essays and six books including *An Approach to Cybernetics* (1961) and *Conversation Theory: Applications in Education and Epistemology* (1976).[2]

The history of digital art must acknowledge the contributions of developments in multiple disciplines. Unlike most genres of art practice, it is a field in which scientific and technical ideas are as important as ideas from the humanities and the arts. Indeed, the entire field can be seen as negotiating and mediating these two disparate and even conflicting areas. In the spirit of this broader art history, I will evaluate Pask's importance to the arts of his time, his legacy in the field of digital art, and the relevance of some of his theoretical concerns to contemporary art practices. I will focus on three areas of Pask's work from the 1960s: his "Proposals for a Cybernetic Theatre"; his best-known artwork, *The Colloquy of Mobiles*; and his ideas for cybernetic architecture. These works exemplify the relevance of his thought to multiple cultural practices as well as his unification of theory with material experimentation, which was characteristic of his entire career.

Pask's primary contribution to all the arts was his concept of aesthetically potent environments, anchored in his understanding of the work of art as a system that evolved independently or in interaction with a participant. These ideas, profoundly informed by cybernetics, entailed complex theoretical propositions involving interactivity, organization, intelligence, communication, learning, and agency. Pask defined "aesthetically potent environments" as those environments designed to stimulate pleasurable interactions. In his view, such an environment should have variety without overwhelming the user and provide "cues or tacitly stated instructions" to guide the participant's learning process. That is to say, the work should be familiar to the user both at a discursive and embodied level so as to make instructions unnecessary.[3] These recommendations contrast starkly with contemporary art works that have complicated interfaces requiring special training.

For Pask, any work of art could be an aesthetically potent environment. It need not involve mechanical or computer-aided interactivity. Regardless of the work's actual responsiveness and adaptability, interactions could result between the spectator or participant and internal representations that the work elicited: "The external aesthetically potent environment, gives rise, bit by bit, to an internal representation and the reciprocal interaction . . . is internalized as a discourse between the internal representation and our immediate selves."[4] This suggests that the boundary between thoughts and reality is a fluid one. This indeterminancy was, in fact, a given in his conversation theory, which evolved simultaneously with his material experiments and his concept of aesthetically potent environments. According to Pask, a conversation was "the minimal situation for a meaningful psychological, or a-fortiori mechanical-psychological experiment."[5] An external observer could judge the conversation intelligent only if the dialogue among participants indicated understanding. Understanding, was "a relation," which involved a specific concept or procedure for bringing about the relation, a memory or reproduction of this procedure, and a self-replicating organization including the topic, the concept, and the memory.[6]

Although some of his contemporaries shared Pask's interest in systems, cybernetics, communication, and interactivity, he was among the earliest to instantiate these ideas simultaneously in technocultural artifacts and theory. Consistent with the style of cybernetics (a science with applications to everything), Pask's work exemplified interdisciplinarity. His machines and theories were neither art nor science; they utilized and exceeded both. Each of Pask's machines built on his earlier experiments regardless of the purpose of the system. For example, *SAKI* (1956) and *EUCRATES* (1957), both "self-adaptive keyboard instructors," incorporated aspects of his audio-visual interactive work, *Musicolour (1953–1955)*. Similarly, his teaching machines influenced his cultural projects. The frustrations that he developed with all of these machines inspired his famous "ear."[7]

Pask had a passion for the theater. While at Cambridge, he wrote and staged plays and continued to write theatrical scripts throughout his life.[8] In the 1950s, in collaboration with mathematician Robin McKinnon-Wood, he created *Musicolour*, a cybernetic system for the theater, which projected colored light patterns in response to a musician's performance. The machine reacted to the cues of the music, by projecting these images onto a large screen. The performer could then respond to *Musicolour*, closing the loop.[9] Pask developed *Musicolour* in tandem with his interest in self-regulating systems. By his own description, *Musicolour* was both a technical and an artistic experiment. It was "the first coherence-based hybrid control computer. It worked by finding a method of coherence . . . that united the internal model of the machine with the external environment of the performers, and established a cycle of activity which passed from one to the other and back again."[10] In Pask's opinion, it was a machine that could learn from the performer, play and co-operate with him to create effects he could not achieve alone.[11]

In a manuscript that was privately circulated in 1964, Pask outlined his vision for the development of a cybernetic theatre.[12] The project would be undertaken jointly by the Theatre Workshop, directed by avant-garde theater director Joan Littlewood, and System Research Ltd., Pask's independent research company. The proposal was never implemented for lack of funding but it embeds ideas of interaction and communication fundamental for later developments in Pask's work in art, architecture, and conversation theory. Pask's cybernetic theater also anticipated contemporary interactive narratives, interactive movies, and technologically mediated interactive theater and performance.

In contrast to his colleagues Joan Littlewood and architect Cedric Price, who intended to revolutionize theater through the design of novel architectural structures, Pask's proposal focused on new kinds of theatrical production that could be implemented in traditional theater spaces. For Pask, the goal of cybernetic theater was audience participation Allan Kaprow's happenings and John Cage's musical performances had already experimented with public participation in the creation works of art but while Kaprow scripted his events for settings other than theaters, and Cage's work focused on sound, Pask remained faithful to the concept of theater (he never called his proposed productions anything else). Pask's vision deviated most markedly from the practices of these other pioneers in his ideas of technological mediation, audience control, and identification directly informed by cybernetics.[13]

For Pask, a dramatic presentation was a control system in which the actors attempted to control the audience, individual members of the audience aimed to control characters with whom they identified, and, lastly, the actions of the actors controlled the sequence of dramatic situations.[14] He firmly believed that the inflexibility of dialogue and plot in dramatic productions restricted the potential of theater. In his opinion, dialogue primarily served a cueing function that determined the organization of the dramatic presentation, but if the play could incorporate other cueing procedures, the plot could become more flexible.[15]

To achieve this end, he proposed to provide communication channels between the actors and the audience. A cybernetic system could select or modify the form of operators that change the system. In theatrical presentations, the operators were the actors, thus in cybernetic theater it was crucial to deliver audience feedback to them.[16] Conversely, it was important to allow members of the audience "to choose agents (with whom they are identified for a certain interval), to know the thinking carried on by those agents in anticipation of the actions they will perform, and to express their preferences in order to determine or influence the chosen action." Writing a play, he predicted, "may come to involve writing a programme akin to a computer programme and writing the 'thoughts' of the characters involved over and above the construction of dialogue."[17]

An inexpensive communication system designed by Pask would enable communication between actors and audience. Each member of the audience would be provided with a pair of buttons to convey her personal identification with a specific character at various points in the play.[18] An "Identification Memory" would retain an image of the identification achieved by the audience at the last identification point.[19] For the system to work efficiently, the number of characters in the play should be restricted to a maximum of four.

In order for an audience member to control her selected character, she should be provided with "metainformation" entailing the thoughts of the character. This information would be delivered via headphones or earpieces used for translation. A device designated as "Identification Memory Output Selector" would connect the various members of the audience identified with a specific character to a source of metainformation about the character's thoughts. The audience would then be able to express preference for one or another possibility of action anticipated by the metainformation they received through hand levers or rating buttons. The preferences of the audience could be separated according to character identification by the "Identification Memory Input Selector" and registered in a short-term "Preference Memory."[20] Pask's diagrams included in the proposal indicated that these various devices would be located on stage.[21]

In Pask's proposed system, the sources of metainformation could be humans (but not necessarily) in possession of a metainformation script constructed through rehearsing with the actors. Consequently, these agents could interpret the possible attitudes of the actors in response to each situation in the plot.[22] At specific points in the play, the dialogue among actors should be sufficiently unimportant to allow them to receive metainformation.[23] The play could end in various ways and it would also be possible to return to previous parts of the program and restart the plot from that point onwards.[24]

Pask envisioned an initial experimental system to accommodate an invited audience of fifty to one hundred people, later to be expanded to an audience of five hundred to seven hundred and fifty people. The equipment for the system consisted of relay circuitry for both the onstage memory and the identification memory located partially on the audience's response boards. In addition, a pair of wires would be required for each member of the audience, one to sense identification and the other action preference. The wiring would all be "low voltage, low current and (in the case of auditory metainformation channels) low impedance."[25] Although Pask recognized that a great number of wires would be needed, especially for a large audience, he foresaw no great difficulties or expense in the implementation of his plan.

In summary, Pask conceived his cybernetic theater as a system that would develop in collaboration with the audience. Communication involving cycles of input and feedback between machines and humans was central to the development of the project. As did many of his proposals, Pask's cybernetic theater remained on paper. It was too early for its time. Some of his ideas would be implemented nearly half a century later. Audience participation in narrative development would be central to interactive cinematic works such as Graham Weinbren's *Sonata* (1990), in which audience selection determines the direction and ending of the cinematic narrative, and recent interactive theater such as *Terminal Time* (1999) by Michael Mateas, Paul Vanouse, and Steffi Domike, and *Façade*, by Michael Mateas and Andrew Stern (2005).

Jason Freeman's *Glimmer*, a musical composition for chamber orchestra and audience that premiered in New York in January 2005, realized some of the aims of Pask's cybernetic theater, although a direct connection between the two cannot be drawn. Each member of the audience was given a plastic glimmer stick. The audience was divided into several sections of alternating blue or red lights and were asked to turn the lights on and off and wave the sticks in patterns. Video cameras in the hall read the images and transmitted signals to the musicians on stage telling them when and what to play. According to Freeman, the lights responded most inventively to the most interesting light patterns. Thus, in a style reminiscent of Pask's proposals for a cybernetic theater, the piece aimed to break down the barriers between the audience, the conductor, and the musicians using technologically mediated communication. Differences between the way the public and the critics responded to the piece may give us an idea of the tensions that Pask's cybernetic theater may have elicited. *Glimmer* empowered the audience but baffled music critics. A reviewer concluded: "The problem was, the light show was infinitely more interesting than the music. Still, the audience seemed elated by the experience, which just goes to show that despite New Yorkers' reputation as hard-hearted urbanites, it doesn't take much to make them happy."[26]

In his best-known artwork, *The Colloquy of Mobiles* (figure 5.1, figure 5.2), exhibited in *Cybernetic Serendipity*, Pask incorporated important aspects his own theories, which he later expanded to include architecture and city planning.

Colloquy may be discussed as a contribution to art, cybernetics, engineering, simulation, sociology, and artificial life. Intended to be primarily playful and humorous, the piece incorporated theories of self-organizing systems, communication, learning, and evolution that Pask had developed for over a decade. The *Colloquy* anticipated contemporary interactive installations and artificial life art by stressing self-organization, interaction, and cooperation among individual agents. It also shared a limitation of some contemporary artificial life narratives in the elaboration of strongly gendered roles and explanations for the behavior of the agents.[27]

Pask described *The Colloquy of Mobiles* as a socially oriented, reactive and adaptive environment in which entities communicated with each other and learned about one another even in the absence of a human being.[28] The work consisted of five large mobiles suspended from a structure of metal bars that allowed them rotational and horizontal displacement. Two of the mobiles were designated male and three designated female. The males had rectangular bodies made of aluminum and the females appeared as bulbous shapes fabricated from fiberglass.

In this piece, Pask radically transformed the contemporary notion of a mobile as an arrangement of two-dimensional forms set in motion by air movement. The mobiles in *Colloquy* were tri-dimensional sculptures powered by motors, individually programmed and also partly computer-driven. Thus they were more alike to a group of autonomous robots than to the quintessential Calder mobile.

Pask provided each sculpture with a hierarchical set of goals, which allowed multiple levels of communication in the system.[29] In order to achieve their objectives, the mobiles had to learn to communicate, cooperate, and compete with one another. Humans could enter the environment, interact with and possibly alter the mode of communication of the sculptures, but ultimately they were inessential to the dynamics of the group.[30] The principal goal of each mobile was to satisfy its drives.

Each male had two drives, O and P. These letters stood for the colors orange and puce, each associated with a light beam representing one drive. To reduce either drive, the male was required to project the designated light beam from a specific part of his body to another. This necessitated the cooperation of a female, who, unlike the males, had a vertical positionable reflector, which could take the beam from

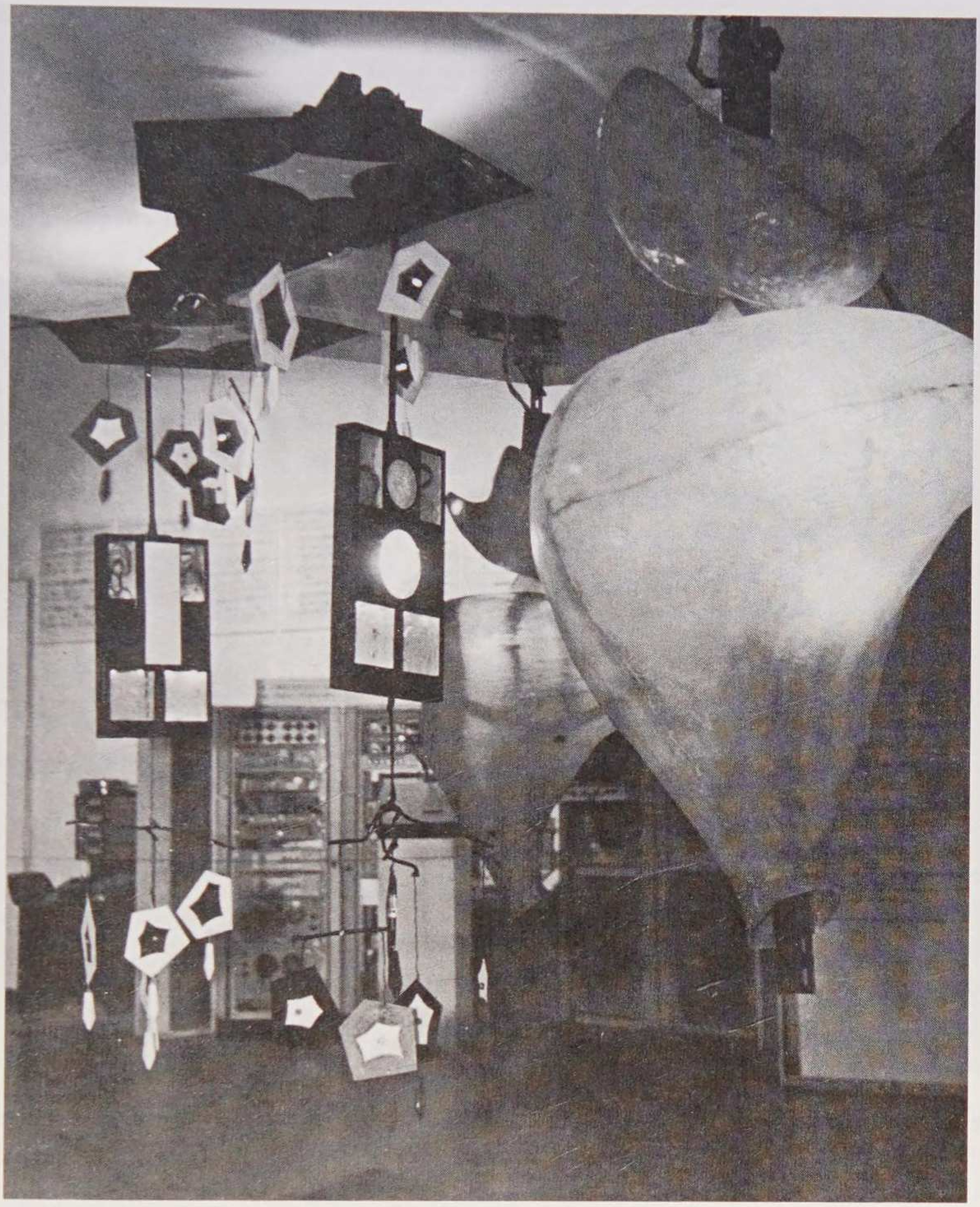

Figure 5.1 *The Colloquy of Mobiles* at the *Cybernetic Serendipity* exhibition, Institute of Contemporary Arts, London, 1968.

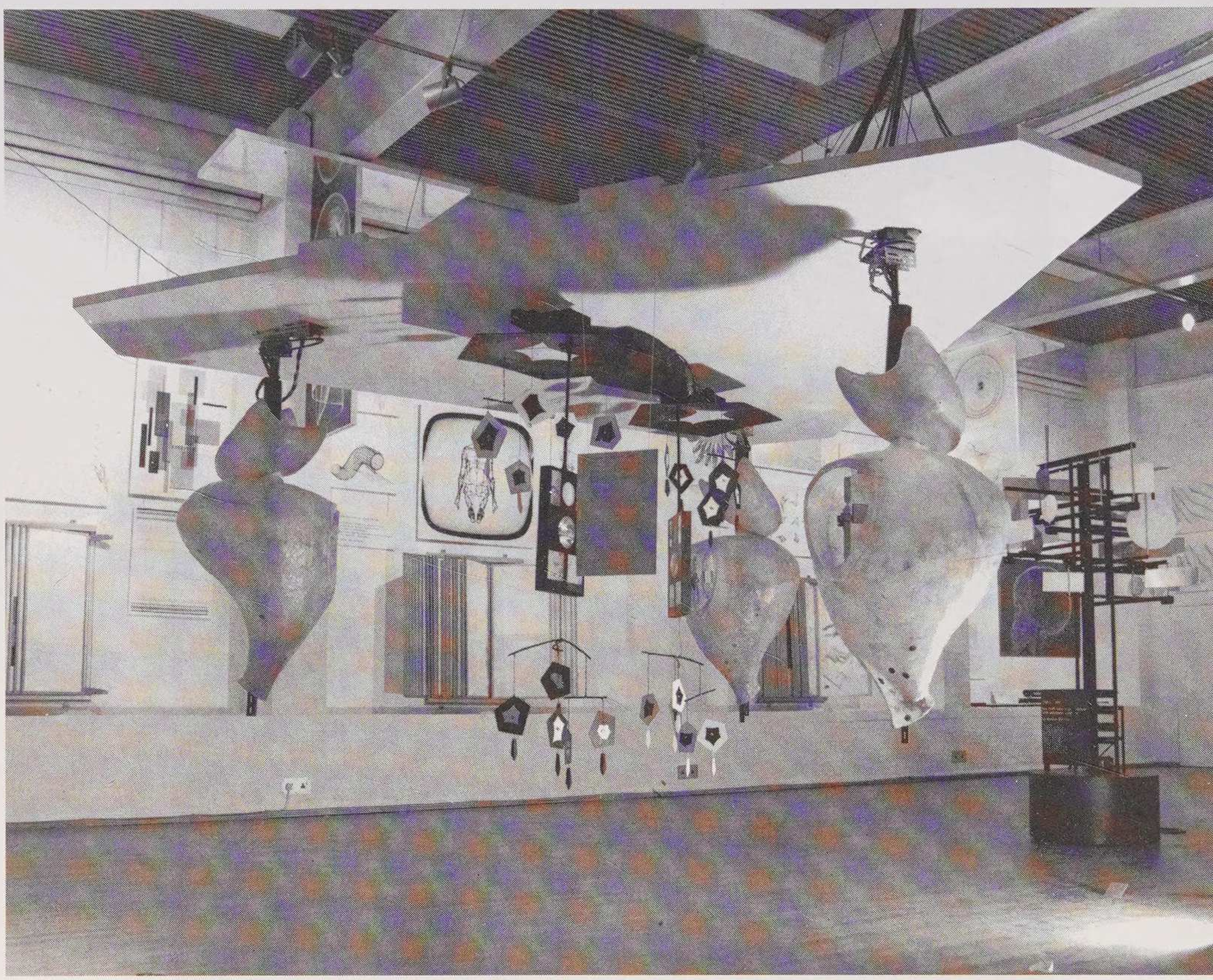

Figure 5.2 *The Colloquy of Mobiles* at the *Cybernetic Serendipity* exhibition, Institute of Contemporary Arts, London, 1968.

the male and reflect it back to the required body part.[31] Females were also equipped with the drives O and P, which they must satisfy. Depending on the state of her drives, a female could be receptive to males offering cooperation. In order to engage with the females, males had to compete with each other. For instance, they could block each other's intermittent directional visual signals identifying them as males attempting to satisfy a given drive.

Pask's description of an encounter between Male I looking for O satisfaction and a female is worth quoting in full as it illustrates the bio-mimetic character of the mobiles' behaviors:

> Male I sends out an intermittent directional visual signal which serves to identify it as "male I" and its desire as "O satisfaction." . . . Should the directional signal fall on the receptor of a female who is trying to cooperate, she produces an identifying sound in synchrony with the intermittent light signal. Male I detects the correlation between the female and his light signal and stops his motion (unless he is prevented from doing so by male II). At this point he triggers off an autonomous energetic event which consists in shining an intense orange light for at least a minimum interval in the direction of the located female. The immediate result is an increase of the O drive. However, male I anticipates reinforcement (which he will achieve if the female behaves appropriately and if the moving part, C, is appropriately positioned during at least some of this behaviour). Reinforcement, which substantially reduces the O drive, is obtained if the O goal is satisfied; that is if orange light falls on receptor C. Supposing reinforcement occurs, male I emits an identifying sound signal which is received by the cooperating female; the autonomous energetic event is prolonged and the O drive is decreased.
>
> The cooperative encounter terminates after a short time if reinforcement does not occur, or if it is externally disrupted. Otherwise it continues until the drive state of male I is modified so that he aims for a different goal.[32]

Pask stressed that the mobiles' ability to satisfy their drives depended on previous experience. The females, for example, had to learn how to position their vertical reflectors. But the system induced them to learn different strategies as not all males demanded stimulation of the same body part. Pask explained: "some may like O light on D and P light on C. She can learn that trick also."[33]

The Colloquy of Mobiles met some of the requirements for self-organizing systems that Pask had identified ten years earlier. In his opinion, self-organizing systems were "systems that we regard as though they have elements in them that make decisions."[34] This definition anticipated contemporary notions of emergence or the development of organized complex systems.[35] For Pask, a self-organizing system depended on the ability of the viewer to make sense of it; that is, "to make use" of it. This demanded both some degree of self-identification of the observer with the system as well as the presence of a common "language" between the two.[36] Reward, competition, and cooperation were also vital to the structure and development of a self-organizing system. Pask constructed an abstract model of a self-organizing system consisting of an indefinitely large but finite set of points or elements, which he conceived not as basic elementary particles but as "unitary elements, automata, players, decision makers, 'neurons' or the like."[37] He posited that some sort of currency, energy, or food must be available in the system to allow for signalling or communication among diverse elements to occur. A reward, he explained, "is something that allows a system to exist and to survive, as a distribution of currency which the system, if it exists, will spend, constructing more pieces of the system in the process. If the system does not exist . . . it allows the system to come into being."[38]

Because a self-organizing system is always evolving, its structure is inseparable from its behavior. Pask argued that rewards and the kinds of games that entities within the system played, whether competitive, collaborative, or both, contributed to form the structure of the system.[39] He posited that some games assigned specific elements in the universe to behave as individual players. Others required fixed coalitions, always involving the same set of players; yet others allowed the formation of "functional coalitions" that performed specific functions. Functional coalitions were made up of different entities on different occasions: they lacked a fixed location and moved around the system. "When this picture appears," proposed Pask, "we are looking at a self-organizing system."[40] Pask's theory of self-organizing systems did not isolate organic from artificial systems. A self-organizing system could serve as a currency converter to any other physically compatible system identified by the same criteria, and thus it could contribute to its evolution and development.[41]

The Colloquy of Mobiles met several of Pask's requirements for a self-organizing system but, at least in its original form, it lacked the ability to expand by constructing more pieces of itself. The entities communicated with a language of visual and auditory signs and appeared to make decisions. The similarity of the activities of the mobiles to sexual behavior hardly needs elaboration. Thus the piece encouraged identification from human observers. The energy or currency in the system was manifested in the building up and satisfaction of each mobile's drives. Individual "programs" compelled each entity to communicate with others and allowed for collaboration and competition.[42] Each mobile was rewarded for successful collaboration with the satisfaction of its drives. Yet this distribution of energy in *Colloquy* failed to stimulate the system's growth. Only in interaction with humans could the system expand.

In an abstract model of evolution, which Pask elaborated in 1961, he distinguished between two classes of automata: 'The first class . . . are things which are able to make decisions, moves, signals, or whatever. They do so on the basis of accumulating evidence about the activities of other automata and possibly about conditions in their environment engendered by other than the activities of their fellows. . . . the other class . . . when presented with this same dilemma (an undecidable situation), either evolves or dies. If it has enough substance it evolves; if it does not, it has had it!"[43] In my view, *Colloquy* belonged to the first class.

The Colloquy of Mobiles was a material implementation of a complex theory of artificial organisms and self-organizing systems, which predated the advent of artificial life. *Colloquy* also illustrated the qualities of an aesthetic potent environment as it provided variety and surprise while encouraging interaction from the viewer at embodied and symbolic levels. Pask's mobiles were machines that could "learn" and communicate with each other and potentially with humans (if they learned the mobile's visual language, that is, using a mirror or a flash light).[44] This was a significant innovation. *Colloquy's* reactive and emergent qualities anticipated later developments in digital art, such as Myron Krueger's concept of "responsive environments" from the early 1970s, and more recent examples of artificial life art including Ken Rinaldo's *Autopoiesis* (2000), and Christa Sommerer and Laurent Mignonneau's *A-Volve* (1994).

Pask applied to architecture the same theories that he had incorporated in *Colloquy*. He maintained that cybernetics and architecture were intimately related as the two fields shared notions of control, communication, and systems. In his opinion, architects were primarily systems designers.[45] Yet the theory of architecture was concerned primarily with taxonomies of building types and construction methods and with prescribing design procedures. He proposed to bring all of these "subtheories" under the general rubric of cybernetics.[46]

Pask understood buildings and cities as systems that grew, developed, and evolved. Anticipating contemporary notions of evolution and emergence in architectural design he wrote: "An immediate practical consequence of the evolutionary point of view is that architectural designs should have rules for evolution built into them if their growth is to be healthy rather than cancerous. In other words, a responsible architect must be concerned with evolutionary properties; he cannot just stand back and observe evolution as something that happens to his structures."[47] Hence architecture was a dynamic system very much like a live organism.

He contended that architects could apply evolutionary ideas from cybernetics to buildings and urban environments, envision cities as self-organizing systems, and employ cybernetics' predictive potential to project, for example, a city's formal and social development. Cybernetics could also enhance architecture's explanatory power for designers could utilize intelligent computer programs that would learn aspects of architectural design from architects and help them teach.[48] This recommendation was consistent with Pask's continuing interest in conversation theory and teaching machines.[49]

In order to design more cybernetically oriented architecture, Pask proposed to redirect the concept of functionalism (form follows function) toward more humanistic ends. For him, buildings were only meaningful as interactive human environments. After all, he argued, an architect defined a building's functions to serve human users.[50] But in addition to serving, architecture regulated the behavior of its users and ultimately made sense only as part of larger systems, which included but were not restricted to human components. It was these larger systems and "not just the brick and mortar part" that architects designed.[51] He named the interdependence and constant communication of architecture, humans, and societies "architectural mutualism."[52]

In Pask's opinion, the humanization of functionalism would result in the understanding of architecture as an art of cooperation between humans, buildings, and technology. He explained:

> The high point of functionalism is the concept of a house as a 'machine for living in' (Le Corbusier). But the bias is towards a machine that acts as a tool for serving the inhabitant. This notion will, I believe, be refined into the concept of an environment *with* which the inhabitant cooperates *in* which he can externalize his mental processes, i.e. mutualism will be emphasized as compared with mere functionalism. For example, the machine for living in will relieve the inhabitant of the need to store information in memory and the need to perform calculations as well as helping out with more obvious chores like garbage disposal and washing up dishes. Further, it will elicit his interest as simply answering his enquiries.[53]

Pask's architectural mutualism was inseparable from his formulation of aesthetically potent architectural environments. He believed that because "man" communicated with his environment, architecture should be designed to foster pleasurable dialogues. According to him, elements of communication were not only linguistic but visual, aural, and tactile. Aesthetically potent environments should be designed to satisfy the symbolic needs of the users by incorporating feedback, variety, and surprise.[54]

For Pask, Antonio Gaudí's Parc Guell was an exemplary mutualistic design, but he suggested that architecture's dialogue with humans could be further enhanced with the use of modern materials and techniques, including sensor- and computer-activated surfaces.[55] In sum, Pask's notion of mutualism required that the architect design dynamic rather than static entities. But in contrast to contemporary theories of art and architecture, his dynamism depended primarily on neither the behavior of users nor the dynamic potential of organic forms.[56] Rather, he understood the term to mean active cooperation between buildings, their components, and their occupants, a formulation that anticipates today's "smart house," and ubiquitous computing, but removes them from functionalist instrumentality by endowing them with affective qualities.

Constructing evolutionary mutualistic environments demanded that the designer relinquish the illusion of total control of the design process. The architect's role as controller of the system was to provide a set of constraints or guidelines to allow for specific forms of evolution without overdetermining the goals. The guidelines included selection of basic materials, specifications for what the system would learn, how it would adapt, and a desired plan for its development.[57]

In coherence with cybernetics, mutualistic architecture and evolutionary city planning were inherently interdisciplinary. Pask foresaw not only the intensification of computer-aided architectural design but also the greater role that sociology, psychology, ecology, economics, and computer programming would play in architecture and planning. We are witnessing his predictions today. An affective view of domestic environments and components such as appliances is an emerging and exciting avenue of research among designers.[58] Ideas compatible with Pask's architectural mutualism are current in interactive architectural projects stressing the communication of buildings with users and with their environment. *Blinkenlights* (2001–2002) and *Arcade* (2003) by Chaos Computer Club, both in Berlin, and the BIX façade of the Kunsthaus in Graz, Austria, by Realities United are three among many examples.

The *Fun Palace* designed by Cedric Price in collaboration with Joan Littlewood and multiple other associates between 1961 and 1964 exemplified Pask's (later) ideas of mutualistic design. As director of the Cybernetics Committee for the Fun Palace Project, Pask played an influential advisory role. In an undated document written and signed by Pask (1961–1964) entitled "Fun Palace Project," he outlined the objectives and theory underlying the proposal. In accord with his own commitment to interdisciplinarity, twenty-eight individuals, including architects, engineers, artists, systems designers, sociologists, psychologists, and civil servants constituted the Cybernetics Committee.

The *Fun Palace* was envisioned as an experimental and adaptive structure that could be modified to accommodate various kinds of entertainment activities. With no permanent walls or ceiling, the building must "be able to perform experiments by way of parametric adjustments (in pursuit of a given goal) and re-arrangement of the structure of partial goals assigned to particular subsystems."[59] Pask specified that in the context of the *Fun Palace*, entertainment entailed feedback and participation from the audience, "indeed, the feedback concerned must resemble the concept-producing discourse of a conversation rather than the arid exchange of the more familiar education channels encountered in communication systems."[60] Cybernetics was fundamental to the project at various levels including the relation of the palace with its environment, the mechanical and architectural considerations, and specific activities, communication, information systems, and educational devices available to the visitor.

Pask's description of cybernetic systems for the *Fun Palace* assimilated his thoughts on cybernetic theater as well aspects of *Musicolour*. He argued, for example, in favor of an audience-controlled drama and for audience-produced and controlled visual spectacles.[61] Also included in his proposal were automatic learning devices, cooperative systems that would help visitors without musical training to compose and perform music. He explained, "A system like this is cooperative in the sense that it must contain some computing mechanism that partially solves the technical problem posed by the music on behalf of the participant subject. It is also adaptive since initially cooperative assistance may limit the subject's capabilities since he has overcome all the technical preliminaries. Hence the system is in a sense instructive."[62] Such a system would have been inspired both by *Musicolour* and his adaptive teaching machines.

As in the later *Colloquy of Mobiles*, Pask's proposal for the *Fun Palace* drew on his theories of self-organizing systems and artificial organisms. Pask wrote: "To what extent can the Fun Palace organization be contrived as a self-organizing system wherein a set of facilities will develop in a fashion that is inherently regulated. (sic) To the extent that the Fun Palace organization be persuaded to evolve in such a fashion it may be deemed successful."[63] As in his later proposals for mutualistic architecture, in the *Fun Palace* his own role as well as the architect's was to provide an agenda for the project, which he referred to as a "genetic code." Ultimately, he proposed that the Cybernetics Committee itself should develop as a self-organizing organism, "the genetic code of the agenda is provided to initiate the evolutionary process and the constraints are not severe enough to inhibit it altogether."[64] Thus Pask's proposal for the *Fun Palace* summarized previous theories and experimental work that he would later expand in *Colloquy* and in his proposals for mutualistic architecture.

In conclusion, Pask was among a select group of individuals who introduced cybernetic concepts to the world of cultural practice. Artists in this group included Nicolas Schöffer, Edward Ihnatowicz, Jack Burnham, and Roy Ascott. Unlike them, Pask also contributed to the development of the field of cybernetics in theory and in practice. Although not all of Pask's contributions to digital art were explicitly works of art (he is uniquely identified as a cybernetician and as an arts practitioner), the prescience of his theories and artifacts established him as a pioneer in the field.

Notes

1. Jasia Reichardt, ed., *Cybernetics, Art and Ideas* (Greenwich, CT: New York Graphic Society, 1971), 71–99.

2. See Ranulph Glanville, "Gordon Pask, a Skeleton for an Unofficial Biography," in "A Festschrift: Gordon Pask," *Systems Research* 10, no. 3 (1993): 9–11. Published books by Pask include *An Approach to Cybernetics* (London: Hutchinson, 1961); *The Cybernetics of Human Learning and Performance* (London: Hutchinson, 1975); *Conversation Cognition and Learning* (Amsterdam: Elsevier, 1975). *Conversation Theory: Applications in Education and Epistemology* (Amsterdam: Elsevier 1976); *Calculator Saturnalia, Or, Travels with a Calculator: A Compendium of Diversions and Improving Exercises for Ladies and Gentlemen* with Ranulph Glanville and Mike Robinson (London: Wildwood, 1981); and *Microman Living and Growing with Computers* with Susan Curran (London: Macmillan, 1982).

3. Ibid.

4. Ibid., 77.

5. Gordon Pask, "Aspects of Machine Intelligence," introduction to *Soft Architecture Machines* by Nicholas Negroponte (Cambridge, MA: MIT Press, 1975), 12.

6. Ibid., 7.

7. Pask and Curran, *Microman*, 144; Peter Cariani, "To Evolve an Ear: Epistemological Implications of Gordon Pask's Electrochemical Devices," *Systems Research* 10, no. 3 (1993): 19–33.

8. See Paul Pangaro, "Pask as Dramaturg," http://www.pangaro.com/published/Pask-as-Dramaturg.html, originally published in *Systems Research* 10, no. 3 (1993).

9. Pask, "A Comment, a Case History and a Plan," in *Cybernetics, Art and Ideas*, ed. Jasia Reichardt (Greenwich, CT: New York Graphic Society, 1971), 78.

10. Pask, *Microman*, 144.

11. Pask, "A Comment, a Case History and a Plan," 78.

12. Gordon Pask, "Proposals for a Cybernetic Theatre," in Theatre Workshop & System Research (1964), privately circulated monograph. Available at Pask Archive, http://www.pangaro.com/Pask-Archive/.

13. Pask seemed to be unaware of the characteristics of happenings. In another document, he referred to them as "a sort of American party" and noted that their goals for audience participation were "hampered by the technical difficulties that attend the provision of novelty and the sensing of indices of response in domestic surroundings." Gordon Pask, "Fun Palace: Cybernetics Committee," privately circulated manuscript, n.d., 10. This document is part of the papers of Cedric Price in the archival collection of the Canadian Centre for Architecture. It was exhibited in "Cedric Price, Fun Palace," curated by Mark Wigley, Arthur Ross Architecture Gallery, Buell Hall, Columbia University, New York, September 19–November 11, 2005.

14. Pask, "Proposals," 5.

15. Ibid., 4.

16. Ibid., 21.

17. Ibid., 6.

18. Ibid.

19. Ibid., 7.

20. Ibid.

21. Ibid., 6.

22. Ibid., 7.

23. Ibid., 11.

24. Ibid., 14.

25. Ibid., 18.

26. Anthony Tommasini, "With Lights in Hand, Audience Becomes the Conductor," *The New York Times* (Saturday, January 22, 2005): Section B; Column 3; The Arts/Cultural Desk; CLASSICAL MUSIC, 17.

27. For critical analyses of artificial life narratives, see Katherine Hayles, "Narratives of Artificial Life," in *Future Natural: Nature, Science Culture*, ed. George Robertson, et al. (London: Routledge, 1996), 146–164; Sarah Kember, *Cyberfeminism and Artificial Life* (London: Routledge, 2003), and Mitchel Whitelaw, "Theorizing A-Life, Art and Culture" in *Metacreation*, 181–205.

28. Pask, "Comment," 88.

29. Ibid., 89.

30. Ibid., 88.

31. Ibid., 89.

32. Ibid.

33. Ibid., 91.

34. Gordon Pask, "A Proposed Evolutionary Model," in *Principles of Self Organization*, ed. Heinz von Foerster and George W. Zopf (London: Pergamon, 1961), 229.

35. For relevant discussions of the concept of emergence, see Peter Cariani, "Adaptivity and Emergence in Organisms and Devices," *World Futures* 32 (1991): 11–132; Stephen Johnson, *Emergence: The Connected Lives of Ants, Brains, Cities and Software* (New York: Simon and Schuster, 2001).

36. Gordon Pask, "Artificial Organisms," *General Systems Yearbook*, vol. 4 (1959): 151. In these theorizations there was tension between Pask's ideas of the observer's involved participation in the system and the observer's detachment required for objective scientific observation. Such tensions were to be annulled in second order cybernetics, a field to which Pask's work was foundational. Glanville, "Gordon Pask," 10.

37. Pask, "A Proposed Evolutionary Model," 231.

38. Pask, "Artificial Organisms," 159.

39. Ibid.

40. Ibid., 160.

41. Ibid., 161.

42. Pask refers to "programs," but like the term "software," the term "program" was less codified than it is today. It can be inferred from his flow diagrams that the programs were instantiated systems which combined relay logic with analog computing circuitry.

43. Pask, "A Proposed Evolutionary Model," 238.

44. It is unclear from available documentation of *The Colloquy of Mobiles* what the extent of the learning was, or how it was technologically instantiated. We do know that a substantial part of Pask's professional practice at the time was concerned with machines, which could "learn" and "teach."

45. Gordon Pask, "The Architectural Relevance of Cybernetics," *Architectural Design* 39 (September 1969): 496.

46. Ibid., 494.

47. Pask, "Architectural Relevance," 495.

48. Ibid., 496.

49. His approach is summarized in "Aspects of Machine Intelligence." Pask collaborated with the Architecture Machine Group at MIT and later served as consultant and advisor to the MIT Media Lab for many years. The extent of his influence on these institutions and their various projects remains to be investigated. See also Pask, *Conversation Theory*.

50. Pask, "Architectural Relevance," 494.

51. Ibid.

52. Ibid.

53. Ibid., 496.

54. Ibid., 495.

55. Ibid,, 496.

56. Pask, "Architectural Relevance," 494. For examples of contemporary positions of interaction and dynamism, see Mark B. N. Hansen, *New Philosophy for New Media* (Cambridge, MA: MIT Press, 2004), and Greg Lynn's *Animate Form* (New York: Princeton Architectural Press, 1999).

57. Ibid., 496.

58. See, for instance, Anthony Dunne and Fiona Raby, *Design Noir: The Secret Life of Electronic Objects* (Basel, Switzerland: August/Birkhäuser, 2001).

59. Pask, "Fun Palace," 2.

60. Ibid., 1.

61. Ibid., 2.

62. Ibid., 6.

63. Ibid., 11.

64. Ibid.

6

In the Beginning ...

Jasia Reichardt

Of all the twentieth-century art movements, two directions that came to the fore during the 1960s were distinct from anything that had gone before. Each included international exponents from the very beginning and both hovered on the borderlines of the art world without ever reaching its center. The first was concrete poetry, and the second computer art. Neither had a Picasso at its head, but both were new, experimental, and involved practitioners from different professions. There were many artists among them, but they were not in the majority.

The foundation of these two developments was experiment. The other premise underlying both was a crossing of cultures. Neither was close to the mainstream of the time. The art world was concerned with neither visual poetry nor computer art. There was little interest in works more technically sophisticated than those belonging to the kinetic movement. A further complication provoked by these two movements was that, at the time, it was difficult for art critics, art historians, and those writing guides, dictionaries, and manuals, to define who was and who was not a bona fide artist. An engineer, like Edward Ihnatowicz, who produced some of the most inspiring cybernetic sculptures during the 1960s, did not call himself "artist" because he wasn't sure if he belonged to this select group, nor was anyone else sure. He wasn't the only artist working with technology whose credentials were surrounded by question marks and innuendo. When it came to computer-generated pictures, everyone tried to avoid the word "art." The term "computer graphics," coined by William Fetter, became a standard description for a time, and it was difficult to know whether it could be used in the singular as well as plural. Lost in the maze of these verbal uncertainties, I opted for the word "art" and stood by it as firmly as possible.

Both computer art and concrete poetry belonged to art's outer periphery. They were treated as separate categories by art critics, art colleges, and galleries. To some extent they still are, largely because there is not sufficient historical background to suggest how we should think about them. There were no galleries that dealt with either concrete poetry or computer-generated art specifically, although Howard Wise pioneered showing computer-generated pictures by Bela Julesz and Michael Noll in his New York gallery as early as 1965. There are still no specialist galleries in either subject.

There were several other ways in which concrete poetry and computer art stood apart from art at large. One of these involved scale. Scale had lost its importance. A concrete poem could be blown up or reduced to any size without losing its intended essence and this was mainly true of computer-generated pictures. Furthermore, in most cases, there was no "original." Theoretically, there might be any number of iterations. In computer graphics, the original was the program; in concrete poetry the original was the idea.

Classification of the origins of a work of art was also important. Was it or was it not made with the aid of a machine? Was it done by hand? Was there a fingerprint? Many of the images from a computer might also have been made laboriously by hand. This is true of all the morphed pictures by the Computer Technique Group that were at the center of *Cybernetic Serendipity*, as it is of much of the work of painter Chuck Csuri. What does belong uniquely to the realm of computer art is the type of image that demonstrates some form of random distribution, where the result is not foreseeable. In these, the artist does not ultimately control what the image looks like. These were some of the topics that were discussed during the mid-1960s at the Institute of Contemporary Arts (ICA). There were others.

Aesthetic Measure

Some of the ideas that preoccupied those making pictures with computers at that time will appear outdated today. The creators were concerned with writing programs to generate aesthetic products. Beauty was not a measure of art's significance or purpose. Other aspects became relevant, some of which had nothing to do with visual appearance. For this reason alone, works produced by a machine in the twenty-first century cannot be judged in the same way as those of the 1960s. Until the mid-1960s, George Birkhoff's "aesthetic measure" was used to help qualify art works that were untested by other means, and especially if they were made in the constructivist idiom. The aesthetic measure was defined as a ratio between order and complexity, and those works deemed to be most satisfactory had a proportionately highest degree of symmetry to the number of angles, curves, or irregular forms flowing from one to another. Birkhoff analyzed paintings, pots, and random patterns.

His system was referred to as a computational aesthetic but although it had influenced the thinking of theoreticians and psychologists, it had little bearing on how computer graphics were made or on how they were received. However, Birkhoff's theory was elaborated in Max Bense's aesthetic analysis, which became relevant to many of those working with computer graphics. This analysis could be applied to any text or any group of elements in any arrangement, since it referred to signs (semiotic elements) that are in a relationship to one another (topological distribution), that appear with a certain frequency (statistical occurrence), and that carry a meaning (information). Bense was also the author of what became known as generative aesthetics, and developed theories underlying computer-generated art. His ideas provided the core of theory for what became known as the Stuttgart Group, whose first exhibition of computer pictures was held at Technische Hochschule in 1965. Two computer artists, Georg Nees and Frieder Nake, became the Group's the best-known exponents. Talking about his computer graphics, Nees insisted that they were not works of art but models for works of art. They belonged to the domain of aesthetics, but to a different category than that of art that requires a human imperative. Even so, direct human intervention involved all sorts of decisions from the construction of the image to thickness of line, color, and the method of pattern building. Another issue relevant to computer art was the ratio between originality and familiarity. If the quotient of originality is too high in a work of art, nobody will recognize the work as art. If it is too obvious, it is likely to be considered trite. Art may have been losing its boundaries, but not its prejudices.

Computer as Catalyst

During the 1960s there were several new significant initiatives in the interrelationship of art and technology, but technological art emerged from two very clearly recognizable and separate streams. The first involved artists who came out of kinetic art, whose art used basic technology: electricity, motors, timers, remote control systems, batteries, gears, lighting, and now used feedback systems, random number generators, and computers. In this stream were artists who were either engineers themselves or had acquired sophisticated technical skills. Later, many of the works came about through collaborations between artists and engineers, but some of the best work then and since has been made by artists who have mastered the technology. Among artists who made cybernetic works at the time were Wen Ying Tsai, John Lifton, Edward Ihnatowicz, Nicolas Schöffer, James Seawright, Nam Jun Paik, Bruce Lacey, Gordon Pask, Peter Zinovieff, and Gustav Metzger.

The second stream involved scientists, engineers, and technicians who had access to computers, and started making images that evolved out of their work. The purpose of their work had nothing to do with art. The computer graphics revolution happened because the work was recognized by people in different countries as appearing to belong to the same category as art. A good example is William Fetter's work for the Boeing Corporation. His images of simulated landings on the runway were used to study the possible movements of the pilot in the cockpit; they came to be looked at in the same way as any images on a wall in an art exhibition.

Other early computer graphics were often essentially random patterns arrived at in scientific laboratories by chance. Their pictorial interest and aesthetic appearance perhaps encouraged people to keep them. Soon, there were several initiatives afoot that led the launching of computer art projects in Europe, America, and Japan.

Where Did It All Begin?

The first twentieth century movement to significantly aim to marry technology, research, function, and aesthetics was the Bauhaus. The influence of its teaching cannot be overestimated. It touched all of the arts. Revived during the 1950s under the directorship of Max Bill, the Hochschule für Gestltung in Ulm continued to promote the idea of social and cultural synthesis. Groupe de Recherche d'Art Visuel in Paris, Max Bense's Stuttgart Group, and the *Nouvelles Tendences* exhibitions and symposia in Zagreb all led to the infusion of computer-generated material into the realm of the arts. In America, two organizations pioneered the development of the art and technology movement: the Center for Advanced Visual Studies at Massachusetts Institute of Technology, a direct descendant of the Bauhaus, had György Kepes at its head; and Experiments in Art and Technology, a collaborative venture under the principal guidance of Billy Klüver.

CAVS

The Center for Advanced Visual Studies was proposed by György Kepes in 1964 and opened in 1968 in Cambridge, Massachusetts, in a building that until then was the MIT students' co-op. Artists who became fellows of the center could work on any projects they wished, drawing on the expertise of scientists and engineers at MIT for help and advice. The purpose of CAVS was to create a community in which the humanities and sciences could cohabit to mutual advantage, under the aegis of the MIT Department of Architecture. Kepes said, "Artists have the job of defining our inner world, scientists discover, define and elucidate the outer world of nature"; the Center was the result of his faith that artists, scientists, engineers, and scholars shared the same values and aims. Among the first fellows were Takis, who was working with magnets at the time; Otto Piene, member of the Zero Group; Harold Tovish, optical sculptor; and Jack Burnham, light and kinetic artist. Otto Piene, himself later director of CAVS, referred to it as a "shared utopia." CAVS started with six fellows but by the 1990s there were as many two hundred fellows per year working within its precincts. During thirty years of CAVS history, technology gradually became the direct means of making works of art, and the number of fellows increased every year. Perhaps as many as a third of the artists who worked with technology passed through the Center's portals or participated in its activities.

EAT

Experiments in Art and Technology, or EAT for short, was founded in 1966 "to make it possible for artists and engineers to work effectively together with industrial sponsorship." The work should not be "the preconception of the engineer, the artist, or industry, but a result of the exploration of human interaction between these three areas." The task of the engineer was to be the broker between the artist and the industry, translator of the artist's ideas into physical possibility, and midwife, bringing the work of art into the world. The initiative for a structured collaboration between artists and engineers came out of *9 Evenings of Theatre and Engineering*, an event devised by Billy Klüver and Robert Rauschenberg that took place October 13–23, 1966, in the Armory of the 69th Regiment in New York. The performances involved ten artists, musicians, and dancers; thirty engineers; and an audience of ten thousand. Billy Klüver later referred to it as "a classic event." John Cage was the star of the proceedings; Rauschenberg was its inspiration. Rauschenberg's game of tennis-controlled lights came to an end when the hall was in complete darkness, only to be flooded with infrared to reveal a crowd of several hundred. Among the artists were Lucinda Childs, Öyvind Fahlström, Alex Hay, Deborah Hay, dancer Stephen Paxton, painter/filmmaker Robert Whitman, and dancer Yvonne Rainer. Not everything worked; not every member of the audience stayed the course, but a precedent was set.

Within a year, EAT had a membership; a board of directors that included Buckminster Fuller and György Kepes; Billy Klüver was president; Rauschenberg was vice president and later chairman. There were also agents, whose task was to represent EAT to industry and to use the influence of their position on its behalf. Among them were Alfred H. Barr, John Cage, Pontus Hulten, and John R. Pierce, executive director of Bell Telephone Laboratories. By 1969, there were four categories of membership and a full program of lectures, discussions, performances, and demonstrations. There were open houses on weekends.

The activities of EAT were documented in *EAT News*, published approximately twice a year. There were local groups and international groups, competitions, collaborations with museums, and, not least, the construction of the Pepsi Pavilion at the 1970 World Fair in Osaka. EAT was a heroic venture. It aimed at social change and at broadening cultural exchange with the artist as the catalyst and focus of the enterprise. At a press conference, John R. Pierce proclaimed that man cannot live without art and that art cannot safely ignore or reject such a powerful force as technology, source of the material well-being of our age. He also said that "artists must learn to use the possible, and technologists must reach out for the impossible." Klüver, meanwhile, talked about the elimination of "the distinction between work and leisure."

Among projects proposed by artists were: the creation of an air wall; solid clouds; infrared television; time compression and extension; mylar mirrors; alteration of heartbeat frequency; writing on walls with laser beams; color change under pressure; home TV projection systems; snowfall that doesn't fall; and the possibility of the artists themselves flying or floating suspended in the air. The latter was proposed on several occasions, by several artists including Robert Rauschenberg, Alex Hay, and Öyvind Fahlström. (That particular dream, however, was only realized some forty years later, in 2000, when another collaborative organization dealing with art and science, the Arts Catalyst, presented their event, "Altered States of Gravity." On that occasion, it was Kitsou Dubois and her dancers who demonstrated a gravity-free experience at the Gagarin Cosmonaut Training Center in Russia.)

If EAT faded out, it was through a natural process of decline, precipitated by developments in technology itself. Some technologies became easy enough for artists to use without much technical support. Some artists made demands that could not be met. Some of the engineers wanted to be artists. EAT belonged to a decade when such ambitions could be fired by the enthusiasm of one man.

Cybernetic Serendipity

Cybernetic Serendipity was the first of five exhibitions and celebrations of the computer and the arts in the second half of 1968. The second was *Computer and Visual Research* in Zagreb. The third was *The Machine, as seen at the end of the mechanical age*, at the Museum of Modern Art in New York, organized by Pontus Hulten, which anticipated the traditional machine being replaced by computer science. The fourth, opening simultaneously with *The Machine*, was *Some More Beginnings*, a collaboration between EAT, the Brooklyn Museum, and the Museum of Modern Art. Meanwhile, September had also marked the launch of the Computer Arts Society. Its stated aims were "to promote the creative use of computers in the arts, and to encourage the interchange of information in this area." It started with eight members. The Society was formally launched with an exhibition called *Event One*, held the following year at the Royal College of Art. Looking back on these events it seems extraordinary that they all happened within five months.

Computer art came out of the explorations of scientists and artists, and the ideas promoted by philosophers and theoreticians. Max Bense, whose work I have described in brief, was one of the most significant theoreticians in the field during the 1960s. He was adept at crossing borders from philosophy to cybernetics, aesthetics to concrete poetry, physics to the theories of chance and the hitherto hidden properties of words. He came to London in 1965 to see an exhibition of concrete poetry that I had organized at the ICA. It was called *Between Poetry and Painting*. I had the pleasure of meeting him several times. One day, he asked what plans I had for the future. I had no plans. "Look into computers," he said. And so I did, and three years later *Cybernetic Serendipity* was the result.

Now I'll tell you a few things about how it became possible to stage such an exhibition in 1968. When I started work on *Cybernetic Serendipity* (and of course the exhibition did not have that title at the beginning), the ICA gallery was on the first floor at 17 Dover Street in central London. We were short of staff, money, and space. But the ICA was well connected through its president, Sir Herbert Read, and its chairman, Sir Roland Penrose. The Institute of Contemporary Arts had only one committee, the Management Committee, which included an architect, a composer, an art critic, and a publisher, as well as the head of the Arts Council. If an idea appealed to them, it would be passed. The idea of the relationship between the computer and the arts interested them, so preparations for the exhibition went ahead. Gradually more and more people became involved: scientists, journalists, universities, societies, IBM; as the project acquired momentum, the Arts Council provided some funds.

In January 1968 the ICA started its move to the new premises on Carlton House Terrace. The gallery then occupied the entire premises. There was also a lecture hall-cum-cinema. Several years later, the gallery was divided into small areas, but at the time of *Cybernetic Serendipity* it was a spectacular space (figure 6.1).

The exhibition opened August 2 and closed October 20. Max Bense came to open it. Anthony Wedgwood Benn, then the Minister for Technology, presided over the official opening. The description of the exhibition went as follows:

> The idea behind this venture . . . is to show creative forms engendered by technology . . . to present an area of activity that manifests artists' involvement with science, and the scientists' involvement with the arts; . . . to show the links between the random systems employed by artists, composers and poets, and those involved in the use of cybernetic devices.
>
> The exhibition is divided into three sections . . . :
>
> 1. Computer-generated graphics, computer-animated films, computer composed and played music, and computer verse and texts (figure 6.2).
> 2. Cybernetic devices as works of art, cybernetic environments, remote control robots, and painting machines.
> 3. Machines demonstrating the uses of computers and an environment dealing with the history of cybernetics.[1]

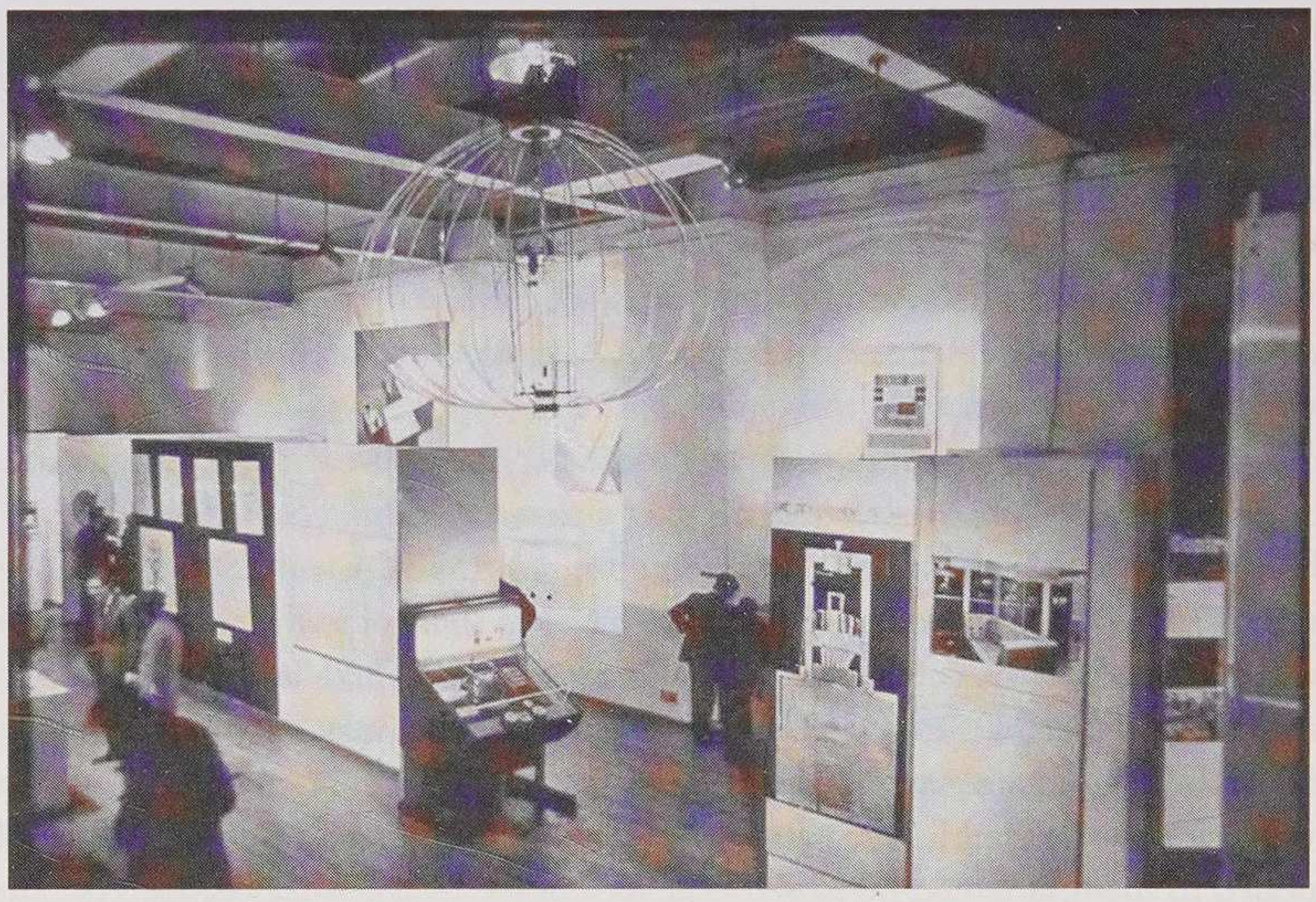

Figure 6.1 View of *Cybernetic Serendipity*.

Some 350 people were involved in making the exhibition possible; 700 press invitations were sent out, and 3,000 people attended the private views. I regret that there are no recordings of the lectures that were given twice a week between August 8 and October 17. Among the speakers were: Frank J. Malina, Herbert Brun, Everett Ellin, Christopher Evans, Rex Malik, Meredith Thring, Gordon Pask, Iannis Xenakis, Abraham Moles, Lionel Penrose, and Robin McKinnon-Wood. There were others too; one person who was of special importance to the exhibition was Christopher Evans of the National Physical Laboratory, because it was during our conversations that we found the title: *Cybernetic Serendipity*. It was approved by Roland Penrose only after some considerable persuasion because he felt that people wouldn't be able to pronounce it.

Several people were intimately involved with the project from the beginning: technology adviser Mark Dowson, music adviser Peter Schmidt, and designer Franciszka Themerson, who was assisted by five students from Bath Academy of Art.

No heroic claims were made for the exhibition. At the time, computers had not revolutionized music, art, or poetry in the same way that they had revolutionized science. What was becoming apparent was that the computer was bringing in its wake new people to become involved in making art and composing music. Those

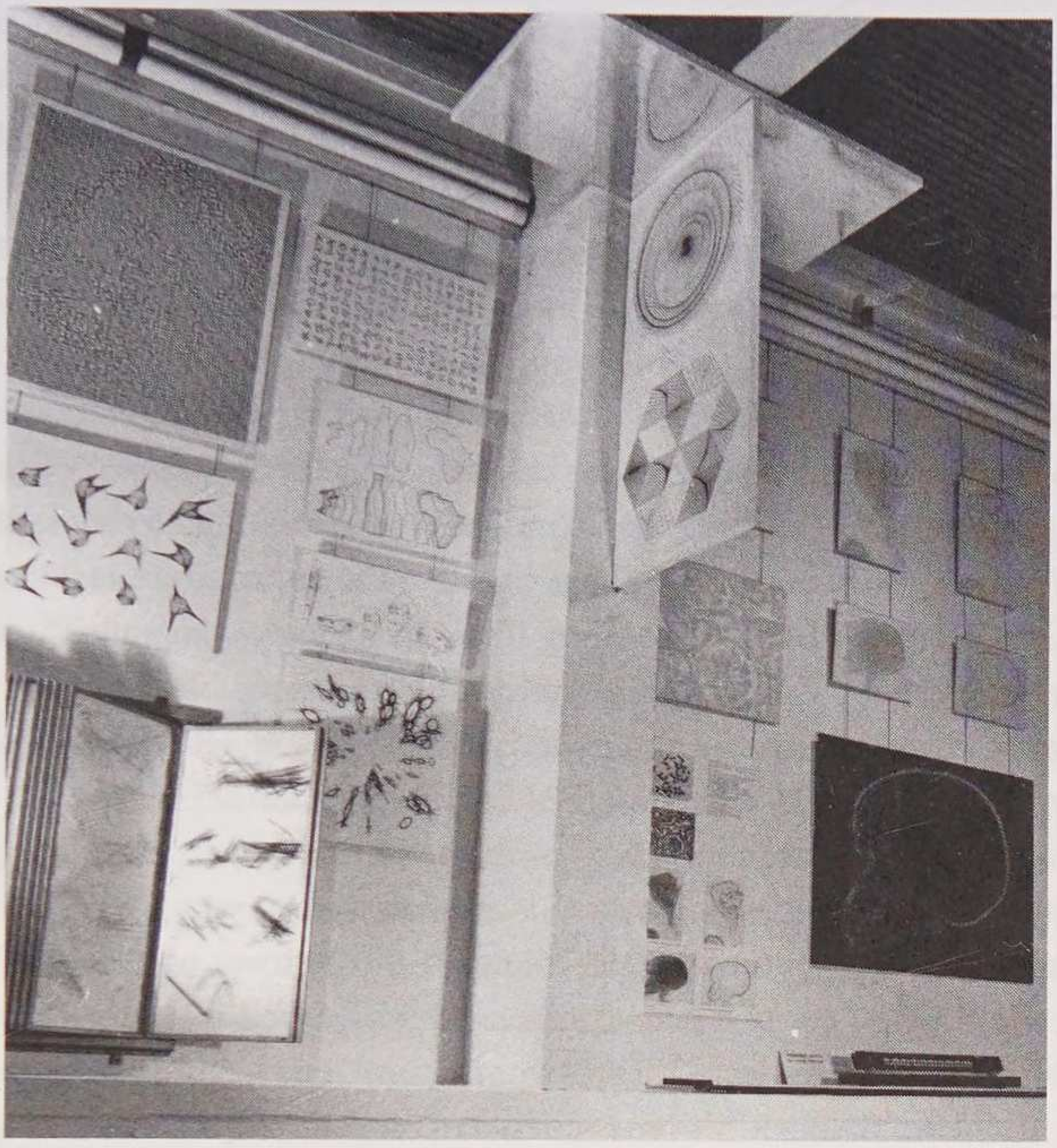

Figure 6.2 View of *Cybernetic Serendipity*.

who had never thought of putting pencil to paper or brush to canvas started making images. With the advent of computers the world of art expanded beyond its conventional borderlines.

Organization of the exhibition was a cumulative process of gaining support among scientists, at universities, and later inviting participation. A travel fellowship in America enabled me to meet some of the contributors and to gather material. Many people, including students, worked as volunteers and, once involved, did not want to leave. Whatever broke down during the day was mended at night. I still suspect that some people lived in the gallery. The exhibition was dense. Each work performed, reacted to the visitors, or demonstrated an idea or principle. Everything meant something; it told a story or produced a transformation, and explanations were available. One of the works that drew a lot of attention was Peter Zinovieff's music computer, which improvised on tunes whistled into a microphone by visitors. Another was the *Colloquy of Mobiles* by Gordon Pask. Here five suspended objects, each with a program to determine its behavior according to its "gender" (Pask designated three as male and three as female), were involved in an elaborate communication through sound, and flashing and reflecting lights. The audience could watch this game of cooperation and competition and interact once it was able to understand what was going on. Bruce Lacey had two remotely controlled robots: *ROSA* (Radio Operated Simulated Actress) *Bosom* and *Mate. ROSA* followed visitors around and, when possible, thrust her huge red lips in their faces. Nam Jun Paik's *Robot K-456* walked about the exhibition distractedly and peed occasionally. *SAM* (*Sound Activated Mobile*) by Edward Ihnatowicz bent its flower-shaped ear to as if to listen to those talking to it. *SAM* had to be addressed in a quiet voice. Shouting produced no effect. Children became far more adept at talking to this sculpture than adults did. However, shouting and clapping were the appropriate means of communicating with the sculpture of Wen Ying Tsai. Its vibrating metal rods appeared to undulate when the sound of clapping altered the frequency of the strobe flash.

The level of noise and light was a problem. Some machines had to be kept in the dark; others malfunctioned when there was too much noise; some had to be kept apart to prevent them from interacting with each other. Apart from sculptures that drew, painted, and responded with sounds and motion or translated sound into visual patterns, there were places of relative peace in the form of fiberglass spheres in which one could listen to computer-composed and -played music. At regular intervals, computer animations were shown in a seating area composed of cubes at the end of the gallery. The exhibition created its own world; it was serious without being solemn. Press reaction was positive throughout. *The Evening Standard* wrote: "Where in London could you take a hippy, a computer programmer, a ten-year-old schoolboy and guarantee that each would be perfectly happy for an hour without you having to lift a finger to entertain them. From today, there is just one such place—The Institute of Contemporary Arts."

The day after the opening of *Cybernetic Serendipity*, another exhibition also aiming to examine the possibilities offered by computers was launched in Zagreb. It was called *Computers and Visual Research*. Apart from a handful of American contributors whose work was also presented in London, most of the participants were from Europe. The exhibition dealt solely with computer-generated material, and there was to be a prize for the best work. The jury, which included Umberto Eco, Karl Gerstner, Vera Horvat-Pintarić, Boris Kelemen, and Martin Krampen, concluded wisely that the work was too experimental for them to have the right sort of criteria for issuing a sensible decision. They resorted to listing all the works that they found interesting. Radoslav Putar, introducing the exhibition, made the point that processing machines determine human behavior in an underhand way. He called it a "secret revolution," and the idea of the project was to bring the phenomenon into the open and to examine it.

And Now?

After the 1970s technological art left its clearly defined position. It became widespread and diverse. The community dispersed. Whereas it was possible in 1968 to gather most of the artists and engineers working with computers and cybernetic devices and include them in an exhibition, *Cybernetic Serendipity* failed to include everybody, although the intention was to do so. By the end of the 1980s it would have been impossible.

After the 1980s use of computers in art became too commonplace to be remarkable. One after another new technological art associations, biennales, colleges, and groups, came into being. Among them, and apart from those mentioned above, were ArtLab, Tokyo; *Artifices*, Paris; ArtWare, Hanover; CAiiA in Newport; *Ascent*, Edinburgh; IAMAS, Gifu prefecture; ISEA, Manchester; ZKM, Karlsruhe; Ars Electronica, Linz; Arslab, Turin; Ars Technica, Paris; Computer Museum, Boston; Ionist Art Group, Wiltshire; *Artec*, Nagoya; ISAST, Berkeley; InterCommunication Center, Tokyo; SCIART, London; Tisea, Sydney; Museum of Computer Art, Brooklyn; several digital art museums and computer art groups on the web; and SIGGRAPH.

With the advent of the Internet, computer art left the ground and took off into that virtual space where everything is illusion. In one sense, it has lost its edge because we cannot separate it from everything else. It is now a language that is applied to everything. According to usage, digital material has separate niches, just like our language, of words and symbols that divide itself into some congenial groups of fiction, or poetry, or fashion. Furthermore, we cannot say it is not art. We can only say it is good, bad, or indifferent.

When it comes to three-dimensional works, there are still major challenges. There is still no satisfactory way of maintaining a museum of sophisticated technological art that will guarantee its survival. At best, three-dimensional works will be represented in broadcast form on a screen, unless holography comes to its aid. Perhaps the very experience of cybernetic art machines could ultimately be embodied in a chip and stored. The solutions to the problem of survival of the works will be found in the technology itself.

Note

1. Jasia Reichardt, ed., *Cybernetic Serendipity* (London: Studio International, 1968), 5.

7

Cybernetic Serendipity Revisited

Brent MacGregor

> A gallery full of tame wonders which look as if they've come straight out of a science museum for the year 2000.
>
> —*Cybernetic Serendipity* Exhibition Press Release, Tate Britain Archive (VA Pub 179).

Introduction

"I think we shall look back to it one day as a landmark," wrote Nigel Gosling, a farsighted journalist, after attending the press viewing of the *Cybernetic Serendipity* exhibition at London's Institute of Contemporary Arts (ICA) in August 1968 (figure 7.1).

This observation was from a man who nevertheless found the exhibition "baffling, not to say impenetrable."[1] He was certainly right, as was Jasia Reichardt, the exhibition organizer, in her predictions about how computers would come to be coveted childhood objects. *Cybernetic Serendipity* is almost legendary as a seminal event in the intersecting histories of computing and art. It is seen today as a landmark event, of unambiguous historical importance to people in the field. Enter the two magic words "cybernetic" AND "serendipity" into an Internet search engine and over four hundred pages of text result, including fascinated inquiries from wide-eyed young enthusiasts not even born in 1968. Such a search reveals many websites devoted to the work of major pioneering figures who took part in *Cybernetic Serendipity*, some of them unfortunately no longer with us. All feature it proudly in their list of achievements. Mention the two words in certain academic company and distinguished professors of computer science will discourse almost endlessly, recalling its impact on them as teenagers. Many such individuals even go so far as to say that the exhibition was instrumental in their choosing to work with computers.

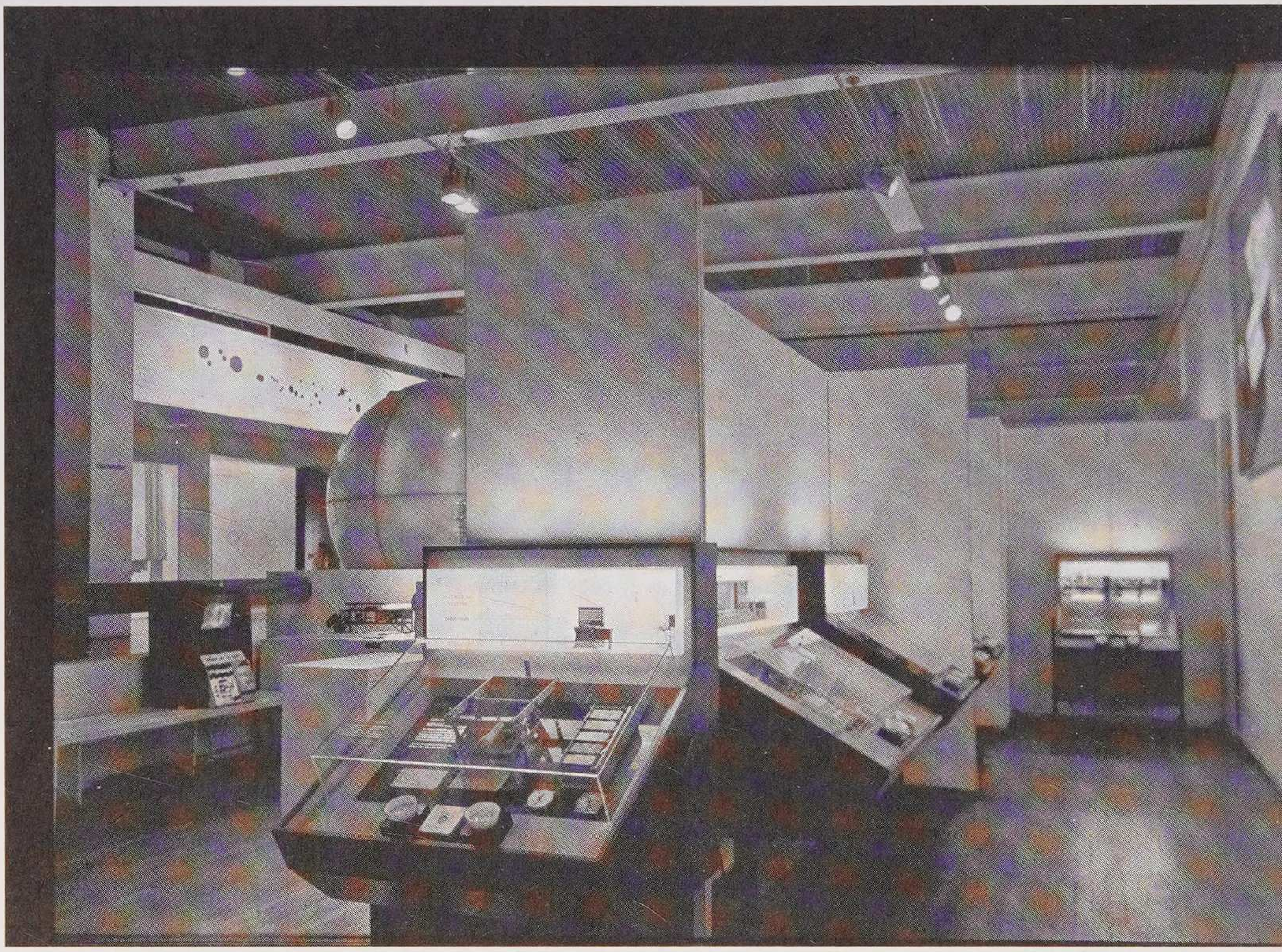

Figure 7.1 View of *Cybernetic Serendipity.*

Whether digital or analogue, online or on paper, whether systematically gathered or anecdotally reported, there is clear evidence that *Cybernetic Serendipity* has had enormous impact and a significant afterlife. Several attempts have been made to re-stage the exhibition in its entirely or in part[2] and anniversary papers have already been written.[3] This chapter is an attempt to undertake a systematic examination of the legend and the facts behind it.

Historical Context

It is important to remember that this seminal event took place in 1968, a year after the optimistic "summer of love," and roughly the same time as the Soviet invasion of communist Czechoslovakia (now of course two separate democratic European nations). There were riots in Chicago against the war in Vietnam and presidential candidate Senator Robert Kennedy was shot in a Los Angeles hotel.

Princess Margaret visited the exhibition accompanied by her husband Anthony Armstrong Jones, Lord Snowdon. The British government Minister of Technology at the time was the Right Honourable Anthony Wedgwood Benn. It was a time when the idea of a computer selling for the price of a small car with a megabyte of memory[4] was a dream and when it took a state-of-the-art plotter sixteen hours to print a monochrome picture of Norbert Wiener.[5]

Whatever the change from 1968 to today in price to performance ratio, many of today's uses of computers were already achieved or anticipated. Equally there were some dead ends or perhaps stories that are not yet finished. What has happened to the "cybernetic introspective pattern classifier," which "allows people to watch their own cerebral processes actually in action"?[6] Did computer generated "high-entropy essays"[7] have a life after 1968? How far have creative robotics come since Nam June Paik's *Robot K-456* (figure 7.2), "a female robot known for her disturbing and idiosyncratic behavior"?[8]

Background

Jasia Reichardt was the assistant director of the Institute of Contemporary Arts in London, when, as a result of organizing an exhibition on concrete poetry, she met Max Bense of Stuttgart University. His inspired words to her in 1965 were "look into computers." Through various professional periodicals such as *Data Systems* and *Computers and Automation* (and their annual computer art competition), she made contact with Michael Noll of Bell Telephone Laboratories. The contact with Bense in Europe and with Noll in America and with the Computer Technique Group in Tokyo led her into new networks. The US State Department provided a travel grant to support a research visit to New York where she made contact with Experiments in Art and Technology (EAT). After a substantial period of research, the ICA held a press conference in December of 1966, announcing the planned exhibition and commencing the process of fundraising. Supported by the Rt. Hon. Anthony Wedgwood Benn, Minister for Technology, letters went out to over two hundred firms seeking support. This eventually futile search for sponsors led to some of the tight-fisted corporations being named and shamed at the exhibition press launch nearly two years later.

Only IBM helped with significant contributions in-kind, in the form of models illustrating the history of computing, without which the exhibition could have not gone ahead. In all a sum of £20,000 was raised, with the Arts Council providing

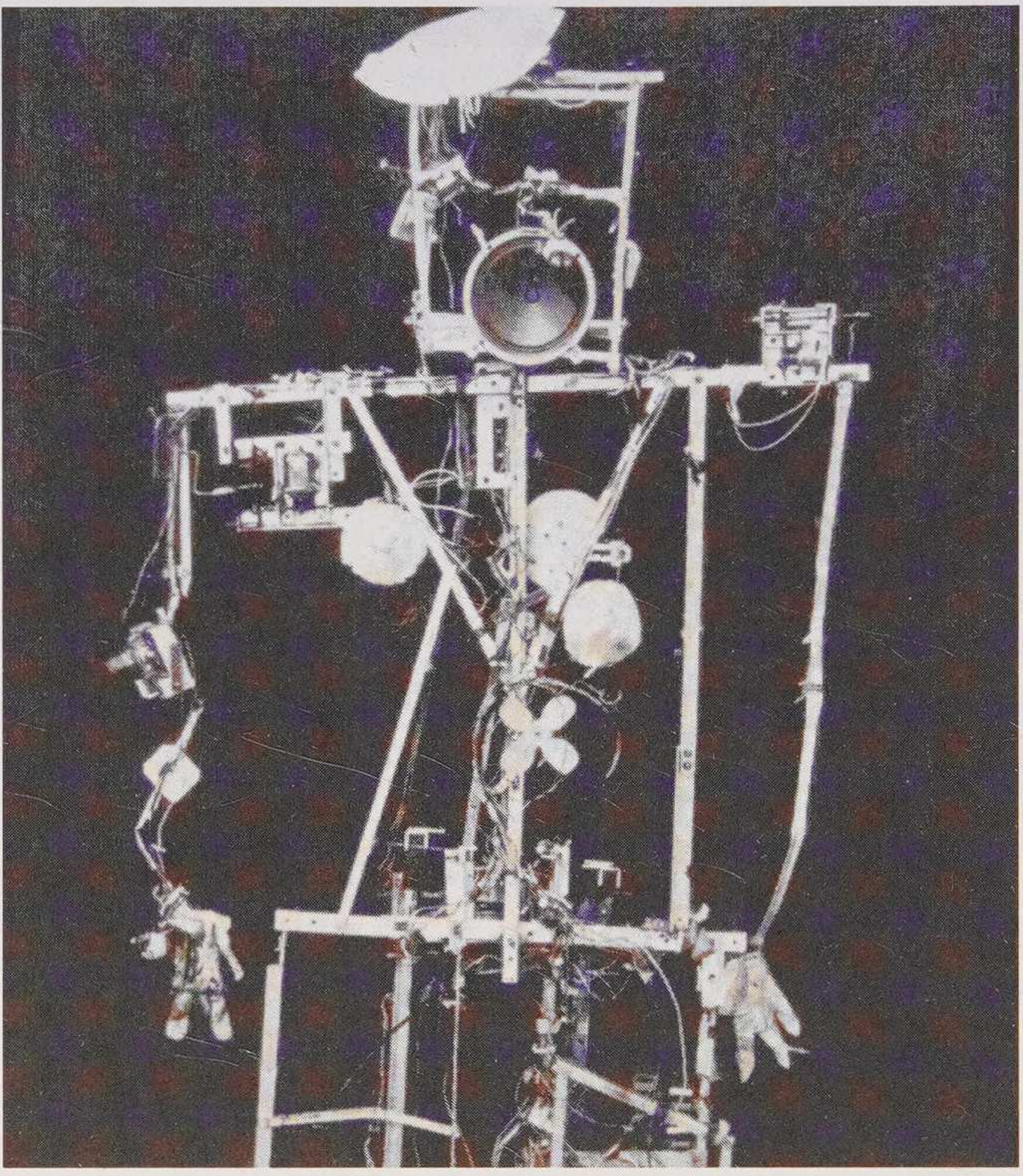

Figure 7.2 Nam June Paik, *Robot K-456*, 1964.

£5000. The scale of the project can be compared to the contemporary Matisse exhibition at London's Hayward Gallery which cost £60,000. This medium sized budget meant the exhibition could afford to advertise at selected sites in the London Underground but was hardly extravagant.

Data

Two substantial surviving archives were examined exhaustively. The original ICA archive is now in the library of Tate Britain and a private archive of the event is held by the original exhibition organizer, Jasia Reichardt. Both of these were investigated thoroughly, as were published sources. The material now in the Tate consists mostly of papers from the ICA press office, including actual material used in the paste up of the exhibition book. This archive also includes press releases, other printed ephemera from the time, and cuttings of the extensive press coverage in the print media, ranging from *Nature* to *Practical Electronics* to *Vogue.* The thirty-two pages of press cuttings preserved in a scrapbook include newspaper coverage from the full range of contemporary tabloid and broadsheet publications. A certain number of press photographic prints are held in this collection. There is extensive correspondence concerning the possible television coverage of the exhibition. Various children's and science programs made inquiries but in the end the arts program *Late Night Lineup* was the only one to actually film, with Jasia Reichardt presenting *Cybernetic Serendipity* speaking straight to camera in a short film shot in the exhibition. The BBC Film Archive and Britain's independent television news organization ITN have no other material in their current libraries. This conflicts with participants' memories of news crews filming Princess Margaret's visit to the exhibition.

One of the few papers that refer to the actual organization of the exhibition is a document dated July 7, 1968. Marked confidential, it is a statement of accounts listing expenses already undertaken, those that had yet to be committed, and an estimate of contingencies. It is noted that £150 had been spent on second-hand television sets for Nam June Paik and a further £60 was needed to be spent on "miscellaneous gear" for the same artist, equipment which is described as a "doubtful asset." The anonymous account keeper passes no more comment on Paik's work or its cost but recommends strongly in conclusion: "We save £750 by canceling Negroponte film now." Other than this fragment, there is very little record of the nuts and bolts of organizing the exhibition.

The exhibition organizer Jasia Reichardt had the exhibition exhaustively photographed. She kept this large private collection. The 137 thirty-five millimeter slides documenting the exhibition have now been catalogued, digitized, and transferred to CD-ROM. A copy of a sixteen-millimeter film showing some of the exhibited computer animation work has been transferred to a contemporary videotape standard. This represents six of the thirteen films that were shown in the specially constructed cinema. This film and the slides were used as the basis for a number of public lectures given in various locations after the exhibition had closed. A copy of the original exhibition publication and other related ephemera have been obtained. Contemporary television coverage from the BBC Television film library has been catalogued and obtained on an accessible modern videotape format. All the print and radio press coverage has been examined and noted. Several original exhibitors have been contacted and a number of surviving works located and examined. Three long interviews have taken place with the original exhibition organizer Jasia Reichardt. The substantial influence of the exhibition noted in both traditional and online sources has been documented. Published and online material by or about individual exhibitors has been noted by way of background.

Participants

The exhibition publication is fulsome in its praise for and thanks to all involved in the project. In addition to Jasia Reichardt, the team behind *Cybernetic Serendipity* were Mark Dowson, credited as technological advisor; the painter Peter Schmidt, who acted as music advisor; and exhibition designer Franciszka Themerson.[9] The ICA records in the Tate include a typed list of 124 "Major Contributors" some of whom are not mentioned in the book. A total of 148 parties are mentioned in both sources. These ranged from corporate giants such as IBM, Boeing, General Motors, Westinghouse, Calcomp, major research institutes such as Bell Telephone Laboratories, and US Air Force Research Labs, down to individuals such as the Reverend A. Q. Morton from Fife in Scotland. Clearly the exhibition was large and complex.

The list of artists involved includes Nam June Paik, Bridget Riley, and avant-garde composers John Cage and Iannis Xenakis, all leading artists of the day, some computer users at the time, some not. Hardly surprisingly the "founding fathers" of both computer art and robotics were well represented: Charles Csuri, Gordon Pask, Frieder Nake, Michael Noll, John Whitney, Edward Ihnatowicz, the Computer Technique Group, Tokyo, and many others. These creators, from various backgrounds, who were using computers in exciting new ways, were joined by "traditional" (non-digital) contemporary artists who worked with machines and whose work had already been seen in various gallery contexts. These artists included Bruce Lacey who contributed robots, Nam June Paik, Roger Dainton, Tsai Wen Ying, Jean Tinguely, and James Seawright. Lowell Nesbitt's paintings of computers were also shown.

The work was not confined to the visual arts. There was the work of avant-garde musicians such as John Cage, Iannis Xenakis, and Peter Zinovieff and poetry including Edwin Morgan's *Computer's First Christmas Card*.[10] Films by Kenneth Knowlton, Michael Noll, Nicholas Negroponte, and John Whitney, among others, were shown in a specially built viewing area. The status of the event was such that Umberto Eco came from Italy to view its wonders.

The Exhibition

As clearly stated in the exhibition press material, *Cybernetic Serendipity* was organized in three sections:

- computer-generated work
- cybernetic devices—robots, painting machines
- machines demonstrating use of computers and an environment dealing with the history of cybernetics

The computer-generated work was mostly on paper. The general photographs show a well-designed and carefully lit exhibition which created a unique environment. The well-known three-dimensional pieces by the likes of Bruce Lacey, Jean Tinguely, and Edward Ihnatowicz are clearly evident but there is a huge amount of two-dimensional wall-mounted material as well.

Not surprisingly, the "cybernetic devices" were the stars of the show. These ranged from kinetic art pieces by Jean Tinguely to robots by Lacey, Paik, John Billingsley, and others. These robotic devices in the exhibition, which were a big hit with critics and the public alike, were not digitally enabled. Edward Ihnatowicz's *SAM* (*Sound Activated Mobile*) was featured in the BBC film and was clearly one of the stars of the show; it is described in the publication as being "electro-hydraulically operated and its creator writes that he is 'currently working on a large structure to be operated by a computer'" (this was to become the *Senster*).[11]

"The Honeywell Emett 'Forget-me-not' (peripheral pachyderm computer)" deserves a particular mention: "The *Forget-me-not* computer, built in 1966 in accordance with Livingstone's Law (Memory *may* hold the door but elephants never forget) is of pleasing outward appearance, being delicately constructed of bamboo so that it may be placed in any executive office without offence. Among its many worthwhile features is a mass-memory, where a number of miniature minds can think instantly in a clockwork direction."[12]

The drawing machines were mostly analogue devices, indeed some were simply mechanical devices without even electric motors. The 'Henry drawing computer', created by D. P. Henry, is described by its creator as follows: "the apparatus is a modified analogue computer, originally operated by two electro-servo motors and air-pressure."[13]

Christopher Evans of the National Physical Laboratory contributed the *Cybernetic Introspective Pattern Classifier*. This metal box 48 inches long by 20 inches wide, offered the user a viewing position where "People looking into the CIPC will be given a bright, brief flash of a pattern which plants an image on the retina in such a way that it can be seen, with eyes closed, for one or two minutes."[14] Gallery health and safety officers of today would no doubt prevent such a device even getting beyond the risk assessment stage.

A whole section of the exhibition publication is devoted to "Computer Texts and Poems," including "computerized Japanese haiku"[15] and "high entropy essays,"[16] which were essays on technical physics written by a computer program. One such creation was inserted into a pile of undergraduate examination answer booklets in the fond hope it would pass for the real thing. Fortunately higher education quality control in the 1960s was sufficient for this rogue, randomly generated paper to be detected by a vigilant assessor.[17] High Entropy essay 4321 begins:

the absolute
the entropy of the universe which determines
microscopic disorder implies the increase of disorder[18]

The third section of the exhibition "demonstrating the uses of computers and an environment dealing with the history of cybernetics," was dominated by six display units and models built by Maurice Trask for IBM, illustrating the history and development of computing. These models and their "audience operated device"[19] were so effective that many enthusiastic eyewitnesses swear to this day that the IBM airline reservations systems illustrated was actually in the ICA. The closest thing to actual IBM hardware was a model of an IBM 360 system in the same display.[20]

Contexts

The exhibition's aim was clear: "Dealing with an exploratory field, all attempts at a historical perspective or firm evaluation were out of place. The exhibition and this record, therefore, are essentially a reportage of current trends and developments."[21] Sensibly, the exhibition did not tear machine-assisted creative work from its context, and contemporary work that was not made in any way by machine was included. For example, Bridget Riley's geometric work was exhibited alongside similar machine-facilitated or computer-generated work. The contemporary avant-garde music on the exhibition record included work that was, for the most part, produced in non-digital ways but that helped to set the context for the computer-generated or assisted work. It is also important to note that a wide range of disciplines were represented in the exhibition, not just the visual arts. Poetry, music, dance, film, and animation with a technological dimension were all shown.

Publication

The much-quoted and consulted exhibition publication is not, as is so often assumed, a catalogue, but rather a book to coincide with the show. The book was published as a *Studio International* special issue and went to a second edition and a further reprint. The first edition is dated July 1968, before the exhibition opened. Some of the machines and some of the works displayed or referred to in the publication were not actually in the ICA show. Some of the text in the publication had been previously published elsewhere. A lecture series ran parallel including the Reverend A. Q. Morton speaking on "The Computer as an Aid to Literary Studies," explaining his use of computer-aided analysis of Greek language texts, including Homer. A 33 rpm long-playing record, including work also in the exhibition, was issued, and some of the contributors performed at a concert at the ICA on August 29, 1968.

Findings

Cybernetic Serendipity has a reputation for being the first computer art exhibition. It was not. There had been a computer art exhibition earlier in Germany (Stuttgart, February 1965) and two in America (April and November 1965). The ICA show was certainly the first on a large scale in a major public gallery, and was, of course, more than computer art, being a comprehensive survey across the cybernetic arts. More crucially perhaps, *Cybernetic Serendipity* was, as its title states, about cybernetics—"control and communication in the animal and machine"[22]—rather than exclusively concerning itself with computer-generated work. The stated aim of the exhibition was to explore "the relationships between technology and creativity."[23] While clearly centering on computers for publicity (and fundraising) purposes, there were only two digital machines in the exhibition and much of the work was produced using analogue technology. One of these computers, used by Peter Zinovieff to compose music, was removed for his continued use. When this happened a set of large soft dice was put in its place, creating a place to sit with the intention of signaling the importance of the chance element in creativity; a case of serendipity replacing the cybernetic. The exhibition photographs show only one machine that might instantly be recognized as a computer today. This was a Calcomp plotter and its refrigerator-sized driving machine. When this research was presented at an international conference, distinguished professors from two continents debated at length about whether such a machine was or was not actually a general purpose computer.

Insights and Foresights

The multifaceted wonders of the cybernetic world were not presented without comment:

> One can foresee the day when computers will replace railway trains and airliners as the cult symbols of the under twelve's.[24]

> Cybernetic Serendipity deals with possibilities rather than achievements, and in this sense it is prematurely optimistic. There are no heroic claims to be made because computers have so far neither revolutionized music, nor art, nor poetry, in the same way that they have revolutionized science.[25]

> The computer is only a tool which, at the moment, still seems far removed from those polemic preoccupations which concern art. . . . The possibilities inherent in the computer as a creative tool will do little to change those idioms of art which rely primarily on the dialogue between the artist, his ideas and the canvas. They will, however, increase the scope of the art and contribute to its diversity.[26]

These observations, made by curator Jasia Reichardt were, and remain, remarkably insightful, clearly standing the test of time.

Serendipity Ain't What it Used to Be

The exhibitors in *Cybernetic Serendipity* were a combination of artists and scientist-engineers experimenting in a way not possible today. Of course in 1968 scientists, engineers and artists all had to write software (or work with someone who could) in order to produce computer work, whereas today artists can use digital tools without needing coding skills. Computer users are less likely to do something just to see if it can be done. Questions such as, "Can we get a computer to replicate a Bridget Riley or a Klee?" were asked and answered in 1968 in a way that they wouldn't be today. Both public and private computer labs were well funded and staffed, and creative serendipity was possible. Whether in university computer centers or the labs of Boeing or Bell, genuine blue skies research was done in a sometimes playful way. Creative people wrote code, not funding applications.

This rose-tinted view of things has quite properly been contested by senior figures with a closer relation to the time. The view of several senior computer scientists was that the interesting groundbreaking work exhibited was very often done in the margins of more mundane funded work for Bell Labs or the air force, for example. Certainly it appears in retrospect that public galleries like the ICA had staff who could take time to do a job properly. What major public gallery today would allow an assistant director to spend the better part of two years following the three-word advice of a respected colleague? Today galleries would look for the surefire success, with clear funding opportunities, which would be curated by a superstar freelance curator brought in for the job.

Afterlife

Some of the work travelled to the Smithsonian Institution in Washington, DC, and to the Exploratorium in San Francisco (for an exhibition called *Scientific Serendipity*). Some pieces were sold to a collection in Japan. While some of the work survives today in the garages of engineers and the barns of artists, other works are in the private collections of the wealthy, and some are in the vaults of public galleries. Jasia Reichardt has one in her study.

Whether *Cybernetic Serendipity* was an exhibition of the cave paintings of the digital age or simply drawings in the digital sand is for history to determine. Very little of the work shown features *yet* in the wider history of mainstream contemporary art, possibly because the history of digital art is only now beginning to be written. Clearly the event itself was historic and influential, greater in many ways than the sum of its very considerable parts. Appropriately, *Cybernetic Serendipity* was itself a wonderful serendipitous accident, a happy coincidence of the right person in the right place at the right time, assisted by a lot of the right people. The resonances will multiply; the story will not be forgotten.

Notes

1. Nigel Gosling, "Man in an Automated Wonderland," *The Observer* (August 4, 1968).

2. *Star dot star* (1998) Available at http://homepages.nildram.co.UnitedKingdom/~site/oldsite/V2/exhib/star.html.

3. Paul Brown, "30 Years On—Remembering Cybernetic Serendipity," *Outline: The CTIAD Journal* 6 (Autumn 1998): 3–5.

4. Jasia Reichardt, ed., *Cybernetic Serendipity* (London: Studio International, 1968), 10–11. Hereafter referred to by page numbers in parentheses in the text.

5. Ibid., 9.

6. Ibid., 51.

7. Ibid., 58–59.

8. Ibid., 42.

9. Ibid., 5.

10. Ibid., 57.

11. Ibid., 38.

12. Ibid., 46.

13. Ibid., 50.

14. Ibid.

15. Ibid., 54.

16. Ibid., 58.

17. Ibid., 59.

18. Ibid., 61.

19. Ibid., 13.

20. Ibid.

21. Note on the exhibition record sleeve.

22. Reichardt, *Cybernetic Serendipity*, 9, quoting Wiener 1948, 1964.

23. Ibid., 5.

24. Exhibition Press Release, Tate Britain Archive (VA Pub 179).

25. Reichardt, *Cybernetic Serendipity*, 5.

26. Ibid., 71.

8

The Technologies of Edward Ihnatowicz

Aleksandar Zivanovic

Edward Ihnatowicz produced arguably the greatest work of computer art to date, the *Senster*, in 1970. It was the first sculpture to be controlled by a digital computer, which controlled the motion of the sculpture in response to the sound and movement of the people around it. This chapter gives an overview of his work, describing the development of his ideas. Further information, including video clips of the sculptures in motion, may be found on the website: www.senster.com.

Ihnatowicz was born in Poland in 1926, left as a war refugee in 1939, and eventually arrived in Britain in 1943. He attended the Ruskin School of Art in Oxford from 1945 to 1949 where he studied sculpture but was also very interested in photography and filmmaking. He retained this interest throughout his life and, for a while, worked professionally in the field. He worked as a junior partner in a small furniture firm until, in 1962, he left the business and his home to live in an unconverted rented garage and return to making art. He barely survived by making window displays and door-handles for shoe shops. He was nearly forty years old and felt that his art had not matured with him, leaving him very dissatisfied. He made a series of portrait terracotta and bronze busts but did not rate them highly. He also made a number of sculptures out of parts of old cars and even sold a few. He did not regard them as "serious" sculpture, but he enjoyed making them and, as he came to believe, doing something that he found enjoyable was essential:

> I had to devise for myself a type of occupation, even if it meant giving up art, that had a best chance of making me feel like getting up every morning to get on with it. This suggested that for safety's sake I should include all the activities that had given me that type of anticipatory pleasure in the past and those were embarrassingly many and most of them had nothing to do with art. The strongest candidates apart from sculpture itself were working with machinery and electronics.[1]

Aesthetics of Engineered Components

In dismantling cars for his sculptures, there were two aspects Ihnatowicz was interested in: the aesthetics of the parts and methods of generating motion. He realized that the shapes of the highly engineered components were more satisfactory from an aesthetic point of view than his abstract sculpture. He thought that they had "more conviction and an air of purposefulness and suitability for the tasks for which they were intended; and also that those tasks invariably involved some form of physical motion or transmission of forces." He decided to investigate abstract form generation "to try to see whether a shape determined wholly by mechanical and functional considerations and refined with care and sensitiveness normally reserved for works of sculpture could be made as aesthetically satisfying as a piece of sculpture or an organic form." He had been toying with the idea of a science fiction play in which there was to be an extra-terrestrial robot and the details of its mechanical construction were proving to be a fascinating problem.

> What sort of shapes might we conceivably expect to see on a machine produced by a civilization with similar material constraints to our own, but technologically greatly advanced? I decided that one of the differences could well be that the shapes of the mechanical components would be recognizably dictated entirely by the forces acting on them in operations and not at all by the constraints of the methods of manufacture or even of design. This was based on the assumption that the design and manufacture technology could be assumed to be so advanced as to make the shape of the original material stock or ease of machining irrelevant. In our own engineering similar conditions exist occasionally when either the cost or weight of the material becomes critical as in the case of a wishbone suspension in a motor-car or when the shape of a component is critical for its performance as in an aerofoil. Such conditions often result in the production of aesthetically very satisfying shapes and it was this together with a suspicion that similar constraints might be applied to sculpture.

It was by experimenting with this approach, and by devising a set of artificial constraints, that he came up with the design that eventually became *SAM* (*Sound Activated Mobile*).

Generating Motion

In addition to discovering the more satisfactory aesthetics of engineered parts, Ihnatowicz found when dismantling cars, the experience also taught him about ways of generating interesting motion. He was fascinated by the hydraulic systems used in cars to transmit the force exerted by the driver on the brake pedal to the brake pads on the wheels. He was impressed by the power, smoothness, and precision with which the system could move. He realized that this was a very good way of producing subtle and well-controlled motion. Oil could be delivered to any number of actuators through flexible piping, but to do this required an ability to precisely control the amount of oil being fed to a hydraulic piston. Foot pedals clearly had to be replaced by a motorized pump and the flow controlled by valves. A method of automatically controlling the valves was required, as was, even more importantly, an ability to define precisely the motion to be produced.

Ihnatowicz found some hydraulic valves in a batch of government surplus equipment and started experimenting with analogue electronic circuits to control the values to produce interesting motion. This fascination with hydraulics, together with his interest in the aesthetics of engineered components, resulted in his first cybernetic sculpture.

SAM (*Sound Activated Mobile*)

Ihnatowicz decided to develop a robot neck, under the following constraints:

1. The structure should be hollow in the centre to allow for the passage of a number of pipes and cables from the trunk to the head for which it would need to offer a measure of mechanical protection.
2. The movement between individual elements of the neck to be restricted to reduce the risk of twisting or buckling of the pipes.
3. Any connection to the elements of the neck itself to be also made from the inside to preserve a clean appearance and to reduce the possibility of damage in operation.

These restrictions suggested that the structure be in the form of a stack of vertebrae rather than some form of a powered universal joint. It also made hydraulic actuation the logical choice, given his interest in this form of actuation. He designed two types of shapes to be stacked alternately on top of each other, eight in all, one interconnection providing the horizontal movement and the other the vertical.

Pistons were integrated into the shapes, two in each section acting antagonistically (in a push-push configuration). Each of the pistons had a small range of motion, but was linked to all the others of its type, so that only two servo-valves were used: one to control all the horizontal acting pistons, and one for all the vertical ones. The result was that the whole column could twist from side to side and lean forward and backward. He modeled the shapes of the vertebrae in wax, and then carved wood patterns, which were used to make aluminum castings.

Ihnatowicz found the shapes much more satisfying than the abstract sculptures he had hitherto been producing. Trying to build the pistons into the shapes caused him many problems. Hydraulic systems demand very high manufacturing tolerances to prevent leaks and he found it very hard to achieve the required accuracies. In finding out more about the engineering and manufacture of these systems, he made many useful contacts, particularly at University College London, who would later assist him in the construction of the *Senster*.

In developing the mechanics of the neck, he had left untouched the problem of the control of the motion, and indeed the reason for that control. He had an idea to construct an acoustic direction finder, mount it on top of the neck and devise some means of utilizing the output of such a detector to drive the hydraulics. The electronics caused him a lot of difficulty. He mounted four microphones in front of a flower-like fiberglass parabolic sound reflector on top of the neck and tried to use the difference in volume on each pair of microphones to determine the direction of sound. This proved unsuccessful and he was eventually helped by John Billingsley from Cambridge, who designed a circuit that measured the phase difference in the sound at the microphone pairs (effectively measuring the time delay between the sound arriving at one microphone and the next). The output of the circuit was an analogue voltage, which indicated the direction of the dominant sound, and this output was fed to a pair of hydraulic servo valves, which controlled the flow of oil to the pistons in proportion to the level of sound. Thus the device turned and bent over to face people talking in its vicinity.

Ihnatowicz named the resultant sculpture *SAM*, for *Sound Activated Mobile* (figure 8.1), and he regarded it as "the first genuine piece of sculpture I had produced."

SAM was exhibited at the *Cybernetic Serendipity* exhibition, which was held at the Institute of Contemporary Arts (ICA) in London in 1968, and later toured the United States, ending at the Exploratorium in San Francisco. The behavior of the sculpture, that of following the movement of people as they walked around its plinth, fascinated many observers. Also, since the sculpture was sensitive to quiet but sustained noise, rather than shrieks, a great many people spent hours in front of *SAM* trying to produce the right level of sound to attract its attention.[2]

As previously mentioned, Ihnatowicz obtained the valves used in *SAM* in a batch of government surplus parts. Neither he nor the dealer were aware of the function of the servo valves, and in researching their use he found out about the whole area of control engineering, which he realized would be central to the work he was interested in:

> I became convinced that Control Engineering was precisely the technology needed to enable artists interested in movement to explore those virtually unexplored areas of our sensibilities. Most people are sure that there is a very basic difference in the quality of movements produced by a human being or an animal, and those produced by a mechanical device and that this can be used as a reliable basis for differentiating between animate and inanimate objects. This is no longer true. Practical engineers have no interest in the simulation of animal movement or behaviour, but the technology clearly exists to make this possible and from the artistic point of view the prospect is fascinating.

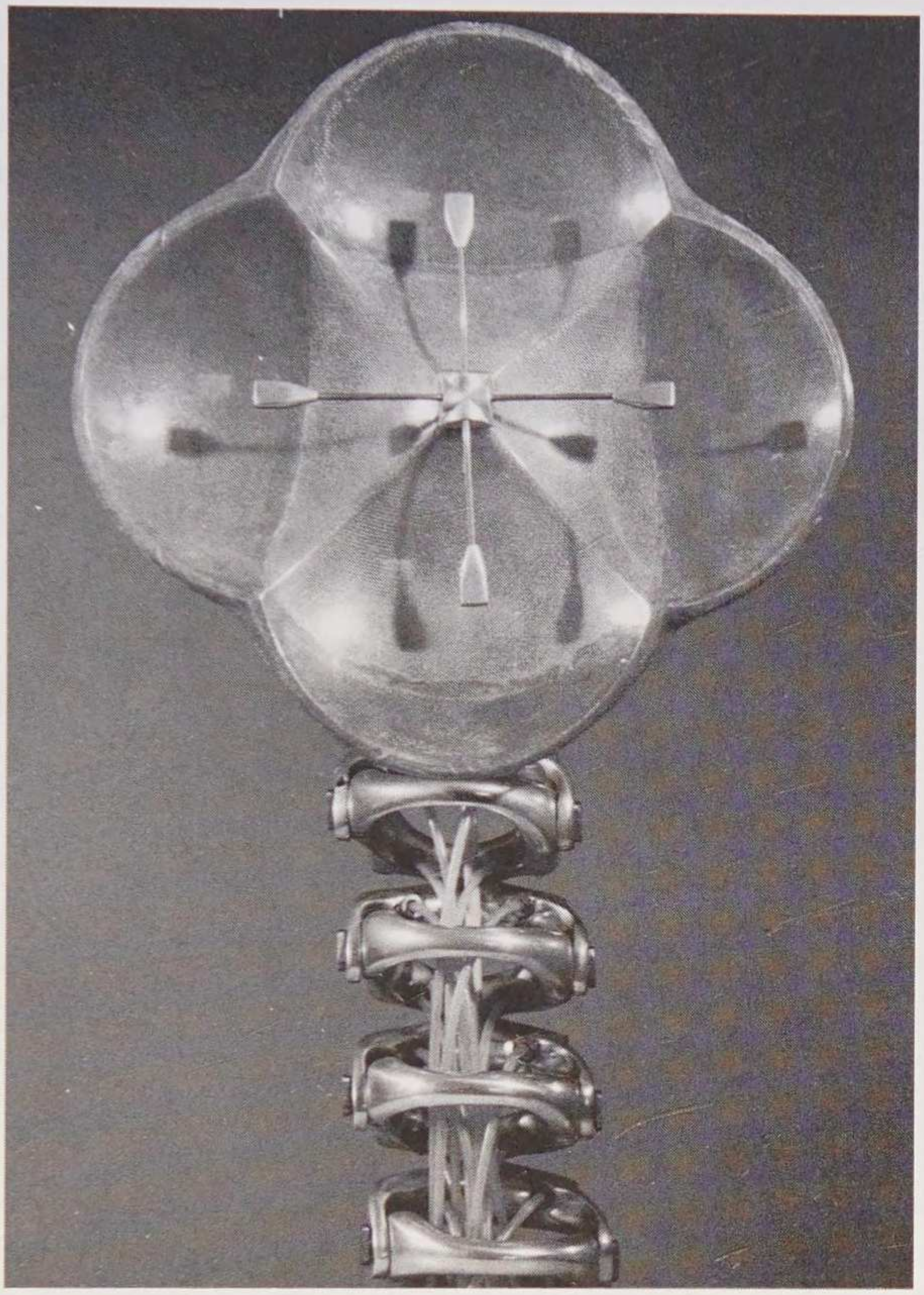

Figure 8.1 Edward Ihnatowicz, *SAM* (*Sound Activated Mobile*), 1968.

He investigated control engineering, but too late to use it in *SAM*, which operated in open-loop[3] mode. To operate it in closed-loop mode would have required altering the structure of the neck to add position sensors.

Ihnatowicz became fascinated by analogue computers, bought an army-surplus oscilloscope, constructed a simple analogue computer, and could make the spot on the screen move in what he considered were quite elegant ways. Using the skills he acquired developing *SAM*, he built a hydraulic system with position feedback and constructed a simple servo-system, which would move a lever in strict accordance with the pattern displayed on the oscilloscope. Although the various waveforms produced by the computer were pleasing, and the physical motion of the lever encouraging, he wanted a more precise way of describing the motions to be produced in terms of velocities, accelerations, and time intervals. He also wanted to understand better how we and other animals move and, to this end, he contacted some people working with powered prosthetics, having learned that they were analyzing movements of human arms during the performance of various tasks. He was amazed to discover that the motion of a human elbow when performing a well-rehearsed movement from one point to another exhibited an almost linear acceleration and deceleration, a sort of motion that he could simulate exactly on his analogue computer. He also noticed that these people were using digital logic circuits to sequence and control their simulators, so he taught himself about digital computing. He eventually constructed a small logic network, which, together with a pair of digital-to-analogue converters, enabled his hydraulic lever to perform a great variety of movements.

The *Senster*

Ihnatowicz realized that the shapes he had produced for *SAM*'s neck looked somewhat bone-like, although he had not tried to imitate natural forms. He was intrigued to discover that an almost identical shape existed in nature in the joint of the claw of the lobster. It was not only the similarity of shape that was intriguing; its operation was like that of his joint: a simple pivoting action, which he had never seen before in nature. Most animals, even those with exo-skeletons, have more complex joints, which, like our shoulders, can rotate in several planes at the same time. In the lobster, all the joints are simple pivots, but in spite of this apparent limitation and in spite of having only six of them in any leg, that leg can perform all the required motions with perfect ease (figure 8.2).

Ihnatowicz started sketching ideas for a full-size sculpture based on such a leg and he was constructing a model (using miniature hydraulic actuators) when a friend of his introduced him to James Gardner, the exhibition designer.

Gardner was responsible for the *Evoluon*, the electronics giant Philips's new (1966) showpiece permanent technological exhibition (it has since been converted to a conference center) in Eindhoven, the Netherlands. Gardner introduced Ihnatowicz to Philips and persuaded them to commission him to produce a large moving sculpture, which Gardner eventually named the *Senster*. It was a huge undertaking that took Ihnatowicz (with the assistance of professional engineers from Philips/Mullard) several years to complete (the contract was signed in May 1968 and the *Senster* went on display in September 1970) but that enabled him to put many of the ideas he had been toying with into practice. It took the general form of a great lobster's claw with the pincer replaced by a moving array of microphones like

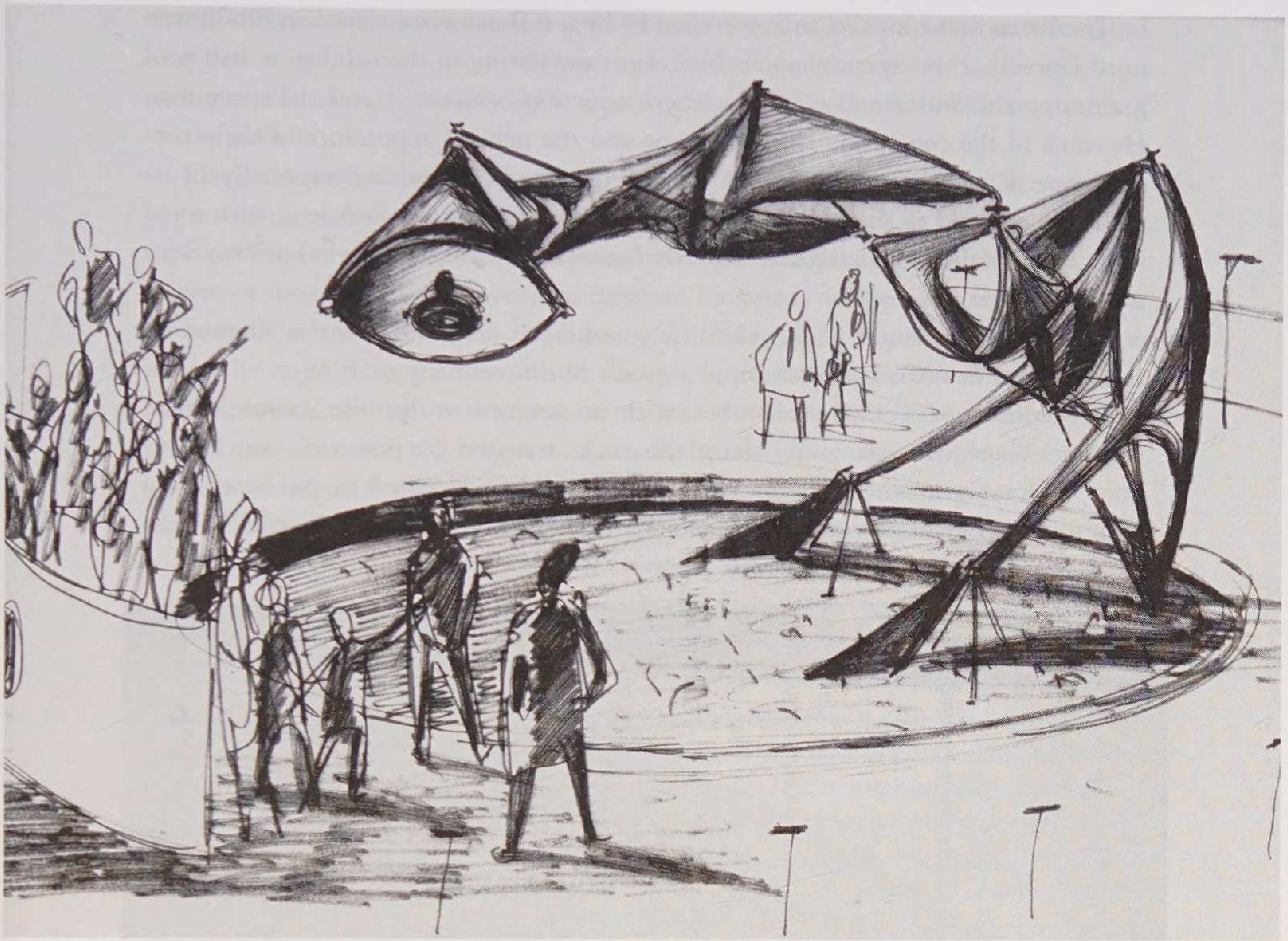

Figure 8.2 Edward Ihnatowicz, concept sketch of the *Senster.*

SAM's, except that the whole thing was now run by a digital computer and had proper industrial actuators and servo-valves.

Ihnatowicz had, by that time, established a close relationship with a number of people in the Department of Mechanical Engineering of University College London (UCL), where he went frequently for advice. For the last year of working on the *Senster*, he moved there completely. A technician at UCL ("Stan the Welder") constructed the huge structure of the *Senster* and it dominated a laboratory in the basement. (There is an anecdote that there was a chunk of concrete missing from the ceiling as a result of a glitch in testing.) After the system was tested, it was dismantled and shipped to Eindhoven in June 1970. The system was insured for £50,000—the equivalent of around US$4.5 million in current value—when it was transported, which gives some indication of the scale of the project.

The *Senster* was unveiled in September 1970 and Ihnatowicz stayed in Eindhoven until December. He spent about half of that time sitting in the exhibition hall programming the *Senster* and observing the interaction between it and the spectators. He came to the conclusion that the shape and the general appearance of the structure were of very little significance compared to its behavior, and especially to its ability to respond to the public. People seemed very willing to imbue it with some form of animal-like intelligence and the general atmosphere around it was very much like that in a zoo.

The *Senster* was large: 15 feet (5m) long and 8 feet (2.4m) tall at the "shoulder," and has been described as resembling a giraffe or dinosaur (figure 8.3).

It was made of welded steel tubes, with no attempt to disguise its mechanical features. There were six joints along the neck, actuated by powerful, quick, and quiet hydraulic rams. (The hydraulic power supply was located in the basement.) Two more hydraulic actuators were mounted on the head to move the microphone

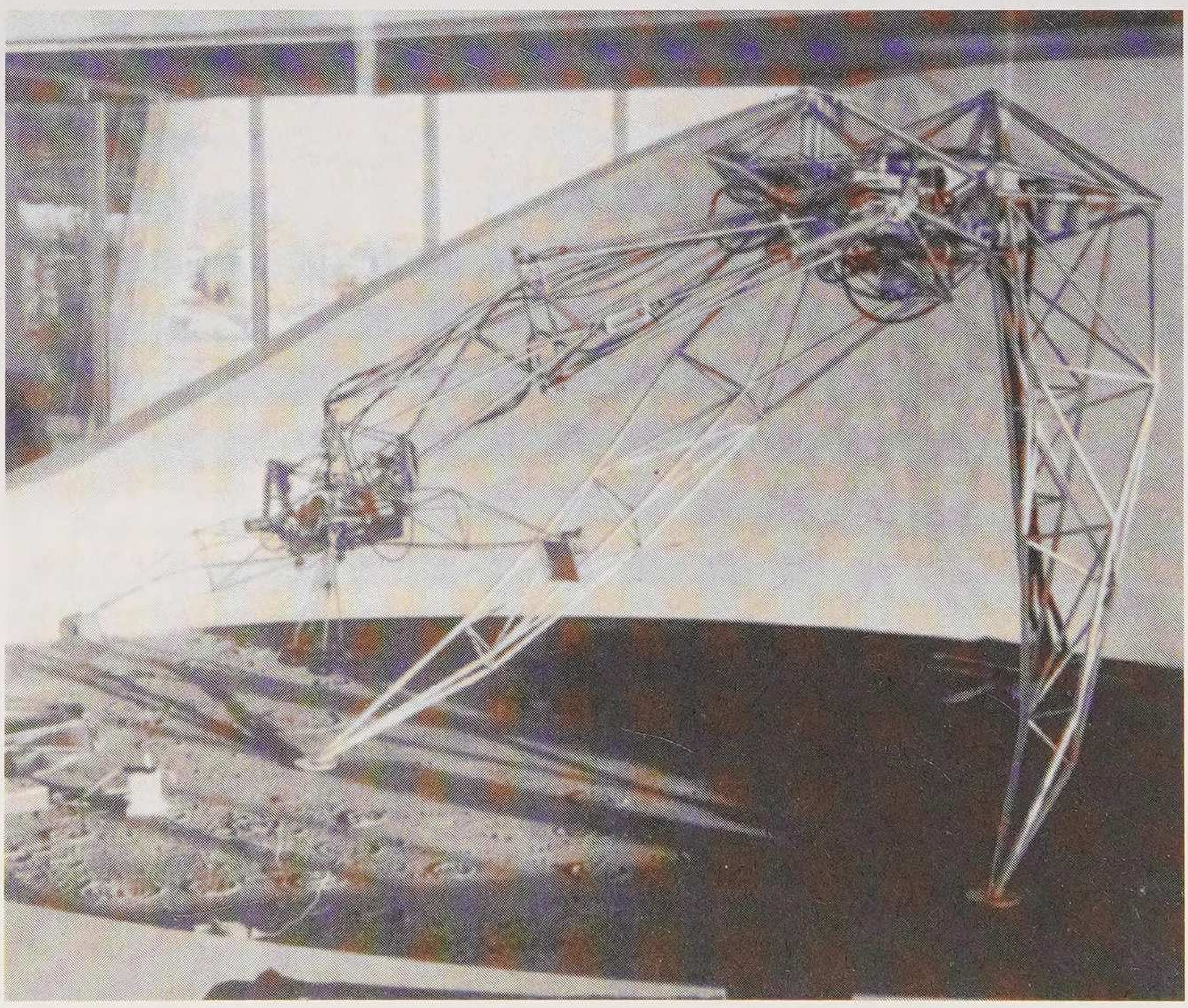

Figure 8.3 Edward Ihnatowicz, the *Senster*, 1970.

array. The microphones were arranged in pairs (much like in *SAM*) but the sound localization was carried out in software by a process of cross-correlating the inputs on each pair of microphones (a much more sophisticated and reliable technique than that of *SAM*).

The actuators in the head moved the microphones quickly in the calculated direction of the sound, in a movement reminiscent of an animal flicking its eyes. The speed of movement was proportional to the volume of the detected sound. If the direction of the sound source remained constant for a particular period of time, the rest of the body would then follow in stages, making the whole structure appear to home in on the sound. Loud noises would make it shy away. If the sound level became overwhelming, the *Senster* would raise its neck vertically and "disdainfully" ignore further sounds until the volume subsided. In addition, two doppler radar units were mounted on the head of the robot, which could detect the motion of the visitors. The *Senster* was attracted toward small motions but sudden movements "frightened" it, causing it to withdraw. The complicated acoustics of the hall and the unpredictable behavior of the public made the *Senster*'s movements seem a lot more sophisticated than they actually were.

> In the quiet of the early morning the machine would be found with its head down, listening to the faint noise of its own hydraulic pumps. Then, if a girl walked by, the head would follow her, looking at her legs. Ihnatowicz describes his own first stomach-turning experience of the machine when he had just got it working: he unconsciously cleared his throat, and the head came right up to him as if to ask, "Are you all right?" He also noticed a curious aspect of the effect the Senster had on people. When he was testing it he gave it various random patterns of motion to go through. Children who saw it operating in this mode found it very frightening, but no one was ever frightened when it was working in the museum with its proper software, responding to sounds and movement.[4]

The computer used to control the *Senster* was a Philips P9201 with 8K core memory, which used punched paper tape to load programs. This computer was a clone of the more common Honeywell 416, and was valued at £8,500 in 1969 (according to a shipping invoice), equivalent to about US$500,000 in current terms. Fortunately, an assembly code listing is still in existence and appears to show that the program implemented a type of "behavior-based" system.

Rodney Brooks at MIT used the term "behavior-based" in 1986 to describe the so-called Subsumption Architecture. He suggested that intelligent behavior could be achieved using a large number of loosely coupled processes, which carried out only minimal internal processing, and that sensory signals should be mapped as directly as possible to motor signals. His view was that intelligence emerges from the interaction of an organism with its environment. This contrasts strongly with the traditional information-processing view, in which information from the senses is integrated into an internal model, then an action is planned and carried out (the sensing-thinking-acting approach). It has become common to use the term "behavior-based" to describe systems that use a non-information-processing scheme, as opposed to the classical knowledge-based approach. The *Senster* used just such a scheme. For instance, its control system did not try to sense where the visitors were standing, put their locations into an internal map, then choose how to move the body. Instead, the head would always turn to point in the direction of the predominant sound. An independent process would monitor the position sensors in the head. If the value of the position sensor stayed the same for long enough, the neck would turn in that direction. The full details of Ihnatowicz's implementation are currently being studied, particularly how the inputs from the microphones and the motion sensors were mediated.

Several racks of custom electronics interfaced the computer to the *Senster*. Again, we are fortunate that most of the circuit diagrams survive. There were eight hydraulic actuators in total (including the two in the head) and they were controlled in pairs so, essentially, there was one standard output circuit repeated four times. The following description is for one such circuit:

The output from the computer was latched as sixteen data bits (the input could also be set via manual switches, for testing). All sixteen bits were also taken to light bulbs for debugging purposes. The sixteen bits were split into two sets of five bits, which represented the next required position for an actuator, thus each joint had 32 (2^5) discrete positions. This was a very low position resolution but was overcome by the use of a circuit called the "predictor." Each set of five bits was passed to a digital-to-analogue converter and thence to the predictor. The predictor was a sophisticated arrangement of op-amps, which operated as a second-order low-pass filter, with a roll-off frequency set by a circuit called the "acceleration splitter," fed by three spare bits from the latch, via another digital-to-analogue converter. This circuit distributed an analogue voltage, with a resolution of 8 (2^3), to the predictor circuits, which altered their roll-off frequencies. It basically set the time by which all the joints were to reach the next set positions, so that they all arrived at the same time, to make the movement look natural. There were two separate acceleration splitters: one for the hydraulics which moved the microphones and another for the joints in the rest of the structure, thus the microphones could flick quickly, while the main structure moved at a more sedate pace. The predictor smoothed the analogue voltage output so that it followed a spline-like curve. (The computer was not fast enough to generate smooth motion in real time, hence the use of analogue circuits.) The output from the predictor circuit was fed to a hydraulic servo system, so that the actuators followed the analogue voltage in a proportional way. The predictor was one of the critical parts of the *Senster*'s control system because it was what made the movement look very natural. It is examined in more detail below.

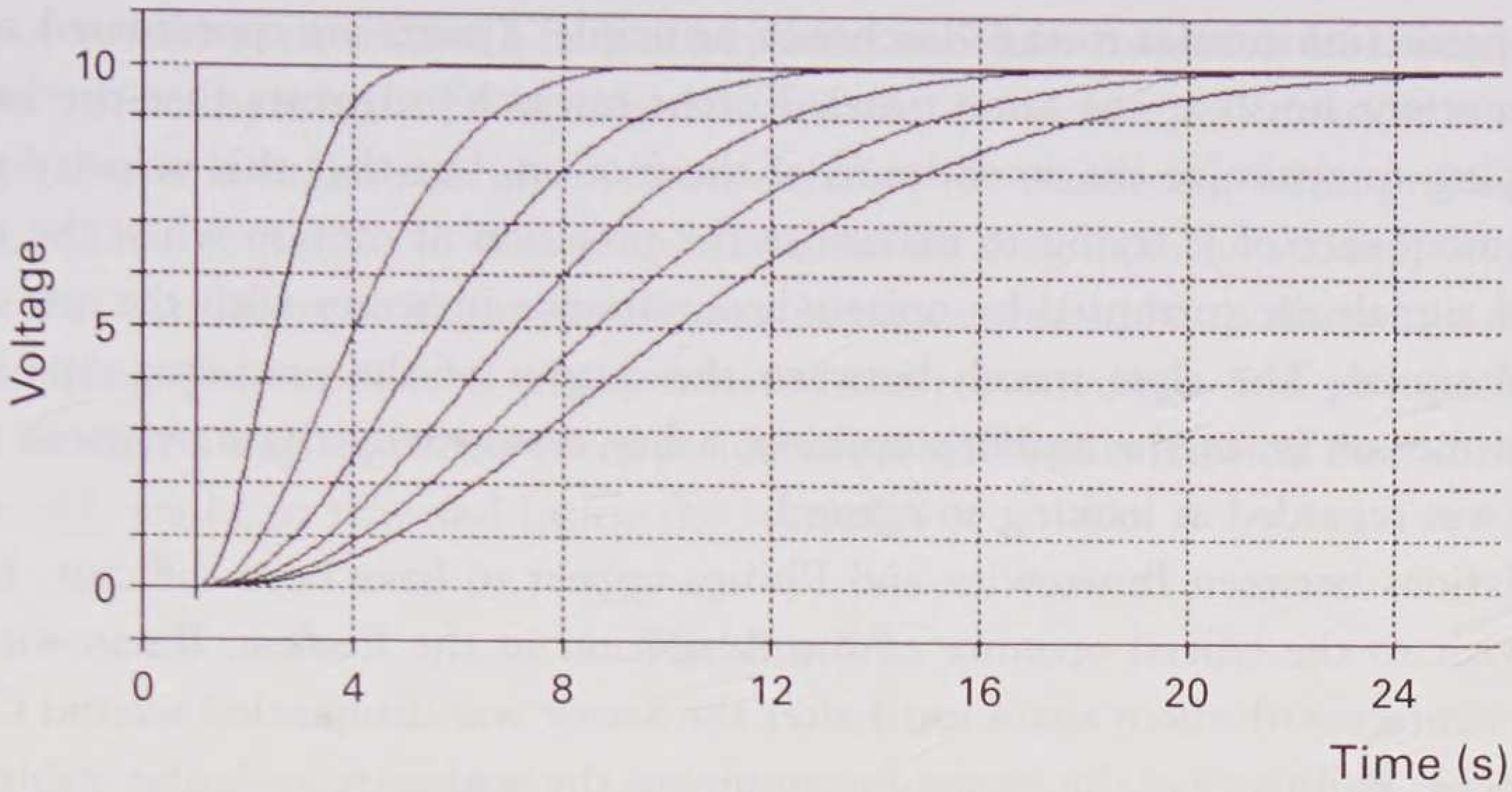

Figure 8.4 Output from the predictor circuit of the *Senster*.

Fortunately, the circuit diagram for the predictor survives and was simulated using SPICE, a standard circuit simulation software package. Figure 8.4 shows the output of the circuit. At time = 1s, the output from the computer goes through a step change from 0 to 10V. The predictor smoothes out the transition, so that the motion of the robot joint starts and stops smoothly. The different curves illustrate the effect of changing the value output by the acceleration splitter, the length of time for motion to be completed may be varied.

Ihnatowicz said:

> I tried to make its movements efficient. In the process of doing that, I discovered that animals, when they perform competent movements, are extremely efficient, and my machine looked animal like, even though I did not try to copy animal movement.[5]

The most efficient (least expenditure of energy) motion can be shown to be when the velocity has a parabolic profile. The actual shape produced by the predictor circuit (the derivative of the spline-like curves shown in figure 8.4) is not this ideal: it is asymmetrical (the peak velocity occurs before the half-way point) and bell-shaped. Later studies of human motion showed that this is very similar to what is observed in biological systems.[6]

Work presented in Flash and Hogan[7] showed that this characteristic bell-shaped graph is consistent with the smoothest possible trajectory (minimizing the rate of change of acceleration over the entire movement). This "minimum-jerk" trajectory model successfully predicts a number of features observed in human motion[8]: invariance of trajectories under translation and rotation in the workspace, scaling of trajectories with time and amplitude, temporal coupling between curvature and speed, and a prediction similar to the "isochrony principle" (joints are coordinated so that their motions finish at the same time). Recent research[9] suggests that the brain is not trying to optimize the smoothness of the motion, but that this velocity profile is a consequence of it trying to maximize the precision of motion when the neural control signals are corrupted by noise whose variance increases with the size of the control signal. The close match between the output of the predictor circuit and human motion is, in the author's opinion, a key reason why the movement of the *Senster* was regarded as looking so natural.

Relations between Ihnatowicz and Philips appear to have been difficult. Except for a visit to the official opening of the exhibition in the *Evoluon*, Ihnatowicz was not in contact with them again until after the *Senster* was dismantled around Christmas 1973. Philips gave the reason for removing the sculpture as "unfavorable publicity" they had been receiving. According to Ihnatowicz, "the bad publicity was due to the fact the machine was not in fact performing as intended, its programme having been severely degraded in order not to cause too much excitement and noise."

It is not known what happened to the computer, but the electronics system was given away to local electronics enthusiasts, and the mechanical structure was given to an engineering firm who had done some structural work on the *Senster*. One of their employees recognized the historical significance of the artwork and the company eventually set it up in front of their premises, where it remains to this day. On his return from Holland, Ihnatowicz was invited to join the staff of the Mechanical Engineering Department of University College London as a research assistant. He wanted to explore artificial intelligence, in part because, when observing the *Senster* and knowing just how simple the controlling program was, he "felt like a fraud and resolved that any future monster of mine would be more genuinely intelligent." He found it disconcerting that "people kept referring to it as an intelligent thing, but there wasn't an iota of intelligence in it: it was a completely pre-programmed responding system."[10]

He believed that he could make his next machine more intelligent by simply consulting the right people in the artificial intelligence fraternity about the correct programs to use in these circumstances. He soon discovered that "those involved with AI concerned themselves with completely different problems, or at least that their methods, and especially the criteria they applied, had very little relevance to my problems."

He decided to do some research of his own into AI and arrived at two conclusions: that mechanical movement was the only means by which we could establish the presence of any would-be mental activity; and that while the concept of intelligence remained as elusive as ever, the notion of perception seemed as important and perhaps more manageable. He believed that "perception, like mechanical motion, must, of necessity, constitute a part of any form of behavior and can be thought of as the mechanism by which the sensory data arriving from the eyes or ears or any other type of sensor is organized into a form suitable for producing an appropriate response." That response, in the simple systems he was looking at, was invariably some form of motion; so the immediate problem seemed to be to discover a method of describing the two sets of phenomena: visual patterns, say, and physical movement, in such a way that their correspondence, which was a physical fact in the outside world, could be reflected inside the system.

The *Bandit*

Ihnatowicz felt that he needed to understand more about the nature of mechanical information and decided to concentrate on that. He helped supervise a PhD student, suggesting a project to develop a hydraulically operated lever equipped with pressure sensors. Connected to a computer, this system could be made to move or exert pressure against a variety of objects. In this manner he hoped something could be discovered about their mechanical characteristics.

Being connected to a computer, the arm was capable of operating in two modes: in the position mode it would move to a specified position with a prescribed velocity, largely without regard to any encountered resistance; in pressure mode it would exert a specified pressure against whatever object it encountered. If the specified pressure was zero, it would become completely passive and compliant.

In 1973 the Computer Arts Society (CAS) staged an exhibition on the fringes of the Edinburgh Festival and asked Ihnatowicz to contribute. The arm was all that he felt he could show, so, together with the student, he turned it into an exhibit, with financial assistance from CAS. The arm was made to operate in both position and pressure mode and people were invited to move it in any way they liked. When compliant, the computer would store the movements the person made and then play them back in position mode. The different ways in which people reacted when the arm suddenly took over were analyzed by a statistical program that was capable of distinguishing between sexes and of classifying people according to their temperament (e.g., MALE, TIMID). The results were printed on a teleprompter and were surprisingly accurate. It was called the *Bandit*, after the one-armed bandits of Las Vegas, which it vaguely resembled.

The *Bandit* was, however, a little beside the point as far as Ihnatowicz's main interest was concerned. He was forming an idea that perception ought to relate to objects rather than events; that it ought to enable the system to distinguish between itself and the outside world. He felt that a very important distinction should be made between what could be called non-dimensional sensing, that is, awareness of changes in some stimulus like pressure, noise, or light, which have a magnitude but no direction; and the type of perception that could enable the system or animal to determine the shape, size, position, or direction of motion of other objects as well as of itself. The *Bandit*, having only one actuator, could deal only with magnitudes, so another moveable segment was added to it, similarly instrumented and forming, in effect, an elbow. The new device was reorientated so that the tip moved horizontally, parallel to the surface of a table, which could be placed beneath it. He devised an experiment in which the arm could be made to run along a piece of metal placed on the table, and the computer could record such runs and deduce the angle at which the piece had been placed from the relative velocities of the two rotating joints.

Further research into robotics was thwarted by a lack of funding. Ihnatowicz left UCL in 1986 to set up his own company: IMA (Industrial Microcomputer Applications). He installed an Io Research Pluto system featuring Designer Paint and Designer 3D, which was largely developed by Andy Wray who worked closely with Ihnatowicz when he was a research student at UCL. The package was mainly used for modelling, illustration, and animation. He received some commissions, particularly for advertising and portraits. He also produced control programs for small computers in engineering and small-scale factory automation. He was unable to complete any more cybernetic sculptures before his death of a heart attack in October 1988.

The Artist as Engineer

Ihnatowicz always regarded himself as an artist (he described his occupation as "cybernetic sculptor") but he was multitalented and ready to teach himself anything necessary to develop his ideas, no matter how difficult or technical. He maintained that art and technology had always been closely linked, quoting Leonardo and Michelangelo. Indeed, David Pye (on the basis of his experience in training industrial designers) observed that one who "is capable of invention as an artist is commonly capable also of useful invention."[11]

In many ways, Ihnatowicz's approach was closer to engineering than to conventional art, a point that was not lost on him—he was writing a book about his work entitled "Portrait of the Artist as Engineer" when he died. Indeed, the similarity between art and engineering has been noted elsewhere, particularly by Eugene S. Ferguson:

> Most engineers today are happy to be called scientists but resist being called artists. Art, as it is understood in engineering schools, is effete, marginal and perhaps useless. It is a "soft" subject, lacking the rigor of the hard sciences and the supposed objectivity of engineering.
>
> Yet engineers' drawings, whether made with pencils and pens on a drawing board or with an electronic cursor on a computer screen, share important characteristics with the drawings

> and paintings of artists. Both the engineer and the artist start with a blank page. Each will transfer to it the vision in his mind's eye. The choices made by artists as they construct their pictures may appear to be quite arbitrary, but those choices are guided by the goal of transmitting their visions, complete with insights and meaning, to other minds. And an artist, other than a particularly anarchic one, generally follows rules implicit in a particular period and a specific style or school.
>
> The engineer's goal of producing a drawing of a device—a machine or structure or system—may seem to rule out most if not all arbitrary choices. Yet engineering design is surprisingly open-ended. A goal may be reached by many, many different paths, some of which are better than others, but none of which is in all respects the one best way.
>
> Design engineers have recourse to analytical calculations to assist them in making decisions, but the number of decisions that are based on intuition, a sense of fitness, and personal preference made in the course of working out a particular design is probably equal to the number of artists' decisions that engineers call arbitrary, whimsical and undisciplined.[12]

Ihnatowicz's work could be said to have had little influence on his artistic contemporaries; no comparable work was produced for about two decades. The engineering skills required of the artist, complexity of the devices, sheer cost of construction, and necessity of ongoing maintenance were major barriers to the development of similar works.

It is the author's opinion (from anecdotal evidence) that Ihnatowicz influenced robotics and AI researchers far more than artists. Much of his work explored concepts in artificial intelligence, particularly the link between perception and intelligence. He was working at the height of "hard AI": the idea that programs that could solve abstract problems, prove theorems, or play chess would somehow result in intelligent robots. As Rolf Pfeifer and Christian Scheier state:

> By the mid-1980s, researchers from artificial intelligence, computer science, brain and cognitive science, and psychology had realized that perhaps the idea of computers as intelligent machines was misguided. The brain does not run "programs": It does something entirely different. But what is it? Evolutionary theory teaches us that the brain has evolved not to do mathematical proofs, but to control behavior, to ensure our survival. The researchers from these various disciplines agreed that intelligence always manifests itself in behavior and that we must understand the behavior. If an organism does not behave, does not do anything in the real world, how would we ever know whether it possesses any kind of intelligence or not? At the very least, the organism, the animal, the person, the machine must make sounds, change the environment in some ways, move, draw something, produce signs that can be interpreted by others.[13]

This concept has come to be known as "embodied intelligence." For an agent to have intelligence, it must have a physical body and it must be able to interact with the environment, because it is only through interaction that the agent can acquire knowledge about the environment. Ihnatowicz explored exactly these ideas two decades before people such as Rodney Brooks at MIT finally broke the dominance of traditional AI with these concepts. In particular he argued that "in order for any system, natural or artificial, to be able to deduce anything at all about any object simply by looking at it, it must first be able, or must have been able in the past, to interact with it in some mechanical way. Moreover, only those aspects of the object which can be modified by such actions can ever be successfully interpreted."

It could be argued that Ihnatowicz achieved so much in this field (after all, the *Senster* was a successful embodied, behavior-based robot) years ahead of his time precisely because he was an artist rather than an engineer or scientist. He was unfettered by the accepted notion of machine intelligence; he achieved the goals he set himself by his own process of artistic exploration.

Notes

1. The quotations from Ihnatowicz's notebooks are from unpublished papers in the artist's estate.

2. Jasia Reichardt, "Art at Large," *New Scientist* (May 4, 1972).

3. Automated systems operate under open or closed loop control. In open loop control, the command is carried out irrespective of the consequences. In closed loop control, the system monitors the outcome of the command using a sensor (obtains feedback) and takes appropriate action if the target is not being met.

4. Donald Michie and Rory Johnston, *The Creative Computer: Machine Intelligence and Human Knowledge* (Harmondsworth, UK: Viking Press, 1984).

5. Reichardt, "Art at Large."

6. Christopher G. Atkeson and John M. Hollerbach, "Kinematic Features of Unrestrained Vertical Arm Movements," *Journal of Neuroscience* 5, no. 9 (1985): 2318–2330.

7. Tamar Flash and Neville Hogan, "The Coordination of Arm Movements: An Experimentally Confirmed Mathematical Model," *Journal of Neuroscience* 5, no. 7 (1985): 1688–1703.

8. Ibid.

9. Christopher M. Harris and Daniel M. Wolpert, "Signal-Dependent Noise Determines Motor Planning," *Nature* 394 (August 20, 1998).

10. Brian Reffin Smith, *Soft Computing: Art and Design* (N. Reading, MA: Addison-Wesley, 1984), 147–155.

11. David Pye, *The Nature and Aesthetics of Design* (Cambridge, MA: MIT Press 1978), 65.

12. Eugene S. Ferguson, *Engineering and the Mind's Eye* (Cambridge, MA: MIT Press, 1992), 23.

13. Rolf Pfeifer and Christian Scheier, *Understanding Intelligence* (Cambridge, MA: MIT Press, 1999), xii.

9

Forty Is a Dangerous Age: A Memoir of Edward Ihnatowicz

Richard Ihnatowicz

When my father, Edward Ihnatowicz, was about to reach the dangerous age of forty, he left home and went to live in a garage in Hackney in order to devote his time fully to sculpture. So began the happiest and most productive period of his life. I was in my teens, about to start working for O-level examinations, but his leaving wasn't entirely a shock. In many ways it was something of a relief and the marker of a new beginning for all of us.

What he did was of course unusual, but at the time it seemed quite normal to me. He was, after all, my dad, and he made sculpture. He also painted and drew and made all kinds of things: a radio, a pair of corduroy trousers, furniture. He could mend cars, weld and work wrought iron, sail a yacht, and he had been a professional photographer. He loved movies, was a good bridge player, and enjoyed chess. He could lay bricks and plumb lead pipes with a blowlamp and wet rags. But then so could a few others that I knew. Self-reliance was forced upon many during World War II. Although he did not consider himself to be a mathematician, Ed was fascinated by math and was always reading about it. He never went anywhere without a slide rule and owned one of the first pocket calculators when they became available.

So the move from Raynes Park to Hackney, although it seemed like to the other side of the Earth, had a certain logic to it, and to my friends it also had a great deal of existential romance, glamour, and drama. They saw Ed as an exciting role model. We were all reading Jack Kerouac and Henry Miller at that time, and somehow Hackney took on the allure of Paris, the Rive Gauche, existentialism, and *La Bohème*.

The reality was a little different. The garage was on the end of a terrace of houses on Ufton Road. It had no heating or lavatory. Ed had to use the outside toilet of the house on the end (as did his many visitors). There was a sink with running water, a large rectangular one usually piled high with pots and pans waiting to be washed. (Ed was lazy about washing up and waited until it was absolutely necessary before doing it.) There was no bath or shower. He cooked on an electric stove of the Baby Belling type, mostly from tins since there was no refrigerator. The garage could be bitterly cold, but he said he had known worse. At least there were no rats, and you didn't have to break ice to wash, although he did complain that his modelling clay got so cold it hurt his hands. He slept in a sleeping bag on a sprung mattress. *La Bohème*, perhaps, but not the Rive Gauche.

I remember the smells. Mild steel has a particular smell, as does acetylene. One wall of the garage was ranged with wrought iron brackets, which held a large supply of grimy steel rods of various thicknesses. Oxygen and acetylene bottles stood in a corner just inside the door. Electric arc welding also leaves a certain odor in the air, together with the tins of flux that attracted so much dust. Another smell came from the tin cans holding the milky looking stuff for cooling drill bits. Sometimes there was the strong smell of solder and hot plastic insulation. Other times it was plaster of Paris or hot wax and wet sand. He built a kiln for firing clay, and in the garden behind the garage, he fixed up a furnace with a crucible for smelting aluminium. I'm sure many of these things would now be illegal, if not even then. It was all fabulously dangerous.

During school holidays I often helped Ed with the jobs he took to pay the rent. My hands were always grimy and hurt from small cuts and puncture wounds from bits of steel, from burns from welding, or from touching things too soon after drilling or sawing. Arc welding made holes in your socks so Ed always wore fireman's boots. The soap in the sink added to the smell. Usually it had bits of metal and other debris embedded in it, which made washing hazardous. Often all Ed could afford for our lunch was soup made from a stock cube and a small tin of pate, spread on crackers. The Beatles hit "Help!" was frequently on the radio at the time, so, for me, Knorr stock cubes and the Beatles are inexorably linked.

Once a week, on Friday nights, we would go to a local spit and sawdust pub for a half of bitter, watch a local pop band, and eye up the local talent, all bathed in the then-fashionable ultra violet light. We seldom stayed more than an hour, after which I would go home to Raynes Park where I lived with my mother.

Ed was fascinated by the grace and beauty of wildlife in motion. He would watch seagulls for ages, admiring the efficiency of their flight. The garage had lots of pigeons around, and Ed would film them on an old wind-up 8mm camera. He had a little hand-operated viewer to watch the results. Their wing beats, especially in slow motion, were another source of inspiration. The piece of film that prompted Ed's move into cybernetic sculpture was shot in London Zoo. It is of a lioness that briefly turned to look at the camera and looked away again, totally disinterested. I remember Ed saying what an impact it would make if a piece of sculpture did that as you came to look at it. And so, from that little germ grew the *Senster*, via *SAM*.

SAM

Ed always thought movement was a perfectly logical development in sculpture, although he was familiar with randomness as a mathematical concept and knew about the computing ramifications of trying to generate random numbers. However, the random movement of mobile sculpture made in the early part of the twentieth century, where movement was the result of wind or water and in some cases light or heat, while important and of its time, did not satisfy him. *SAM* (*Sound Activated Mobile*) came into being as a result of an experiment unconnected with sculpture. A dentist friend expressed the need for a chair in which he could move his patients more freely than hitherto. Ed had used a pair of aluminium joints, one that was vertically articulated and another that rotated from side to side. The movement was quite small, but by replicating the pair the end result was a much wider range of movement. The movement came from hydraulic pistons. He carved the first models in wood. They were cast in aluminum and then machined to fit the bearings and hydraulics. Finally they were polished by hand using carborundum powder. The chair was never made, but Ed was very happy with the model spine. I don't know when exactly his "Eureka" moment came, but when it did come it changed his life forever. He realized that he had the basis for a sculpture that would not only move like no other, twisting and turning, but if it could "hear" the spectator, he could engineer it to turn and face them. Imagine his joy. He designed a simple cross made from aluminium rods with a small microphone on each end. The four microphones each had a sound reflector behind. He combined the reflectors into a single fiberglass structure so that the whole resembled a flower or four-leaf clover. By comparing the volume of sound received in each microphone, the direction of the loudest sound could be determined, and *SAM* would turn to face it.

SAM was exhibited at the Institute of Contemporary Arts *Cybernetic Serendipity* exhibition in 1968, and was a great success. The reaction of the public was intensely satisfying for Ed. He loved to watch the different ways people interacted with *SAM* and was gratified that a photographer spent a morning taking pictures of the surprised and delighted faces of the spectators. But *SAM* kept breaking down because it wasn't very robust; I don't think Ed had expected so much interest, nor the resulting wear and tear. Nevertheless, artistically, he had crossed some kind of threshold and he must have felt a new confidence and sense of purpose. If it were ever needed, here was proof of his maxim that the way to "find yourself" is by "doing."

SAM was a relatively simple device with no computing power at all. It simply turned to face the strongest sound source. The movement was direct and clumsy. Ed wanted graceful movement, something that looked natural and animal-like, something that would look as though it had intelligence and moved for a reason.

His curiosity had been aroused, during a meal, by a lobster arm. Each joint can only move one way (one "degree of freedom") so the process of manipulating food from seabed to mouth is rather challenging. Ed built a wire-frame model to examine the problem in more detail, and he considered making the model move in much the same way as *SAM*. While he was working on the project, James Gardner introduced the Dutch electronics firm Philips to the idea of commissioning a large version of the model for their Evoluon building in Eindhoven. This piece would not only hear the spectator but sense movement as well—a lobster arm with a kind of eye. The name *Senster* was coined, representing half sensor, half monster.

Philips rented space in the thermodynamics lab of University College London, and the *Senster* was built there. When I left music college, Ed invited me to help on a part-time basis and I joined the team. Work had been underway for some time with the help of Salim Bukhari and one of UC's staff, Bill Gillham, who assisted with mechanical requirements and troubleshooting.

Ed liked to start early each morning in order to beat the traffic, but also because the computer took half an hour to boot up. Philips supplied the computer, which was the size of a small refrigerator but had only 8K of memory. All the programming was done via punched tape. Once the boot-up was started, we would go to a nearby café for coffee. On our return the tape had to be rewound for the next use using a dedicated winder. Quite typically for him, Ed had taught himself to program. There were no books then, only the Assembler code manual that came with the computer, which gave merely a brief description of each command, and so a lot of tape was wasted and a lot of coffee was drunk. Happy days.

The lab itself is like a long tunnel with offices along one side. The floor is made from aluminum sheeting that covers a lower level. The hydraulic compressor for the *Senster*'s hydraulic system was put on this lower level in a vain attempt to reduce noise. The lab could be very noisy indeed on occasions with jet engines occasionally being tested and other machinery left running for days on end. But the side offices, where we spent most of our time, were fairly well protected from the din. The ceiling was high but not so high that the *Senster* could not reach it. There is still a mark where the *Senster* flew out of control one day. I don't remember why, but it is worth noting here that the reason Ed needed such a noisy and powerful compressor was because to achieve graceful, controlled movement, great strength is required—ask any ballerina or concert pianist. To hold something steady that weighs the same as a small crane, after it has swished ten feet through the air, calls for a lot of hydraulic pressure, but not pressure alone; it also requires a predictor circuit. This is what I feel is the most interesting and significant technical detail of the *Senster*'s development. A number of current theories about intelligence suggest that one of the brain's mechanisms for dealing with the huge amount of sensory data received at any given moment is prediction. The super cortex doesn't scan every detail; it is being bombarded by information (feedback) from all the senses all the time. So it makes assumptions and predictions based on what it already knows, and it only takes notice if something changes and reacts accordingly. We all know what it's like if the bottom step of a staircase is an inch shorter than all the rest. Ed did not understand that fully at the time, but he realized that the *Senster* had to have some idea about when its arm was close to reaching its destination in order to slow down and not stop with a jerk, and also to react appropriately if new data arrived and a change of direction was needed. The predictor circuit was the single biggest challenge—it took the most time to develop and cost the most lost sleep of the entire project.

A mathematical genius, whom I knew only as "Stan," designed the predictor circuit. I had never met anyone like him. He was in his early to mid-twenties and considered himself "over the hill." He had serious doubts about being able to design the circuit at all, never mind to a high spec. No one, so far as we knew, had ever made such a thing. I cannot pretend to have understood the half of what he and Ed considered, but the effort of Stan's thinking was extraordinary. He seemed to be in pain much of the time. We built and tested many versions, and it could well have been an early version that caused the *Senster* to hit the ceiling that day.

This was a totally different world from music college. (For example, I had never imagined there could be whole books devoted entirely to screw-threads.) Transistors were relatively new back then, and the new buzzwords "gates" and "flip-flops" were part of the new, mystic language of computing that I found terribly exciting. I needed to use a low voltage soldering iron, which was another thing I'd never known existed before. Salim and I used to build test versions of the circuits using the kind of components usually associated with ham radio. If they worked, Ed sent off for printed circuit boards, which we then drilled and soldered in the necessary components. These boards were destined for the interface. They plugged into sockets that we mounted on a large metal frame. The reverse sides of the sockets were a mass of metal pins by which the boards were wired to the *Senster* and to the computer. We had a special "gun" to connect the wire to these pins. Although the work was pretty straightforward, in that I only had to follow circuit diagrams and assemble them, I still find it astonishing that the *Senster* actually worked. Ed confessed that if he had known in advance just how much work was involved in building the *Senster*, he probably never would have started.

The *Bandit*

I got married before the *Senster* was finished, and I had started to make my way as a musician. Although I continued to work at UC, sometimes I was away from London for extended periods and as a result, I never went to Holland and never saw the *Senster* in the Evoluon building. The success and ultimate sad end of the *Senster* is documented elsewhere and I don't want to enter the arena of recrimination that followed. Philips and Edward disagreed as to the exact reason, but as I see it, the exhibition management had not been prepared for the noisy reception given the *Senster* by the spectators, especially schoolchildren, so that when at some point the *Senster* broke down, they welcomed the relative peace that ensued. Although Ed agreed to go and effect repairs and maintenance, Philips did not take him up on his offer. Ed was deeply saddened by this and felt that no one at Philips really understood what a significant piece they had commissioned. They removed the *Senster* from the exhibition and left it outside where very little now remains. But Ed moved on. He returned to UC and worked in the robotics department as a postgraduate supervisor.

Originally the arm of a manipulator, the *Bandit* used a "test and compare" principle, not unlike the predictor circuit, to "guess" the sex of the spectator by shaking hands. The spectator would move the arm, which resembled a "one armed bandit," and the *Bandit* would respond. The next movement from the spectator would provide enough information for the *Bandit* to compute the sex of the user. It was correct about 90% of the time. Ed was amazed at the accuracy because the sample data were taken from a very small sample: three men and three women picked at random from the nearby offices at UC.

Facing Death

After he retired from UC, Ed began complaining about discomfort when eating, and finally his doctor agreed to let him undergo some tests. I remember phoning him from a call box in central London to find out the results and he said, in a resigned kind of way, "Yes, it is a cancer." He seemed to have been expecting it. He was not afraid of death and after an operation to remove a particularly vicious stomach cancer, he said that had he known how his quality of life would be affected, he would not have bothered going on with it. He died from a coronary not long after that. In the time between learning of the cancer and his death, he and I talked more than ever before. He was anxious to pass on as much information as he could, especially about computing, and he was very aware that his time was running out. We became closer than at any other time.

I feel sad that he was unable to attract the funding he desperately needed to continue his work, but he was years ahead of his time and only a very few enlightened people understood what the *Senster* heralded. It is only now, thirty years later, that many of the ideas about art and science that he toyed with are becoming widely circulated. He wished he had achieved more, but then that was also true of many other creative and visionary people as they neared the end of life. His real legacy is the example he set by always searching and being interested in everything. In our money-conscious society, his is a difficult example to follow.

10

From System to Software: Computer Programming and the Death of Constructivist Art

Richard Wright

Today we stand between a society that does not need us and one that does not yet exist.
—El Lissitzky, Theo Van Doesburg, and Hans Richter, *Statement by the International Faction of Constructivists (1922)*. Reprinted in *The Tradition of Constructivism* (Cambridge, MA: Da Capo Press, 1990)

History has not been kind to the constructivists. Unlike the other big hitters of the modern art movement, they have received what almost amounts to ridicule: the first artist geeks with their rulers and protractors, polishing their little Perspex maquettes and planning their rectangular utopias. One can still find artists who feel an affinity with surrealism's uncovering of the irrational, designers who take inspiration from cubism's fragmentation of space, or radical intellectuals who find a precedent in the anarchic interventions of Dada. But it seems as though constructivism has lost its relevance to British artists since the end of the 1970s. Its enthusiasm for science and engineering has been superseded by the rise of mass digital computing and telecommunications. In fact it feels as though constructivism has become a victim of a kind of success story. Many of constructivism's core values of collaborative working and research, of objective process as opposed to subjective meaning, and of deference to the machine as a source of artistic inspiration have now been absorbed into the assumptions of current new media art practices and funding strategies in the United Kingdom.

Constructivist art was an art built not on technology but on technique—on definable and reproducible creative acts. Its historical development has taken it through the machine aesthetic of the Russian pioneers, the semiotic systems of the post-war Germanic artists, the cybernetics of the English and North American groups, and finally to the conceptually minded systems artists of the 1970s who tried to capture and harness a single thought as the starting point for a constructive process. If we accept that this idea of the "programmatic"—the recasting of artistic work into an objective, reproducible discipline—was a central tenet in constructivism, then it is a little hard to see why the movement should have declined precisely at the point at which the "programmatic" seemed to reach its fullest potential for expression: the programming of the digital computer.

Why did constructivists find it so hard to switch from calculators and graph paper to BASIC and PCs? Was something lost when programmatic ways of working became wholly identified with the control structures of digital processing? Was there something in the wider context of the programmatic that did not readily transfer to computer programming—something that could now be recovered and used to refresh current software-based art practices that constantly struggle with the limited imagination of proprietary operating systems, desktop interfaces, and network protocols?

The First Rise and Fall of Constructivism

The constructive approach is an aesthetic and a technique comparable to montage as one of the main driving forces behind avant-garde art. Montage values fragmentation, conflict, the staccato rhythm of the machine and opposes continuity and organic unity. Construction values openness, clarity, and the structuring process in opposition to predetermined content, completeness, and individual subjectivity. Yet at various periods these very structuring principles have threatened to become a new form of idealized content, to close down the depth of its enquiry into a rigid functionalism or, in contrast, to lose direction altogether and become the generator of empty optical effects.

It was at the Congress of International Progressive Artists in Dusseldorf in 1922 that El Lissitsky, Theo Van Doesburg, and Hans Richter issued a joint statement in protest of its conservatism entitled "Statement by the International Faction of Constructivists." This was the first time that a central set of concerns were identified under the name of constructivism. Significant is the fact that it was signed by Lissitsky representing the functional Russian constructivists, Van Doesburg representing the aesthete de Stijl group, and Richter representing the dadaists. One passage in the statement sums up the basis of their shared interests succinctly: "We define the progressive artist as one who fights and rejects the tyranny of the subjective in art, as one whose work is not based on lyrical arbitrariness, as one who accepts the new principles of artistic creation—the systemization of the means of expression to produce results that are universally comprehensible."[1] Right here we can already see the close relation between order and chaos as existential phenomena of the objective world, and the root of a productive tension between construction and destruction, progressive constructivism and anarchic dadaism that formed the twin poles of modern art's new role in the world. At the same time, the phrase "systematisation of the means of expression" gives us the central technique by which the new movement would seek to exercise this role. Its artistic inspiration could be traced back to a work exhibited seven years previously in Petrograd: Vladimir Tatlin's sculpture known as the *Corner Counter Relief* of 1915. Tatlin's sculpture was both a development of Picasso's cubist fragmentation of space as an aesthetic and also an "opening up" of the previously unified technique of art-making into a series of manufacturing operations. In this work not only did he return to reality by including real industrial materials like synthetic cubism had; he also returned art to everyday activity by making it possible for the audience to discern how one might go about making one's own relief sculpture from bits of tin sheeting, wooden laminates, rods, and bolts. This explains an important sense in which a "systematisation of the means of expression" could lead to those "universally comprehensible" results—as though it were an IKEA flat pack wardrobe complete with instruction book and a set of allen keys.

Equally relevant in the *Corner Counter Relief* was Tatlin's decision to build the work across the corner of the exhibition space, a design that built it into a structural feature of its physical environment. It presaged a central ambition of the Russian avant-garde: to have their art recognized as both an aesthetic and a utilitarian contribution to the building of socialist society during the 1920s. Along with El Lissitsky and Alexander Rodchenko, Vladimir Tatlin labored to demonstrate a role for art whose aesthetic values were not above the sensibilities of the proletariat and the commissars, and whose awareness of constructive possibilities could guide the bureaucrats who were implementing social policy—to inspire the rebuilding of society through their "creative processing of practical materials," as the critic Boris Arvatov had put it.[2] But by 1922 their influence was already fading in the face of hardening attitudes to the conflicting aims of social engineering and artistic experimentation. Over the next ten years the Russian Constructivists were to learn that Soviet politics is about control, not experimentation. By the 1930s the avant-garde artists who had remained in Russia had been forced to turn their skills solely to the promotion of Soviet restructuring or else flee from the threat of the gulags.

Two Russians who had always remained skeptical that the social role of constructivism lay in its industrial utility were the brothers Naum Gabo and Antoine Pevsner. After publishing their aptly named "Realistic Manifesto" in 1922,[3] they both left Moscow, never to return. Gabo reached England in 1936 and with the encouragement of Ben Nicholson and Barbara Hepworth, married and settled for a while with a growing community of modern artists at St. Ives in Cornwall. Along with other émigrés like Moholy-Nagy and Piet Mondrian, Gabo exerted great influence in bringing to this backward country the ideas of abstraction in general and of constructivism in particular until he left for the United States after World War II.

Of particular significance for us in this early period is Gabo's seminal *Kinetic Sculpture* of 1920, consisting of nothing more than the shape made by a vibrating wire powered by an electric motor. This work expanded the constructivists' desire to open up the artwork in visual terms, yet at the same time introduced an apparent contradiction in technique that systematic art was to return to in various guises again and again. Through its rapid oscillations, a vertical wire generates the image of a "standing wave," a perceived physical space yet one without physical mass or solid boundary. At once this work was able to demonstrate not only the dependence of physical form on structure, time, and motion, but also its construction as an intangible image in the mind of the observer. Yet this was not pursued by Gabo, who quickly returned to static constructions and the engineering of industrial materials. He described his reasons for pulling back from the further employment of electronics and machines in an article for *Circle: International Survey of Constructivist Art* in 1937. He spoke of his fear of "killing through mechanical parts the pure sculptural content"[4] as though the point of his constructivism had to be what could be expressed through the visual form of the entire work. For Gabo, a kinetic sculpture would at least have to be separated from the distracting appearance of its underlying engine, cogs, coils, and capacitors. Unlike the open construction of Tatlin's reliefs, Gabo just could not see how you could open up the construction of things like electric motors and still meet the aims of an art based on the visual knowledge of physical forces. A bunch of electrical parts soldered together just did not express anything. It was the first recorded instance of what would later become known as the black box syndrome.

Programming before Computers

The influence of the constructivist refugees in England did not come to full fruition until after World War II. It began in 1948 when Victor Pasmore, a successful figurative painter, shocked his patrons by announcing his complete conversion to abstraction. In contrast to other forms of abstraction, which were based on abstracting from the visual appearance of the natural world, Pasmore emphasized an art that originated at the level of abstract creation itself. Later in 1967 he wrote of this need to search for a new artistic premise "concentrating on the nature of objects and processes as 'things in themselves' whether they be a sheet of paper, a blot of colour, the mark of a tool, the movement of the hand or the motion of a machine."[5] Pasmore meant this art to be founded not on the idealized meaning of visual elements as religiously motivated artists like Piet Mondrian and the Christian Scientist Ben Nich-

Figure 10.1 Mary Martin working on maquettes for *Tidal Movements,* 1960. Courtesy Annely Juda Fine Art, London. Copyright the Estate of Mary Martin.

olson had intended, but "existentially" on the properties of material things and "what they may become." The surest way to rid non-materialistic illusions from one's art was to reject the plastic idealism of the flat surface entirely, and Pasmore added his voice to the call to turn to the physical reality of the constructed relief.

By 1951 Pasmore had been joined by artists such as Kenneth and Mary Martin (figure 10.1), Adrian Heath, and a young ex-student of Pasmore named Anthony Hill. Straight away they felt the need to differentiate themselves from the concerns of the previous generation by calling themselves "Constructionists." They were not engineers like Gabo nor were they believers in the pure emotional qualities of pictorial form like Mondrian's neo-plasticism or Malevich's suprematism. It was during this search for a new direction and identity that the young Anthony Hill emerged as the chief theorist of the group and started corresponding with three very different influences from outside these shores: the Swiss concrete artist Max Bill, the

American structuralist Charles Biederman, and the spiritual father of conceptualism Marcel Duchamp.

In 1948 Charles Biederman self-published his magnum opus, *Art as the Evolution of Visual Knowledge.*[6] Biederman presented the history of art as the history of the analysis of the natural world in visual terms. The main turning point in this history was in 1917 when Piet Mondrian painted the first full geometrical abstraction. This achievement was the signal that artists could now turn their attention away from the appearance of nature and toward the "structural process level of nature." "In the past the artist 'imitated' the RESULTS of nature-art; today the new artist 'imitates' the METHODS of nature-art."[7] But like Tatlin before him, Biederman's preferred methods were actually quite intuitive, as he believed that mathematical approaches were idealist and would cut off creative development from the external inspiration of nature. In fact what Biederman really meant by "visual knowledge" was a form of realism in the tradition of Leonardo da Vinci, a perception informed by scientific knowledge and directed toward a communion with the natural world.

Eventually Biederman's identification of objective processes with processes "natural" in origin proved to be an artificial and restrictive distinction. Anthony Hill considered the theoretical products of abstract logic to be just as real as anything in nature and became drawn to the mathematical work of the Swiss concrete artists Max Bill and Richard Lohse. Their use of mathematics had moved away from the metrical relationships and geometrical proportions of the pre-war period to a level that was no longer tied to the visual world. "The mathematical approach in contemporary art is not mathematics in itself. . . . It is primarily a use of processes of logical thought towards the plastic of rhythms and relationships."[8] It was this that gave the Swiss artists the theoretical justification to move from constructed reliefs back to painting. An intangible mathematical object has as much validity in two dimensions as in three.

During the 1950s Hill began thinking in terms of three materialities in art: the physical properties of the art object itself (which formed the raw materials for early constructivists), its perceptual properties (which underscored the aims of Van Doesburg's neo-plasticism), and something he called its "thematics of construction."[9] By taking a definition of mathematics as the "theoretical phenomenology of structure,"[10] Hill sought to find a new place for an abstract formal language in art by fusing it into the structural process of creative thought itself, including the artist's physical and perceptual sensibilities.

If we look at two works produced during this period we can see some of the ways in which Anthony Hill and his contemporaries developed the role of rational methods and paved the way for the subsequent generation of English constructivists. In 1954 Hill painted *Orthogonal/Diagonal Composition.* It consisted of a four by two arrangement of white squares with the alternate squares separated by thick black orthogonal lines and criss-crossed by thick black diagonal lines. This austere looking grid betrayed none of the classical concerns for harmony and balance that Mondrian strove for; it simply was what it was. Later, Hill cited Duchamp as an influence in this work in that it could be described as a "geometrical readymade."[11] For Hill, this work represented the appropriation of a mathematical object for an artistic purpose. Unlike Duchamp's urinals, mathematical objects have no sensory existence in themselves. Yet although they are primarily theoretical objects, a square tessellation seemed to have at least a historical reliance on visual perception, as when the Greeks first studied them in geometrical diagrams to prove their theorems. After all, if no one had ever drawn a square, would it still have been possible to imagine one in purely theoretical terms? The square's visual instantiation had been necessary to the development of mathematical thought even though its visual properties had since come to be seen as derived from mathematical structure.

In *Prime Rhythms*, a low monochrome relief constructed in 1958, Hill had moved away from the mathematical object as such and toward mathematical "themes." By "theme," Hill was referring not to the subject of the work but to its starting point at the level of formative structural processes. In this particular work, Hill took all the prime numbers less than one hundred as his "thematic idea" and used them in a succession of what he termed "structural modifications."[12] This consisted of operations such as throwing out all the even numbers, selecting only consecutive primes, and then a whole myriad of systematic procedures based on "distribution, deviation and density ratios, equalities and inequalities."[13] These were always derived with reference to the visual properties of the relief, such as the use of planar intervals in order to embed the sequence in the form of two sets of horizontal bands. It is clear that during the making of this work Hill developed quite an appetite for and familiarity with the pattern of primeness, yet he was at pains to point out that the work was not about the prime numbers as such. It was simply about what you saw when you looked at the relief, a particular visual rhythm, prime numbers forming the "idea in the work as opposed to the idea of the work."[14] Regarding the significance of the procedures that he applied to this idea, he said, "Certainly other procedures could have been found to achieve the same sort of end, but the satisfaction of the one chosen lies for me in the fact that it had to be worked on and did not involve chance or 'aesthetic trial and error' at every level, nor did it carry with it some notion of finite ideal order."[15] It was in this way of working on objectively defined qualities and operations that Hill and others were developing a practice that began to remove the distinction between visual invention and mathematical investigations.

In the early 1960s Hill began a second career as a mathematician, publishing the results of his research in mathematical journals. During the early 1970s he was an honorary research fellow in the Mathematics Department at University College London. By this time he had moved away from classical quantitative math to qualitative ideas like topology and graph theory as employed in works like *The Nine—Hommage á Khlebnikov* of 1976. At each stage in the development of his relief sculptures, aesthetic judgments were allowed to favor the direction taken. It was not simply that Hill chose the most attractive option resulting from a set of mathematical permutations, but that he adjusted the perceptual properties of the work with reference to mathematical ideas in order to achieve a bodily perception of their spatial structure. His works were not like the result of running a program (not even an interactive program that relies on being steered by choosing from pre-selected options); nor were they like the visualization of a program through its decomposition into a series of discrete graphic elements like an elaborate flow chart. They were more the result of a mathematical logic or thematic structure being articulated or realized by applying the varied refractions of different visual or sensory logics.

It is useful to compare Hill with his contemporary, Kenneth Martin. Although each artist worked with an entirely different set of thematics, they both found ways to absorb systematic techniques into every pore of their creative thinking. Whereas Hill started with the theoretical structures of math, Martin started with movement. During the 1950s Martin started to produce a series of *Screw Mobiles* and *Transformables* that were made by applying sequences of transformations to simple metal objects—typically bars, rings, and rods. The resulting sculptures exhibited the spatial displacements he applied by shifting and rotating them, twisting, expanding, and contracting them in the form of a progressive series. Rings and bars might first be positioned in such a way that their relationship defined a set of possible actions or measured intervals. Sometimes the movements they defined could be described and replaced by the shape of a parabolic band. Sometimes the descent of a ring was replaced by a cylindrical extrusion or rod. The effect of forces like gravity to roll or oscillate objects when suspended was noted. These domains of movement were repeatedly exercised, transcribed, ordered by number sequences, transformed into shapes, and then re-examined for the next stage of development.

Instead of concentrating on what kinds of rational structures could be used in the constructive process, Martin tried to structure the process itself by recasting each stage as one of a series of rhythmic changes. In this sense his approach was more general than Hill's. "To be interested in the kinetic," said Martin, "is to be consciously interested in sensation as such, for not only is form-making a corollary of movement, but so are sensation and feeling."[16] It was as though he was trying to choreograph, as they happened, all the shifts and unfoldings that his mind, body, and senses went through over the course of a creative enterprise. For Martin the kinetic experience was in the practice itself, and he was therefore able to express movement without having to engineer actual movement, thus removing the necessity for any of Gabo's hated "mechanical parts." Although he described his analogue methods as programmed transformations, it would be as difficult for us to appreciate

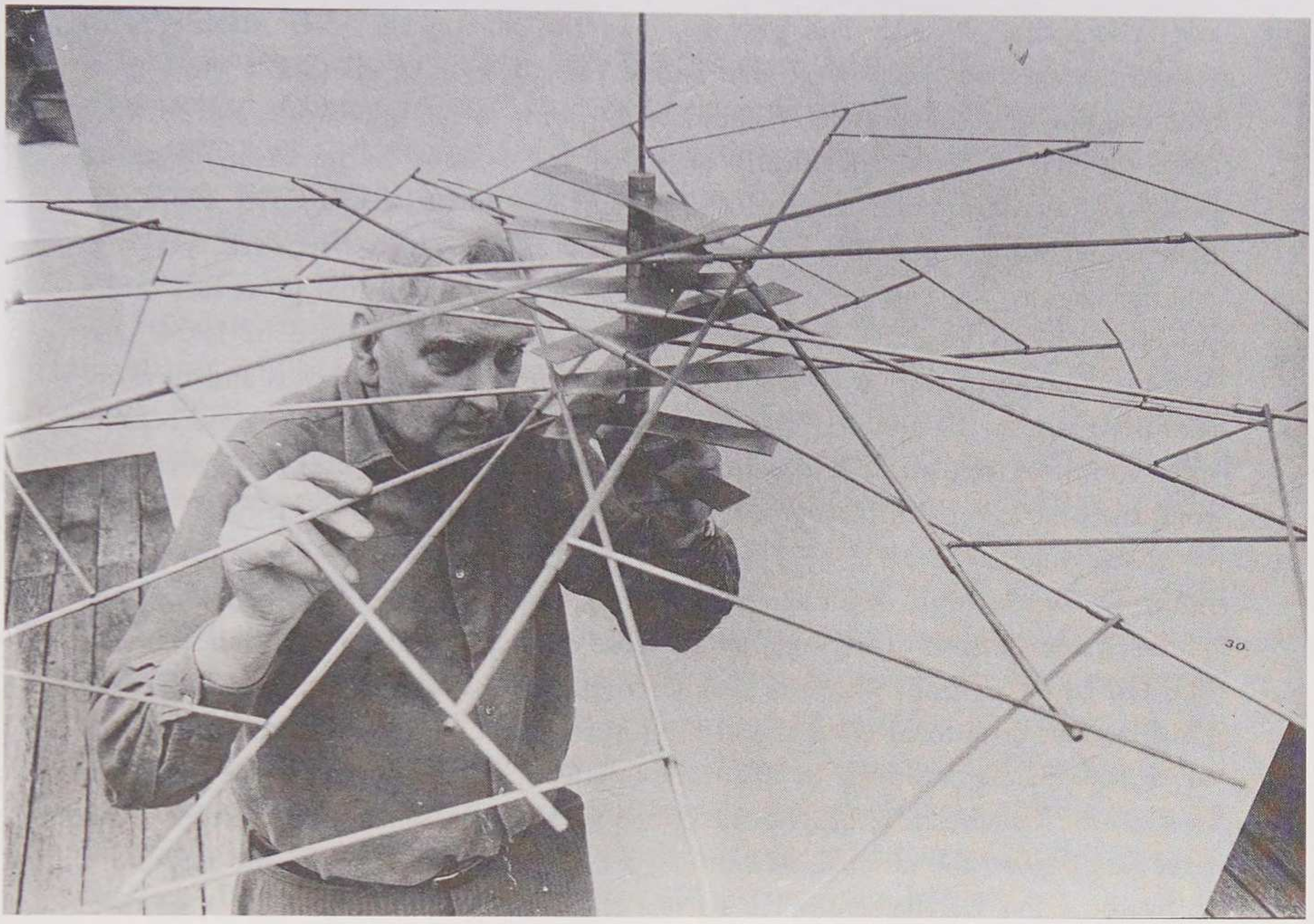

Figure 10.2 Kenneth Martin with *Screw Mobile,* 1967. Courtesy Annely Juda Fine Art, London. Copyright the Estate of Kenneth Martin.

today as if you tried to write a computer program by notating the progress of leaves falling from a tree in a storm. They were programmed in the sense that "a logic and a counter-logic are set in operation and the results are accepted," as his wife Mary Martin stated.[17] Furthermore, because his transformations were his own acts rather than machine executions, the experiential difference in making the work would be similar to that of climbing a mountain versus taking the cable car (figure 10.2).

Wild Systems

In 1969 the former op art painter Jeffrey Steele founded the Systems Group, including John Ernest, Gillian Wise, Malcolm Hughes, Jean Spencer, Michael Kidner, and several others. Many of the previous generation of artists like Hill and Martin associated with Systems as it continued many of their aims, yet now with a more conscious emphasis on the constructive process itself as much as the resultant work. As they took advantage of the new techniques provided by post-war mathematics and cybernetics, the scale and complexity of the systems they were dealing with started to escalate and prompted new issues. The question of whether it was important that the underlying system should be apparent in the final work, and in what sense the system could realistically be called the content of the work, began to be asked more and more. Artists like Hill and Martin had managed to avoid this issue by retaining a closeness between their different levels of systematic working. Another way to prevent the work splitting between a conceptual procedure and a perceptual result was to follow what Kenneth Martin had advised in 1964, that "construction must start with the simplest and most practical means and to avoid confusion aim at the simplest results."[18] But as the power of formal logic became more and more sophisticated and prolific, there was mounting pressure to move beyond the processing abilities with which the human mind could keep up.

As the different levels of materiality that could exist as a single system began to multiply—knowledge, documentation, feeling, perception—it become a challenge to the Systems artists to tie together all these different bodies. For instance, artists like Gillian Wise and Malcolm Hughes thought it could be revealing to make visualizations of rational systems and use intuitive "feeling" to help make new discoveries about them. Similar in technique to later applications of computer graphics in scientific visualization, Hughes described "a relatively unexplored intuitive creative area beyond the rational, where unexpected linkages are sensed and responded to by the mind via the senses."[19] To test this idea, John Ernest made a series of sculptures based on modelling the mathematical Möbius strip. Hoping to make interesting discoveries about the relevance of its topological properties to the concrete world, he instead realized that the sculptures' properties as physical objects far outstripped their status as theoretical aids. Instead of the sculptures having a representational correspondence to a mathematical object, they were more accurately the result of the "action" of a mathematical idea upon a physical material. The Systems artists realized that they were already beyond traditional modes of representational art or scientific modelling that relied on the consistent relation of ideas, objects, and sensations.

The Systems Group made a serious effort to compile their discoveries into a collective body of research. They often exhibited working drawings and notes alongside finished pieces to draw attention to "the course of the investigation."[20] In 1978 Steele noticed that one could collate and edit this material into substantial documents that had as much significance as the paintings. Other artists such as Jean Spencer thought it possible to design a work in such a way that it completely documented itself: "It is possible to display all permutations within a particular configuration of grids, and through the complete series reveal the nature of the system."[21] It might even be possible to recover the original system from an analysis of the work. But as the systems of construction strained to become more complex and abstruse, this looked increasingly impractical. The theorist Stephen Bann noted that the system that one sees when one looks at these works might not be the one that created it but might have a separate character formed by its visual qualities; "the system of the work is not necessarily the systematic procedure that determined its creation, any more than the biographical details of the process of fabrication can be said to establish the way in which the work will affect the spectator emotionally."[22]

Some artists like Steele now pushed ahead in the direction of what we now recognize as a fully materialist "generative" art practice, including a renewed acceptance of the irrational. Constructivism had originally had a close relationship with Dada through figures like Theo Van Doesburg. Its attitude to chance as an objective phenomenon was summed up in works such as Hans Arp's famous collage of 1917, *According to the Laws of Chance*, produced by tearing up pieces of paper and letting them flutter down onto his canvas like drops of rain. In 1972 Steele reformulated this interest in the unpredictable to fit their program of enquiry—"To grasp the full extent and power of systems entails giving as much attention to chance, deranged, anarchic systems as to those with a more manifest regard for law and order."[23] Steele suggested that they start building "deranged" systems that would function in place of subjective motivations and personal significances. By examining the kinds of information that these systems could generate they might find a way to test or validate them, not for their truth value or meaning but for their productive capacities, as engines of chaotically fertile invention. Systems could now be freed to move beyond human categories of order and disorder. To try to constrain them to the production of comfortable human meaning would be as pointless as "trying to communicate by signals with an intelligence on another planet with whom we have no common experience and therefore nothing to communicate about."[24]

While some artists wanted to stand back and give the system more room to grow, others worried that this would weaken the practice of retaining a close personal proximity between the artist and the system during the course of its unfolding. There arose a danger that the system would disconnect from the artist altogether, becoming a completely autonomous machine. An overview of the situation was provided by Kenneth Martin in 1968 when he divided systematic work into three types.[25] First, there was the completely predefined system that, once set in motion, could generate work independently of any further artistic input—what we now usually refer to as generative art. Second, there was the system that, while initially predefined, was constantly altered through feedback, coming into contact with other systems, etc.—the program is thereby written in conjunction with the work itself. Third, there is the system that builds up from a primary act without any previous planning, like a self-propelled aggregation of logical steps—the writing of the program is indistinguishable from the practice itself. Martin himself thought that the second category would hold the most for the artist because "the act of programming will be in operation throughout the whole progress of the work."[26] For artists like Colin Jones, a continuous relation between the artist and his system was also paramount for a process of discovery to take place; the system would be modified during the course of the construction of the work and would therefore allow a "continual meditation (by the artist) on the possibilities of connections."[27] For Martin, the more the system is predetermined like the first example, the more problematic things become, not just because of the marginalization of the artist but because of the system's distance from the specificity of any given situation—"it is difficult to predetermine a system for forms whose properties one is in the way of discovering."[28] What is at stake here is how one can be expected to work with a form of logic without the direct motivation and stimulus of the object of that logic, such as its material consequences or its physical or historical situation. One is inventing a process, not just a program. It is this awareness of trying to retain a purchase on formal systems as the computer made them more and more autonomous that would become an increasingly pressing concern.

Program, Be Programmed, or Fade Away

The neo-constructivists of the post-war period had often referred to their methods as a form of "programming." Yet despite the mounting complexity of their programs and the opportunities for practical implementation afforded by computer programming, most Systems artists continued with rulers and graph paper. Later Systems artists like Tony Longson became keen programmers and Malcolm Hughes went on to found the Experimental and Electronic Art Department at the Slade School of Fine Art, becoming a hub of activity for a new generation of computer artists in the late 1970s. But there are reasons for the reticence of the others, even apart from the fact that several confessed to finding the discipline of programming beyond their abilities.

To begin with, formal programming languages made it difficult to mix together different kinds of logic. Everything had to be reduced to and encoded in the same terms. The programmer had to formulate his or her task in algorithmic terms, type in a large body of text that imposed some very unforgiving rules of syntax, and then painstakingly debug the whole thing. Constructivists were by this time used to switching freely between different number systems, geometries, topologies, and all sorts of methods on the informal basis of what was suggested to them by exercising their shiny Perspex tiles and exploring the plastic possibilities of the picture plane. To have to find a way to translate an act as fundamental as a shift in one's mental focus into Cartesian coordinates and conditional statements sounded stifling. Programming offered them little more than the ability to calculate various permutations and combinations of elements that were relevant to only a part of their overall practice.

The constructivists were used to identifying their systems with the concrete actions, matter, and sensations that had inspired them. Jean Spencer had stated that "a system cannot be taken out of the context it originated in."[29] The making of a constructed relief was derived from structuring processes like molding, resistance, mass, occlusion, and the acting of rational operations upon them. Even if these physical qualities could be simulated through operating computer software, the systems' functioning would not be linked directly to the manipulation of the source materials but would be a limited abstraction of their assumed potentialities. It was not that the constructivists reliance on tangible processes gave them systems that were superior or more useful than those of formal logic; the inclusion of physical and analogue systems gave them a richer perspective on the whole formative process. Computer programming might have universal potentialities in theory but this very freedom could become problematic. When objects are digitally defined one must approach their potentialities from some point of interest in order to avoid becoming lost in them, as Kenneth Martin had hinted. When one is modelling the properties of physical metal rods and rings in a computer simulation, one can model any properties in any way one likes but a particular method must be chosen. And once that decision is made, the rods and rings themselves tend to be lost as sources of procedural insight. What, then, the constructivists might have asked, can take their place?

Some artists did try to use techniques such as interactive sculpture to make computer programming part of a wider system of human behavior and cognition with some success, such as Edward Ihnatowicz's famous *Senster* sculpture of 1970. The more complicated these constructions became with all their logical, electronic, and mechanical components, the more they began to suffer from Gabo's "black box" problem of sculptural clumsiness and functional inscrutability. Norman White's 1977 piece, *Facing Out, Laying Low*, used photo-electric cells to detect light patterns and emit tones. Describing himself as "an artist of logic,"[30] White hoped that it would be simple enough for visitors to be able to work out its principles by performing little experiments on it and testing its responses. He also encased all the electronic circuitry in transparent Perspex to encourage users' enquiry into its functioning. The programs that controlled these sculptures still remained invisible, yet the sculptures were clearly not representational pieces that communicated an underlying coded idea. But they could not offer the audience a completely open construction either and instead moved toward explicating themselves as effects.

It should have been possible to put software into the mix of a wider practice of systematic art. But computer programming is a jealous mistress. From the beginning of the 1980s, the pressure was on to standardize all aspects of computing for mass consumption, and moving all possible functions into software was a cheap and flexible way of achieving that. Software would now automate all possible operations. Instead of seeing manual dexterity and gesture as a way to structure process, interaction was reduced to the input of parameters or a direct mapping onto pixel values, as in "electronic painting."[31] These tendencies were reinforced by the development of interface models and stabilized by the menu lists, parameters sliders, and icons of the modern windowing environment. The computing environment become more and more oriented toward electronic forms of display, individual workstations, and the standard computer lab provided by university learning resources. By the middle of the 1980s computer-based art was largely produced on desktop boxes and consumed through desktop boxes. It was hard for many artists to find much enthusiasm for a visual space that was increasingly colonized by unsympathetic interests.

Through the increasing dominance of structured programming styles, the computer began to absorb all systematic means of expression, encoding them into macros, object classes, libraries, data types, and file formats, categorizing and separating them out into myriad sets of structural elements. The granularization of the creative process into logical decision making impeded its natural flow. The more intimate one gets with coding the more narrow one's practice threatens to become due to the kind of expertise required—having to relate to each proprietary component of a system through its technical specification rather than its technical potential. The Systems artists could not use the intimate physical and perceptual qualities they were used to as a basis for their investigations in programming languages, and this lack of bearings threatened to turn the unfettered formal power of computer logic into a blizzard of arbitrarily designed information ordered only by contingent commercial agendas. Some of these issues had been foreseen by the neo-constructivists as early as the 1960s as they attempted to structure each nuance of their working process with greater and greater exactitude. The Systems artist Gillian Wise had written, "Working with a concrete form with discipline . . . leaves one more conscious of the irrational or non-rational element in taking decisions, and, in making very precise choices, the range of possibilities often seems overwhelming."[32]

Yet some artists were willing to throw themselves into the maelstrom and take on the strictures of the code. In 1978 the computer artists based at Malcolm Hughes's Experimental and Electronic Art Department published a catalogue of their recent graphics and sound work with the help of Jean Spencer. *Working Information* featured pieces including Chris Briscoe's generative audio, Darrell Viner's animations, and plotted graphics by Peter Beyls.[33] The following year there was a student show, *EXP at P.C.L.*, featuring Paul Brown's computer simulations, Stephen Bell's interactive graphics, and perceptual studies by Dominic Boreham.[34] Visually the work was more formally sophisticated and texturally richer than previous Systems work, but most striking was the sheer quantity of graphics and audio that was now being produced; it approached a continuous torrent of sensory data.

This was the most obvious change in programmatic art as it entered the 1980s—it came to be about images. Jagged lines were anti-aliased, planes were shaded, spline curves were smoothed out. The increasing continuity of the visual surface now possible in computer graphics made it difficult for the resulting image to retain an identifiable connection to the program that generated it. But in the period between this loss of representational function and the move toward visualization there lies a certain form of numerical image that asks to be accounted for. This is the kind of image that flourished in SIGGRAPH art shows, IMAGINA conferences, and glossy coffee table books like *The Beauty of Fractals*.[28] In order to construct this kind of image, data was "grabbed" or "captured," plotted, extrapolated, extruded, and massaged by dozens of algorithms, then ray-traced, smooth-shaded, and printed by the Cibachrome method. This image was the result of collections of different systematic components yet without following any actual system; it was guided instead by executive opportunism, scientific curiosity, engineering prowess, and artistic confusion. For some viewers the reaction was to impute to it a symbolic content, becoming a sign for technology without telling them anything about it. For others it seemed to float free from liabilities and significations entirely, its strident visual qualities standing alone for its raison d'etre. It is this lack of connecting that made the numerical image another factor in the alienation of the artist programmer.

By the early 1980s, the older paradigms of cybernetics and ecology were outstripped by the more internal issues of modelling, representation, and meaning. As if in rehearsal for the conversion of the bureaucratic society into the information society that would occur over the next twenty years, computer artists turned from the original resolution of the post-war English constructivists not to abstract from the world to a perverse version of Biederman's realism. This time they were not abstracting from the "structural process" level of nature but were implementing and mixing different models of nature—not so much with the aim of gaining knowledge of nature but as a way of giving a direction to the formal freedom the computer had unleashed. Scientific models were hacked until they contributed only the required operational components, a montage of physical laws, mathematical calibrations, and logical grammars. Biederman's realism had returned as a formalism. By mimicking a set of realistic styles and conventions, computer art could create a familiar reference for its arbitrary generative power. It was now a matter of systems modelling other systems and becoming increasingly rarefied.[36]

The work of Harold Cohen is a good example of this search for a new basis for the constructive process under the absolutism of code. In the mid-1970s Cohen decided to give up his career as a successful painter and turn to programming full time. His aim was to reproduce his practice as a painter using artificial intelligence techniques. He wrote a program called AARON, which could control a small device to paint simple marks, fill in shapes, sketch textures. Cohen sought to recreate himself as an "expert system," using a model of artmaking as a process of cognitive development. He built up a series of programming functions that could construct a plausible painted image from scratch. Yet in the end the project failed in its original objective—it was not possible to tell from the image what was the cognitive function any particular element.[37] The program was in fact more the simulation of markmaking, a Turing test for painting. This was the new performative mode of knowledge, a behavioral technique that produces the required results but without any explanatory value. Cohen had succeeded in substituting the inexplicable psychic volitions of the artist for the empty performance of the simulation. Instead of remaining so resolutely humancentric in his focus, Cohen could have taken advantage of this discovery and recast human drawing as a subset of machine drawing thereby allowing us a much wider perspective on drawing's possibilities (a tactic that Jeffrey Steele might have approved of). Machine logic undermines subjectivity, knowledge, and authenticity by copying them, but without offering an alternative to those categories the power to copy and to manipulate that copy then becomes equally as dominant. Because it never found this wider context, Cohen's work, which had at first functioned as an effective critique of artistic subjectivity, had by the 1980s paradoxically reinforced the new anthropomorphic and metaphorical approach of the desktop interface design as the default strategy.

The Systems artists were well aware of the tradition in constructivism of applying aesthetic inventions outside of the domain of art, most commonly to that of architecture. But with the possibilities of using the computer's instrumentality closed to them, their insights led them into a practice that was both more ambitious and more introverted. When considering the lack of a suitable route for the social diffusion of their ideas, Jeffrey Steele lamented in 1978 that "this particular function remains symbolic and the present social use of this art is mainly critical and didactic."[38] This painted them into a difficult corner, for constructivist artists were also ideologically constructive—progressive and utopian, they believed that it was the destiny of artists to make a contribution to advance society's well-being. In contrast, the rising force of conceptual systems artists like Sol LeWitt and Adrian Piper were more openly critical and oppositional, self-reflexive and increasingly ironic. English constructivists like Roy Ascott and Stephen Willats, who were closer to this conceptual approach, survived better, able to adapt their practices to a wider range of technological and discursive contexts. So too did the computer artists, who, instead of architecture, eventually found a practical outlet that could support their hunger for complexity and scale in the form of television and the advertising industry. But for the Systems constructivists, there was nowhere left to go. Unlike the conceptualists, they were still resolutely visual artists, yet unlike the computer artists their intimacy with and erudition concerning "the system" was usually too great to allow a recalcitrant machine to come between them.

The System of Software

It was the Internet that finally recreated the computer as a mass medium and brought with it a new technology, a new audience and a new system: the network. Since the conduits of society had been replaced and restructured using the fiber optics and ADSL of information technology, programming could more fully become the subject of a systematic art as well as its technology. Everyone now has to use software to work, to communicate, to spend their leisure time. By the end of the 1990s this shift was finally recognized in the emergence of "software art." The formation of subjectivity and social relations were now within the domain of software-encoded exchanges.[39] For this reason software art has seen itself within the tradition of media art or conceptual art rather than the progeny of constructivism. Computer art has acted as the engine of this historical transition yet without passing on its aesthetic agenda.

But this mass integration of computing has also brought mass normalization—the homogeneity in patterns of usage, streamlined design templates, reductive interface models, and restrictions in access to information. Whereas during the final years of the twentieth century these forces were the subject of conflict and critique, within a few short years they had settled into universally accepted strictures of browser navigation, digital rights management, search engines, and the standardization of object-oriented functionality.[40] To oppose these edifices much faith has been put in practices like Free/Libre/Open Source Software (FLOSS), yet without a creative agenda its main achievement to date has been the LINUX development platform for an audience conditioned to expect free imitations of Microsoft applications. In the art world the dominant aesthetic of conceptualism is also ill-equipped to deal with the demands of software culture. The success of software and software art is dependent on the material contingencies of its deployment and perception, not on an appreciation of the idea behind it. Its extreme sensitivity to "look and feel" and other unforeseen consequences of actual use makes it impossible to decide what is or is not essential to the purposes of the concept. We have now gotten to the point where critics evaluate software-based art by reading press releases, without looking at or engaging with it directly, despite the fact that as software it is uniquely accessible for being experienced or applied in a wide variety of day-to-day situations. Like conceptual artists, government-sponsored agencies and corporations use code to construct social reality in isolation from the full implications of that reality. And the means by which that code is itself constructed through the discipline of software engineering is also guided by standards designed to achieve industrial and commercial efficiency.

The systems of the 1970s were about process; computer programming was about control. Software is about fitting in, observing standards, listening to the message queue, relinquishing control over context. Under these conditions, where does the artist's system end and the computer's begin? The proliferation of materialities—codes, interfaces, platforms, and output devices—creates confusion about where the focus of our attention should lie and how to keep the construction open under such conditions. As Christiane Paul wrote in 2002, "While every art form may be processed and mediated in one way or another, it usually does not constitute a fusion of fundamentally different 'materialities' . . . as software art does."[41] Yet fused they are, and it is in the tracing of the passages and leaks between these levels that the art of the system now lies.

Conclusions

The systems artists were the last programmers before the digital computer, the machine made that practice synonymous with its own functioning. Through their intimate proximity to the many varieties of order, it was as though they trained themselves to act creatively like a species of computer, internalizing procedural patterns and abstract logic, and running them on their own wetware. They absorbed the programmatic into the very core of their thought processes until the logic of series, modularity, and permutation became an indistinguishable part of their perceptions and sensibilities. But for an audience, the work could be as inscrutable as the most introspective of subjective art, as though each work were in a private programming language, emphatic yet utterly remote, produced by "an intelligence on another planet."[42] At times the Systems artists seemed half-paralyzed by the struggle to wrest every decision from the guardianship of order without resorting to the blindness of subjective intention. Theirs became a hermetic practice, a faint reminder of a kind of deliberate psychic objectification that has not been seen for hundreds of years, perhaps since the alchemists of the pre-Enlightenment era identified their own subjective inflections with the drama of chemical experiments. This is why Anthony Hill once described himself as a solipsist. Like an adept, Systems art required a mental attunement to a discipline of thinking that was largely limited to a process of personal development for the artists themselves.

Without the ability to share and disseminate their techniques more widely and without an external context for their work that was familiar to their audience, the Systems artists' diversification of the "programmatic" turned in on itself. It might have helped to return to the constructivist tradition of looking outwards and seeking a concrete effect in the external world. It is exactly this practical process of testing, deployment, and dissemination that is now easier for software-based artists due to its integration into the technocratic infrastructure.

Constructivists did retain a belief in the power of aesthetic and sensory perception to make a significant contribution to knowledge beyond the theoretical or cognitive. "Precise feeling" can tackle problems that reason cannot formulate.[43] And Systems artists in particular integrated formal language into creative thought to the degree that an artist can reclaim the rational as part of a more heterogeneous intuitive practice. There is now a fresh desire among artists to open up the wider expressive potential of formal logic and abstract machines beyond the atrophied state of software, to make code directly perceptible, embodied, affective. Can a systematic means of expression bring the operations of modern software within the human distance that the Systems artists enjoyed, yet retain a relevance to the complexities of the networked society? Can we use the wider range of expressive means that are now available in digital media to get this kind of practice out of the artists' heads? It is at this point in history that the problem of how discursive categories arise from computation, of how conceptual structures and mathematical themes might be realized in a form that has a relevance for the uninitiated might become more tractable.

Acknowledgment

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Notes

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11

Reconfiguring

Harold Cohen

This part of a much longer story begins in September 1968. It was just days after I'd arrived at UC San Diego, where I had gone for a one-year visiting professorship—a visit that did not end, in fact, when I finally retired from teaching a few years ago. I was showing some silkscreen prints I had brought with me to the chair of the Visual Arts Department, Paul Brach. "Hey," he said, "I should introduce you to this kid in the music department who's into computers. He could help you do some new stuff."

Computers? Evidently he thought he had seen something in the prints that prompted the remark; this was odd, considering that neither of us had a clue about what computers could, or should, be able to contribute to artmaking, and that neither of us could have called to mind a single example of an artwork made with a computer.

Computers? Sure, why not?

The next day a scruffy individual with a recorder poking out of his back pocket walked in while I was talking to Brach again. Jeff Raskin was a graduate student, apparently having completed a master's degree in computer science from somewhere back east. "You two should get together," said Brach, "famous artist, crack programmer . . ."

"I'm not doing anything for you," said Raskin.

"Don't recall asking you to," I said.

"On the other hand," he said, "I could teach you to program, then you could do everything for yourself."

"Sounds okay," I said.

"When d'you want to start?" he said, looking kind of dubious.

"How about tomorrow morning?" I said.

And so it began. Raskin's goal in life—self-proclaimed, with recorder accompaniment—was to teach programming to everyone in the world except computer scientists. But he'd never really thought through what teaching programming required and he proved to be less than inspiring as a teacher. For six weeks he talked flowcharts, flowcharts, nothing but flowcharts. Then one day, having perhaps come to the end of what he had to say about flowcharts, he walked me over to the campus's computing center, a bedlam of clanking card punches and strange machines (the purposes of which I could not begin to guess), and not a computer in sight. He handed me a duplicated manuscript. The cover page said "DITRAN Manual." He mumbled something about my being ready to start, and left. DITRAN was, apparently, a helpfully diagnostic version of FORTRAN, the programming language spoken by the university's computer, which, I soon discovered, lived in its large air-conditioned sanctum away from the damaging fingers of ordinary folk, tended by a staff of high priests and temple servants.

I opened the manual. I could not understand a word.

Was I going to be defeated by this gibberish, having endured six weeks of flowcharts? I came close. But I knew I had to give it my best try. I took the manual home with me. I resolved to read it slowly, sentence by sentence, and not move on until I was sure I'd understood each sentence, even if I had to read it a dozen times (as I did). I'd clinch my understanding by writing out the sentence in my notebook. I started around eight o'clock that evening. Understanding began to dawn as the sun rose on the next day.

FORTRAN was the language of serious people, physicists and the like. It came with an impressive collection of subroutines for doing mysterious things like Fast Fourier Transforms—I never did discover what they were—and various graphing functions, but not a one for making images of a more general kind that might have something to offer an artist. Which was hardly surprising; I was the first artist ever to have set foot inside the place.

This was well before computing became interactive, and this computer, a CDC 3200, ran in "batch" mode. You used the card-punch machines to punch your program onto IBM cards, one line to each card, and then you handed your entire deck of cards over a desk to an operator, who would feed them through a card reader into the computer, along with everybody else's cards. There was little chance you would get any results the same day and when you went back the next day, hoping for a printout that would indicate forward progress, what you would get, more often than not in my own case, was a cryptic message saying there was a missing semi-colon on card seventy-three.

Computers were supposed to be smart, I thought. If the damn thing knew there was a missing semi-colon, why didn't it put one in for itself? Most of the messages were a good deal more obscure than this one, however, and the high priests, the consultants, were there to tell you what they meant.

"What is wrong with my program?"

"Well, to begin with, you're an idiot who should really leave the computer to smart people who have serious reasons for using it." No, it wasn't usually delivered in so unadorned a fashion, but that always seemed to be the underlying message. There was one time when I called to make an appointment, but on my arrival found the consultant in question about to go off to lunch with a friend. She turned to the friend and said, loudly enough for everyone in the room to hear, "Oh, I can't go yet; there's some idiot coming over from the art department."

"How do you know?" I said.

"How do I know what?" she said.

"How do you know he's an idiot?" I said.

The truth was that the high priests were mostly graduate students in a department called Applied Physics and Information Science—the campus did not even have a computer science department at that time—and their expertise was, probably, more in the performance than in the substance of their jobs. This was all new stuff to them, just as it was to their congregation; we were all flying by the seats of our pants. All the same, there was no missing the priesthood aspect of the performance; they Knew Something; they were on the Inside; they were on a different plane from all the Ordinary People on the Outside.

What with slow turnaround, unhelpful high priests, and my own stupidity, it could often take days to accomplish something one could do now in a couple of minutes. Then I discovered the night people, who only showed up at the center late in the evening, when almost everybody else had gone home and you could submit a job and get the output in a few minutes. That was the way to go, obviously. And in joining the night people I found that I, too, acquired a little status. I got to know some of the operators and was even allowed into the computer room once or twice. The only graphic output device, a Calcomp plotter, was kept there. I doubt it ever produced anything but graphs until I came along and I think the operators must have been intrigued by the odd "freehand" shapes my programming efforts were producing. I cannot recall that I ever had any serious reason for being allowed in.

It must have been during this period that the center switched from magnetic tape storage—the room was lined with tape drives—to disks, because I remember seeing the drives shortly after they'd been installed. They were enormous; like washing machines topped by stacks of platters about two feet across, with inches of space between the platters, all open to the air and to the folded up newspapers the operators would ram between the rotating disks to clean the surfaces when—as I guessed happened with some frequency—they got an error report from one of the drives.

"Computers?" I'd said, "Sure, why not?" The truth is that any sensible person could have found plenty of reasons why not. From all outward appearances computers seemed to have nothing at all to do with art; there were no prior examples, to speak of, to indicate otherwise. My new colleagues in the art department clearly thought I'd taken leave of my senses and—without a doubt—my reputation as a painter. The friendly physicists I'd meet among the night people thought I should be interested in fractals and who knew what else: interestingness seemed to be a universal, context-free quality to them and all drawings that weren't graphs were equivalent. Even the flimsy, almost transparent paper used by the Calcomp plotter held little promise as an exhibitable medium until I figured out how to laminate it to heavy watercolor paper and color the drawings by hand.

Why was I doing it? I could not have said why I was doing it. It is only recently that I've come to see how it all followed from what had gone before; that it might almost have been predicted if I'd been paying attention. Not because I was aware of computers before 1968, but because, at least four years previously, I'd become fixated on the idea that one could shift the burden of invention from the individual painting to rules that would allow the painting to paint itself, so to speak. All the paintings I showed in the *Venice Biennale* of 1966 were made by following my own predetermined rules. That was long before I knew there were languages in which such rules could be written and environments in which they could play themselves out without human intervention.

By early 1969, I was beginning to see that working in the computer center had a couple of serious limitations, both of which had to do with finding a suitable format for exhibiting. The physical output could be framed and hung, as drawings had always been framed and hung, but that, I thought, would be missing the *wholeness* of the enterprise. I wanted the audiences to be aware of how the physical output came to exist, and the first step to that goal, I thought, was for them to see the work actually being made. I could not cart the university's central computer off with me to a gallery somewhere—this was many years before the Internet would allow me to use it remotely—and, even at the computer center, I would never have been allowed to attach an output device more suitable to my needs than the Calcomp plotter, not that I had any idea how to go about building one.

Obviously I needed a computer of my own.

The University's research committee came up with money for me to buy one. For ten thousand dollars I got one of the very first "mini-computers" to hit the market, the original Nova machine, made by a startup company, Data General; it had a little console panel that flashed address and data lights above a string of switches. It had all of eight kilobytes of internal memory and used punched paper tape for mass storage. The pretty flashing lights and switches weren't there for decoration, of course. Before there were higher level language compilers, the standard way of running a program was to enter it in machine code—instruction by instruction, address by address—on the console switches. But things were moving forward and there was now an alternative to machine code: BASIC. It had to be loaded from paper tape, with the tape reader running at ten characters per second.

It was not exactly how one thinks of computing today! Yet I was able to build my first drawing machine as an output device and did several exhibitions with this gear, including one at the Los Angeles County Museum.

By this time it was becoming clear that I'd involved myself in a capital-intensive medium and I thought I'd better see about trying to find some support. I'd heard that one or two artists had somehow won after-hours visiting privileges to a couple of IBM facilities, so when I was in New York and was introduced to an IBM vice president at a party one night I was happy to take him up on an invitation to visit him at Armonk and make my case at top level.

A couple of weeks later, I found myself in his office—rosewood paneled, deeply carpeted—in Armonk. "Okay," he said, after I'd refreshed his memory about what I was doing, "I think that falls in George's area. Let's go see George."

George listened to my tale and reflected that this was really something to take up with Hector. So the three of us went off to visit with Hector. Hector pronounced himself extremely interested in what I'd told him, but this was, without a doubt, something in Harry's area.

By the end of an hour or so I was being accompanied down the long carpeted corridors by half a dozen IBM vice presidents, on our way to meet Charles. Charles listened to my story with a stony face. "Sounds like an expensive way to make art," he said.

My vice-presidential entourage rose as one. They all shook my hand in turn. "How nice to meet you, Professor Cohen," they said. "Good luck with your project."

Since private patronage was not looking promising, I tried my hand at writing a grant proposal, this one to the National Science Foundation. I mailed off the required thirty-six copies and waited patiently for a response. It came eventually: no grant, but included was a selection of comments made by some of the external reviewers to whom the proposal had been sent. "How can Professor Cohen learn Fortran?" asked one. "He's an artist." Since it should have been clear to anyone actually reading the proposal that Professor Cohen had *already* learned Fortran, and a couple of other languages besides, evidently there was a sizeable problem of cultural stereotypes to be overcome. Could I overcome it singlehanded? It seemed unlikely. I concluded that if I had to choose between doing the work and finding money, then I'd be better employed doing the work.

Several years later, by which time my program, AARON, had won a measure of attention within the AI community and I'd given invited papers on my work at a couple of international conferences, I was persuaded by a friend Who Knew Such Things that it would be smart to visit Washington and talk directly to the program officer who would handle any new proposal I might want to submit. I told him about this early response and he said, "Are you still programming in Fortran?" (Groan.) "I never programmed in Fortran," I said. He looked sort of blank.

I did, eventually, write a second proposal. My son Paul, by that time a professor of computer science and a master grant-proposal-writer, helped me write it. "Can't lose," he said. "Want to bet?" I said.

That first NSF proposal was not a total loss, however. One review copy was sent to Ed Feigenbaum, a professor of computer science at Stanford University, who apparently responded that it was one of the best proposals he'd read. Ed flew down to San Diego to meet me; to check out, no doubt, that I was who and what I claimed to be: not one of the art-and-technology guys looking for a tame technologist to do the hard stuff for him, but an artist who believed in doing the hard stuff for himself. One whose thoughts, unclear as they were, might well find resolution in Ed's own community.

The result of the visit was an invitation to come up to Stanford to work at the Artificial Intelligence Lab. By this time I'd been at UC San Diego long enough to have accrued some sabbatical leave and this was obviously too good an opportunity to be missed. I spent two years at Stanford, commuting weekly back to San Diego during the second year to do my teaching.

Life at the AI Lab was very different from anything I'd experienced previously. The single PDP 10 was shared by the entire population of faculty and graduate students—maybe thirty or forty in all. The system crashed from time to time and we would play ping-pong for an hour while the gurus figured out what the problem was. Whenever a LISP user ran a big job the system slowed to a crawl. But this was a different world from batch-processing and a very different community of users. Some worked all day; some worked all night; some slept behind the computer and never went home. The utopianism of the enterprise was palpable; we all shared a vision of a world in which computers would be central, an unshakable faith in the rightness of what we were doing.

Once a week or so I'd have a meeting with Ed Feigenbaum, tell him what I was doing, and take note of his advice. After the first year, which I spent at the AI Lab, I transferred my affiliation to Ed's own Heuristic Programming Project, working remotely on a different system located in the medical school. By the time that second year ended and I returned to San Diego, the computer revolution was out in the open and well under way. I had previously judged the progress of this revolution by the number of people I'd hear talking about computers in restaurants. That did not work any longer; people in restaurants weren't talking about anything else.

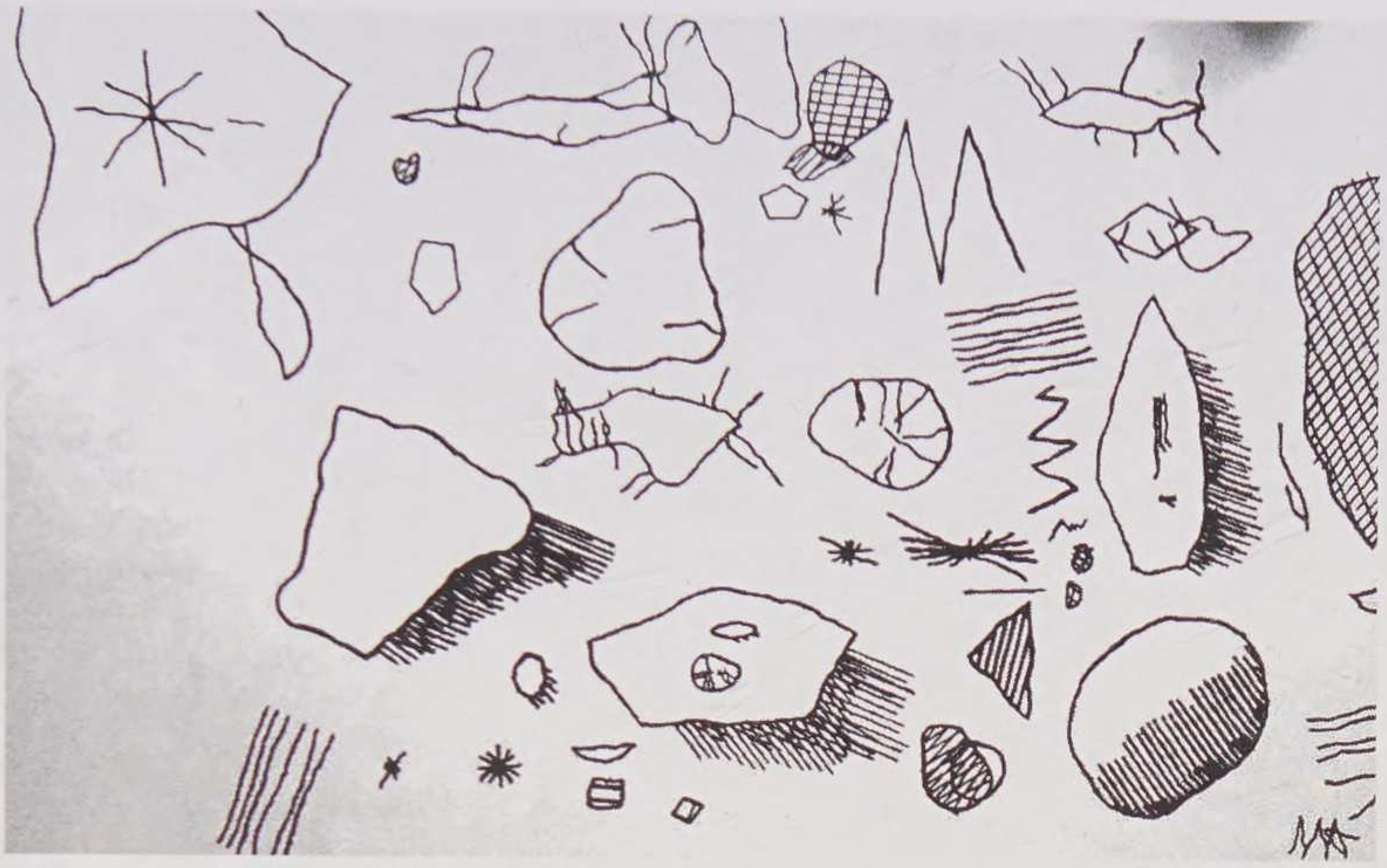


Figure 11.1 Drawing for *Machine and Four Hands* (detail). Mural enlarged from machine-generated drawing, 12′ × 80′, Art Gallery, UC San Diego. 1975.

AARON came into being at the Stanford AI Lab in the early 1970s. It began as an attempt to model what people do, cognitively speaking, when they make and read freehand drawings. The effort to enlist what I thought of as "cognitive primitives" into the program—the ability to differentiate between figure and ground, for example, and between closed forms and open forms—lasted about eight years, during which I abandoned the first drawing machines in favor of a small "turtle," which rolled around on large sheets of paper leaving a trail of ink behind it (figure 11.1).

I did three major shows with the little turtle—*documenta* 6, the Stedelijk in Amsterdam, and the Museum of Modern Art in San Francisco—before I finally came to see that the audiences were finding the turtle so engaging that they were scarcely paying attention to the drawings it was making. Clearly, it was time to retire it and develop something a little less attention-grabbing.

The program itself developed quickly, providing material, mostly photographed off the monitor, for a number of prints and several murals, all of which were colored by hand. But by the end of the 1970s I'd reached a critical juncture. I had assumed that the program would continue to develop indefinitely as I uncovered and incorporated more and more "cognitive primitives." But it was becoming clear that the question of how many primitives I could find was not really central. Human cognition develops in the real world: AARON's had developed without any outside world to apply itself to. Interesting and evocative though AARON's drawings were, it was missing this critical feature of human cognition.

Figure 11.2 *Greeting.* Oil on canvas, 54″ × 77″. 1985. Enlarged from image generated by AARON program, painted by hand.

And so the early 1980s were devoted to providing AARON with a small body of knowledge about a very small number of real-world objects, principally the human figure. I developed new drawing machines, created many black and white drawings, and did much coloring by hand. There were more mural projects and more exhibitions (figure 11.2). It was at one of those exhibitions, at the Tate Gallery in London, that someone remarked that it seemed a bit sad that the program could make its own drawings but needed me to color them. "It certainly is," I said. "D'you have any ideas about how to change that?" No, he did not, and nor did I; it was another couple of years before I spotted the key that unlocked the door to AARON's development as a colorist.

The breakthrough on color came for me in 1985, and it followed from the realization, so obvious in hindsight, that the human brain and the computer program are so fundamentally different that they cannot possibly do things in the same way, even when they have the same goals. Once I understood that I wouldn't be able to solve the problem by trying to capture my own performance as a colorist—the standard "knowledge-engineering" approach—things moved forward quite quickly. So, fortunately, did display technology; its hard to realize, now, that the lowest display

Figure 11.3 Digital print, 9.75″ × 8″ (edition of 10). April 2002. HC ref: #020412. Image generated by AARON.

standard available today, VGA, wasn't introduced by IBM until 1987 and SVGA—true 24-bit color—didn't appear until two years later.

I've been remarkably lucky, without a doubt. I learned to program at a time when programming wasn't an option, it was a necessity. And computing technology itself, following Moore's much-quoted law, seemed always to have been ready just in time to support my own expanding ambitions. (I had to check my numbers before I could actually believe what Moore's Law meant. If computers have been doubling in power-per-unit-cost every eighteen months, then the twenty-four doublings since I met my first computer computes to a factor of more than sixteen million, which means that the little lap-top on which I'm typing this postscript is about sixteen thousand times more powerful than the university machine on which I wrote my first programs, and cost about a thousand times less.)

I've been focused on color for the past twenty years now, developing an increasingly sophisticated rule-base, which allowed AARON to become a much better colorist than I ever was myself. I can let the program run overnight and then sit down the next morning to review fifty or sixty original images. Choosing which ones to print is the hard part; they're all good, especially with respect to color. Some of them are spectacular (figure 11.3).

Yet color has not itself been my primary goal; rather it has served as the domain in which my primary goal has been pursued. Looking back over the years, it seems clear to me now that the overarching direction of my work, which began—several years before I met my first computer—with my attempts to find a way for the paintings to paint themselves, has been toward the idea of program autonomy.

Autonomy is a relativistic term, of course, not an absolute; I can only report on how far AARON has come.

Last year, a new version of AARON lost its extensive, well-tuned rule base. Now it sets its own goals with respect to the appearance of an image and continuously monitors the image as it develops, using the results to determine the coloring of the next element and thus to stay on track. To that degree, it is self-controlling. To that degree, it is autonomous. A small step, perhaps. Then again, it may be the most important single step in AARON's thirty-something-year history. I cannot wait to explore the implications.

12

Reconstruction

Tony Longson

One of my favorite toys as a child was a motorcar, roughly pressed out of tin, but printed with lots of detail. You could see the driver's face looking out of the front window clutching the steering wheel. You could also see him printed in profile in the driver's side window, hands on wheel, with the same anxious expression on his face. I was fascinated by this. Holding the car at an angle, I could see both of the views at the same time, but preferred to look at one view and then quickly turn the car around to see the other. Was this the same, or two different people? Did the real person exist inside the car in three dimensions? Why could I not see him from the passenger side or rear window?

As an artist in my early teens I lacked the skills to represent a three-dimensional world on a flat surface, but thought that perhaps I could make a three-dimensional object, and paint it to look as if it were flat. It was a creative goal that no one else seemed to be dealing with, and for good reason! Our sense of visual space is acute, we have two eyes dedicated to seeing depth, and our movement in space reinforces this perception. In stark contrast to this fundamental physiology, we are happy to be fooled, and have developed a strong ability to interpret two-dimensional pictures, drawings, paintings, photographs, movies, etc., as convincing representations of the real world on a flat surface. This fascination with visual space, the pictorial representation of it, and our perceptual and cognitive understanding of it, have always been the motivation for my creative work.

I studied fine art at Reading University in England and was fortunate to find an environment that would encourage and nurture my ideas. Teaching was based on the studio system. After the first year of foundation we could choose to work in one of three painting studios, a sculpture studio, or the construction studio, which was led by Terry Pope. He was a recent graduate from the Bath Academy of Art at

Corsham Court, and was hired about the same time that I became a student. Terry can quite literally make you see things in new ways. He has designed and built spectacles that vividly change the way we see space and depth. The *Hyperscope* is a device made of mirrors that extends the effective distance between our eyes to provide a dramatic impression of depth, as if we were seeing in three dimensions for the first time. A pair of spectacles called a *Cyclopter* folds the view from both eyes into one. These glasses provide quite a different experience from just looking through one eye. It is almost as if the real world were compressed into a perspective painting.

Pope comes from the English constructionist tradition and many of his colleagues were visiting lecturers to the art department at Reading. They included Anthony Hill, John Ernest, Malcolm Hughes, Gillian Wise, Norman Dillworth, Jeffrey Steele, John Law, and Michael Kidner. Typically they would spend a couple of hours with me each Wednesday afternoon. As an arrogant nineteen-year-old I was amazed that they understood "my ideas" so well, until one day Terry pointed out to me that there was a long and rich tradition for what I was trying to do! He encouraged me to discover things for myself and established an environment for that to happen. He encouraged my interest in visual and spatial perception and provided some of the formal mechanisms for exploring these ideas through art.

At one of these visits John Ernest introduced me to group theory, a geometrical process where symmetry operations are performed on simple shapes. Following the process creates a grid of the shapes in which no shape is repeated in any row or column. I extended this idea into three dimensions to make *Group Theory Grid*. Four shapes make up a grid pattern in three dimensions; each of the four shapes is unique in any row, column, or depth. I designed the shapes so that when seen from straight on, they overlap to make up a regular, seemingly flat, pattern (figure 12.1).

This was my first construction. The patterns were screenprinted in white ink onto four layers of clear Plexiglas, each spaced about an inch apart, and set against a black background. Several things about *Group Theory Grid* appealed to me.

- The shapes had a strong spatial definition. The horizontal and vertical elements reinforced the sense of depth, but the diagonal lines seemed to float in an ambiguous space, neither flat nor three-dimensional. There was also something about the work that required the viewer's participation—people tended to move around it, looking at it from different angles and different distances.
- There was a logic to the organization of visual elements that a viewer could read. This organization was essential to the design. It was not necessary for the viewer to understand how the image was made, but the information was there to be retrieved by anyone who was interested in looking for it.

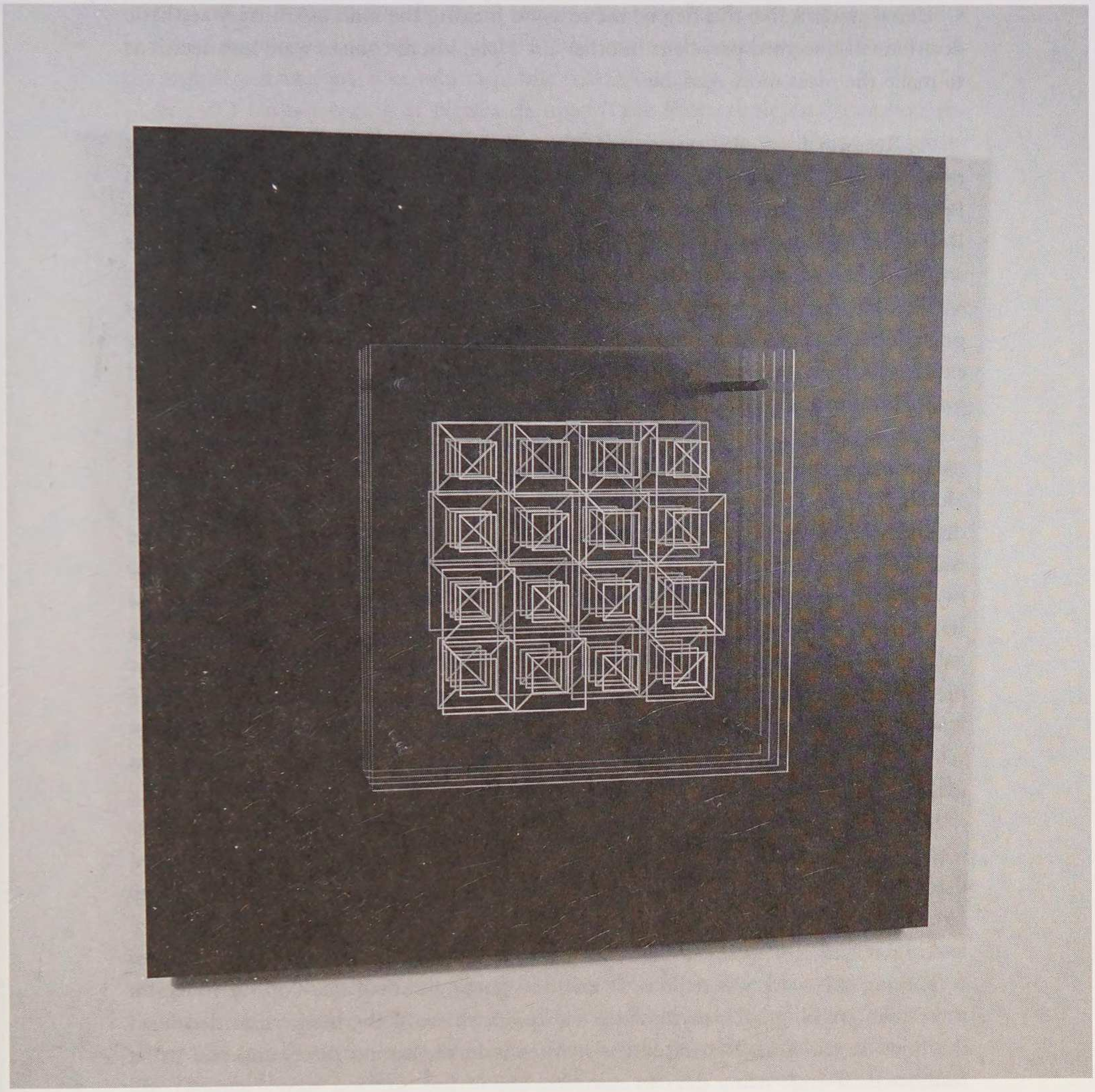


Figure 12.1 Tony Longson, *Group Theory Grid*, 1969.

- Using systems like this helped me to avoid making the kind of arbitrary aesthetic decisions that seemed prevalent in other art. Here, visual choices were just decisions to make the ideas more readable.

At Reading I was also extremely lucky to have Dr. Kerry Downes as my art history professor. He introduced me to the wonderful renaissance architect, Francesco Borromini, whose subtle use of perspective in the Arcade at the Palazzo Spada in Rome, and in Santa Maria of the Four Fountains in Florence, enabled him to create an impression of space that wasn't there.

I hadn't found out about computers yet. The closest I got was the Sinclair Programmable Calculator, which cost ten pounds—the cost of my student living expenses for two weeks. What I did have was a foundation for creative ideas and goals that had the potential for significant development.

Continuing to explore ideas based on the visual ambiguity between flat grids and three-dimensional lattices, I made a series of work during my year in Den Haag, Holland, when I was on a British Council Arts Scholarship. I set up a Dürer-like drawing device with a fixed viewpoint looking at a grid pattern drawn on the wall. Unlike Dürer's intention to map a three-dimensional object onto a flat surface, my simple device let me do the opposite: map the flat grid pattern onto a series of sheets of clear Plexiglas arranged in layers in front of the drawing. The result is a pattern of lines in space that look flat when seen from a certain viewpoint. The depiction of space in these constructions is curious. It seems to shift continually as we look at it, as if our perception of what we are looking at is vying with our understanding to reconcile what we see. The object and the viewer are participants in making the artwork.

Terry Pope has talked about the notion of his artwork as visual instrument. Telescopes and microscopes are devices to let you see the world in different ways. Pope describes his work as a visual device that directs the viewers' attention and requires an active creative visual participation. His art is not only the thing that you are looking at, but is the vehicle that allows you to see it in the way that Pope intends.

Making this work was tedious. It involved putting a small mark on the Plexiglas sheet then walking back to the fixed viewpoint to see if the mark coincided with the lines on the grid. Inevitably the mark was in the wrong place, and had to be readjusted. It took many days to complete the image, so these were "one-off" 3D drawings.

The cultural and artistic climate in Holland was invigorating. There was a strong community of artists and many active galleries. One highlight was getting a tour of the basement of the Gemeente Museum, which was full of Rietveldt furniture waiting to be restored by the last remaining craftsman from his workshop. Mondrian's *Grey Lozenge* was in the gallery, and, because of its implied space, was a source of inspiration for several artworks that I made subsequently. At the end of the year I had my first solo show. It was at Galerie Mathoom in the Denneweg, and four out of my eight constructions were sold to public collections.

In 1973 I was working at Newcastle upon Tyne Polytechnic on a two-year research fellowship. I was making elaborate stereoscopic perspective drawings at the time, and a professor from the University suggested I could do the same thing more quickly and accurately using a computer graphics display device. He wrote a simple program for me in FORTRAN using the GINO-F graphics package. The green on black vector display screen sat in an air-conditioned cubicle in the basement of Newcastle University. I could type a list of x, y, and z coordinates on a keyboard and instantly see flickering 3D geometric images appear on the screen.

My first response was that the drawings lost all meaning for me. The computer could make so many of them so effortlessly and so perfectly, unlike the drawings I'd labored over for weeks, which had had an intrinsic value proportional to the effort that I'd put into them. It reminded me of a story I'd heard about Marcel Duchamp: Apparently, at an exhibition opening he delighted Id signed anything that people put in front of him. Asked why he was willing to do this, he happily replied, "Because it *devalues* them!"

Fortunately I realized that if I could find out how to use this device, I could work with visual ideas that were beyond the scope of existing creative tools. This was the beginning of my involvement in technologically mediated art, and was also the start of my career in teaching art with technology. That same day I went back to my students at the Polytechnic and asked them to start thinking about how computer technology could help them express their ideas. I'd always been interested in teaching as a career, but this was when I became passionate about it. The challenge then, as now, was to find ways to integrate technology into creative curriculum. And the reward has been to see the profound changes that have taken place in art and technology, a trend that shows no signs of fading.

Coincident with the excitement of finding out that computers could help me make art was the realization that there were some problems to overcome. The first was getting the images off the screen. Display devices were vector based, usually a bright green or bright orange line on a dark background. Plotters used very thin paper about ten inches wide, infinitely long, with perforations along two edges. The lines were drawn with a fine-tipped ballpoint pen (for accuracy), which resulted in very clinical looking images. How could I make use of this in 3D?

In the late 1960s, Hatfield Polytechnic in England, now called the University of Hertfordshire, set up a new computer science department. This was a new academic discipline and the department was staffed almost entirely by young graduates from this emerging field. Gordon Bull, department chair, and math professor Peter Kay wanted to have an artist-in-residence program. The Arts Council of Great Britain agreed to fund the program. In 1974, this was the first fellowship of its kind in the country, and I was the first recipient. I was fortunate to have a studio, resources, and many colleagues at the forefront of computer science who were interested in what I was doing, and pleased to help me.

The equipment at Hatfield Polytechnic was remarkable, and my access to it was unrestricted. Though they had lots of mini-computers for special projects, the main graphics machine was a DEC GT40 interactive vector display hooked up to a giant PDP 10 computer with flashing lights and banks of switches on the front panel to "bootstrap" the machine. I was looking for output devices that would allow me to build things in 3D, and discovered that the engineering lab had a Cincinnati numerically controlled three-axis milling machine. This huge machine, which looked like something from the *Starship Enterprise*, moved a drill bit-like cutting tool in three dimensions to cut out shapes from metal or resin. It was used just a couple of hours a term for class demos. The rest of the time it was available to me—with a technician!

The machine was controlled by a set of instructions punched into a paper tape that determined the path and speed of the cutting tool. I could write a BASIC program on the PDP10. The paper tape was punched on a Teletype machine, which was noisy and slow and smelled of hot oil.

The milling machine had certain built-in features to make engineering tasks simpler. Large levers could be set to mirror the movement of the cutter along the X or the Y axis so that the same paper tape could be used to make symmetrical cuts. I was looking for features of tools, materials, or processes that could provide creative insights, so I started to use the mirror symmetry that the machine offered in ideas for new work. Now it is not unusual to hear artists say of technology, "Here is something new, how can I use it to make art?"

One day I went to an art gallery in Pangbourne to see an exhibition of computer art. Only one artist appealed to me: He had a small plotter drawing of a grid of fragments of cubes in different orientations and varying degrees of completeness. The drawing had an elegance and tightness that I hadn't seen before, similar to that of the constructivist artists' work, but much more precise and detailed. The drawing was by Manfred Mohr. I came to know his work better just a couple of years later when Ruth Leavitt, a New York artist who had written a book on computer art, was instrumental in making a movie, *Idea, Experiment, Result*. The movie was sponsored by IBM of West Germany; it profiled four artists who were using computers to explore creative ideas—Manfred was one of the artists and I was another.

I have encouraged artists to learn to program for themselves. I set up computer graphics programs in the art and design departments in the early 1980s at West Coast University, Los Angeles, and CalState, Los Angeles (where I still work), to teach artists and designers to program. There were no PCs or software applications, then so teaching programming was an obvious choice. Most applications today have an embedded programming language; web applications have Java and Javascript, graphic design applications use Postscript, 3D software usually has an embedded scripting or scene description language such as Alias's Mel script or Pixar's Renderman. It seems that the need for artists to know how to program is stronger that ever.

Disciplines such as drawing or photography are often referred to in art education as "visual languages." I believe that programming is more than a visual language—it is a "creative language." The program can encapsulate an idea. It provides a vehicle for expressing the idea and a method for discovering a creative solution. Then with the right output mechanisms, the technology can make the idea visible. Unique to this creative language, input devices to the program can actually mediate the viewer's experience of the artwork, and this experience that may be unique to each person. Best of all, the technology and the languages can, themselves, be the source of new creative ideas. Paul Brown maintains that computer art has not been recognized by the galleries and critics, and the reason may be that the technology provides such a wide range of creative possibilities that attempts to categorize them are meaningless.

Generously, the Arts Council renewed my fellowship at Hatfield for three years. At the end I put on an exhibition of work called *Space Drawings*, and one visitor to the show was John Lansdown, one of the people who founded the Computer Arts Society in 1968, an architect and author of a magazine column called "Not Quite Computing—Almost Art."[1]

At the exhibition I talked to Lansdown about the foundations of my work and the use of technology that might qualify it as mainstream art rather than a novelty. Apparently I was convincing enough for him to change the title of his column to "Not only computing, also Art." Considering Lansdown's contribution to computer art, through his own work deriving a language for computer-based dance choreography, and his leadership of the Art and Technology initiative at Middlesex Polytechnic, it was a significant decision.

When my fellowship ended I moved to London and did some part-time teaching to support my studio work. I knew I wanted to make objects, but did not have access to anything like the milling machine at Hatfield Polytechnic. I also wanted to get more detail and complexity into the work. Bela Julesz had just published his book, *Cyclopean Foundations of Perception*, in which, through random dot stereograms with hidden depth information, he showed unequivocally that stereo vision occurs in the visual cortex, after the information from both eyes has been combined in the brain. His drawings had a seductive quality; they appeared to be random, but contained hidden 3D geometry that was only revealed when the two images were seen in stereo. I was looking for appropriate equipment to explore these new ideas and the opportunity came from the Slade School Experimental and Electronic Art Department.

Part of the postgraduate Fine Arts Department at University College London, also known as the Slade School, was the Experimental and Electronic Art Department, founded by Malcolm Hughes in 1972. Though it lasted for just a short time, until 1981, its graduates made a significant contribution to art, the history of art, education, and animation.

I was invited to teach in the Experimental Area occasionally, and I asked if I could use their equipment. The studio was impressive. The Data General minicomputer usually had it is guts on show, side panels off, racks pulled out, with rainbow-colored ribbon cables snaking across the benches to tiny osilloscopes that had been commandeered to act as display devices. Raster graphics was in its infancy, so most of the equipment dealt with vector display and output. The attraction for me was their large format flatbed plotter, which sat in the middle of the room. At first I thought I could use it to draw directly onto sheets of Plexiglas but that was not practical; however, I could make black ink lines on white paper that I could then copy to photolith film, transfer to a screen, and print on to the Plexiglas.

The plotter used Rapidograph pens, which could be unreliable. I had to work after hours, so would usually set the plotter to work at about six o'clock in the evening, expecting a drawing to take about four hours to complete. Then I'd meet up with Chris Briscoe, Paul Brown, Dominic Boreham, and others at the local pub, typically getting back to the lab at around ten o'clock to find that the ink had dried up somewhere in the middle of the drawing! The failures were frustrating, but the process was good enough to work some of the time, so I persevered.

Screenprinting is a process that takes some effort to set up, but is ideal for printing multiple identical copies of an image. When I began printing, I wanted to try to make up my constructions of single images that could be printed four times identically, and yet make up a single grid-like design in three dimensions. Rotational symmetry seemed to be a good way to do this, and using some simple rules in the program I could make an image that would work in this way. Using the characteristics of the tools, materials, and processes that one has available was important to me, and extending this notion to the way program control structures work, such as loops to iterate through a grid, conditionals to decide if a mark should be made at each location, etc., seemed an obvious idea.

The screenprinted plotter output allowed me to make objects that were much more detailed than anything I'd been able to do before. The programming constraints forced me to think of logical ways to express my ideas and also, amazingly, suggested new creative avenues to explore. I was able to make things that were perceptually engaging in a new way. I used titles like *Square Tonal Drawing* for this series of work because I was able to make sufficiently small marks, and in sufficient quantity, to get a kind of texture or tonal gradient. The visual impression of space is intriguing, and there is a compulsion to make order out of the seemingly random marks that make up the image.

It seems to me that the programming language is a clear analogy to the visual expression of an idea. The structures in a program have a direct formal equivalent in the artwork they produce. Programming was a new creative language that embodied a remarkable set of tools that encouraged a rigorous conceptual foundation for the expression of ideas. As a bonus there was a history of research into topics such as AI, fractals, artificial life, etc., that garnered new attention with the availability of computing. These topics have provided a rich source of ideas to artists.

In 1980 I applied for one of the arts fellowships set up by the Arts Council of Great Britain and the U.S. National Endowment for the Arts to celebrate the bicentennial of the founding of America. This was a cultural exchange in which a handful of artists, writers, dancers, musicians, etc., from the United States and the United Kingdom were funded to spend a year in the other country. A stipulation was that you had to have a good reason for going.

I had seen an image of the surface of Mars that was sent back to NASA's Jet Propulsion Laboratory in Pasadena from the Viking Lander in 1976. The image was remarkable in several ways. Obviously not a photograph, it was a raster image made by scanning a vertical slice of the landscape to sample the light intensity at hundreds of points, then rotating by a fraction of a degree and doing the same thing again and again. Because no camera lens was involved, the device could make a 360 degree panorama. Parts of the spacecraft were visible at the bottom of the image and appeared strangely distorted. The raster image was made up of pixels, tiny, square "picture elements," which had a single solid color. The surface of Mars appears to be strewn with evenly sized, small rocks. Foreground rocks were quite distinctly represented by many pixels, but as rocks appeared to be smaller with distance, there was a fascinating point in the image where the size of a rock corresponded exactly to the pixel that was representing it. The content of the image, and the means of representation are one. I wanted to be at the place where these images were arriving from space.

One day, after a meeting with the graduate students at the Slade School Experimental and Electronic Art Department I was talking to Malcolm Hughes in his office. He had spent the morning on a jury to pick candidates for the Bicentennial Arts Fellowship. "Your name came up today," he said. "I had to work really hard to get you through to the next round, but you should forget about it now as you don't stand a cat-in-hell's chance of getting the Fellowship." I guessed that Malcolm had a better idea about this kind of thing than I did, so it was a surprise to be called for an interview!

When I got the Fellowship I had to confirm sponsorship from someone working at the Jet Propulsion Laboratory. Gordon Bull from Hatfield Polytechnic told me to contact Bob Holzman, who had founded the Computer Graphics Lab at JPL in the late 1970s. It was one of the first places in the world to use raster graphics effectively in a large scale project. Their task was to model the solar system and to provide animated simulations of the journeys of space probes for publicity purposes. This was an ideal application of computer graphics, as the laws of physics in space lend themselves to calculation. Jim Blinn was the programmer, and his work was so accurate that mission control staff used his simulations to anticipate and direct the position of several NASA spacecraft.

Bob Holzman has an amazing understanding of the intersection of science and art, and has been one of its champions. To get his permission to sponsor my visit I nervously phoned him armed with a list of answers to questions he might ask. Typical of Bob, there was only one question:

Bob: "Do I have to pay you?"
Me: "No."
Bob: "Okay, you can come." [Click.]

Being able to work at the Jet Propulsion Laboratory was a terrific opportunity, but presented its own set of challenges. Blinn had developed an impressive set of tools to facilitate his work, including one of the earliest paint programs, 3D-modeling tools driven by a command line interface (not unlike the current *Renderman* scene description language), texture mapping and lighting, and, of course, the capacity to animate images over time. David Em was another artist-in-residence at the time, and used these tools to great effect, producing some seminal images that still resonate twenty five years later.

The dilemma for me was that I still wanted to make objects, and could not see how screen-based images, despite their appeal, would let me do that. Instead of using the tools that Blinn had written, I decided to learn as much as I could about how he was doing what he did. The goal was to develop my understanding of computer graphics programming in order to extend the scope of my creative ideas. I was in the perfect place to do this. The research there was groundbreaking and the people working in the lab were happy to share their ideas.

The Association for Computing Machinery's Special Interest Group on Graphics (ACM SIGGRAPH) was a burgeoning organization in the early 1980s showcasing and disseminating developments in computer graphics and interactive techniques. Bob Holzman introduced me to the annual conference in 1982. No "live" images were shown there then, so we put together an annual *Frame Buffer Show*. People from the major studios and universities in the United States sent me images on

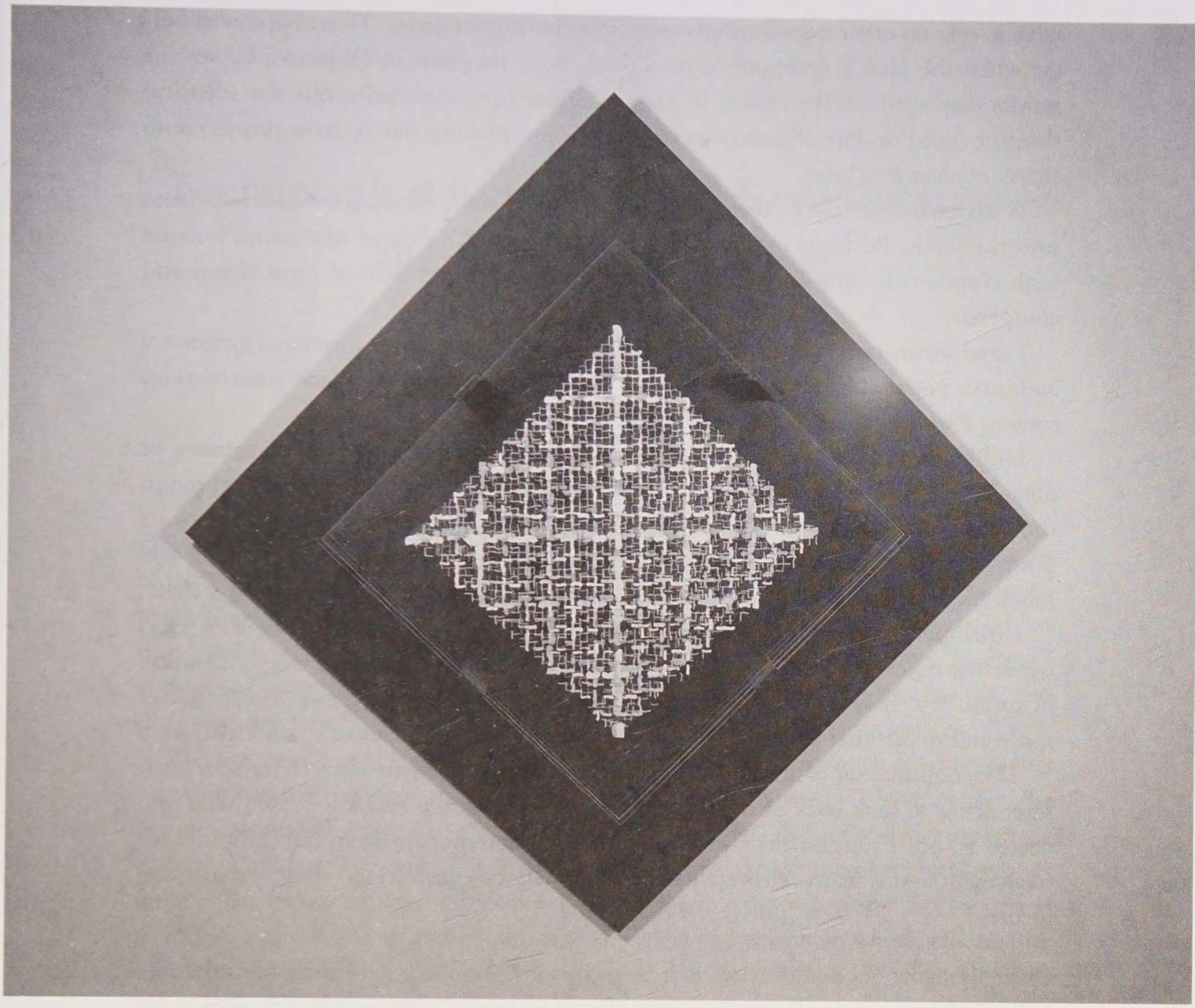


Figure 12.2 Tony Longson, *Pool #2*, 2001.

half-inch magnetic tape, which we collated and displayed cyclically on a Ramtek Frame Buffer driven by a PDP 11/750 at the conference each summer. This equipment comprised the entire computing resources of West Coast University in Los Angeles, whose students seemed not to miss it for the week or so that we trucked it to wherever the conference happened to be that year!

In 1986 Apple Computer started selling the LaserWriter printer. Driven by the page description language, Postscript, it provided the output that artists and designers needed. For me it meant I could do everything "in house"; I did not have to rely on other organizations to provide output facilities. Things got even better when the NeXT computer came out. I could program in Objective C, see the results displayed on the screen in Display Postscript, then print out the identical thing. I could do lots of iterations of ideas before picking one to have printed onto sheets of clear Plexiglas.

With such a flexible working environment I was more free to introduce new ideas into the work. I'd been impressed by Loren Carpenter's *Fractal Mountains*, because with simple rules applied recursively one could achieve a look of great detail and complexity.

I used recursion to generate space-filling patterns along with rotational symmetry and other position-based rules to make a series of large white on black constructions such as *Pool* (figure 12.2), *Crinkly Tape*, and *Cheetos*.

Unlike previous work, which used very simple geometry such as lines, squares, or dots, I delighted in the curly (spline-based) shapes that Postscript provided through the "curveto" instruction. The curliness and weight of the mark was related to its position on the grid, or its generation level in the recursive process. This work was much more relaxed and whimsical than previous stuff, and the titles reflected that.

I still make layered constructions but have also been developing some new ideas where flat reliefs are printed with tonal gradients that disguise their true orientation in space. My creative goal is the same: to provide a compelling visual experience of space and depth that is out of the ordinary, and invites the viewer's participation.

The combination of art and technology is clearly a mainstream activity now. It is interesting to look back at the origins of this convergence and the people who pioneered it, but I suggest that we stop looking for commonalities in the computer art movement and start to celebrate its ability to defy categorization—past, present and future.

Note

1. John Lansdown, "Not Only Computing—also Art," *Computer Bulletin*, periodical of the British Computer Society, no. 9, (September 1976): 12–13.

13

Technological Kindergarten: Gustav Metzger and Early Computer Art

Simon Ford

On January 21, 2003, a large crowd of onlookers watched as the seventy-seven-year-old artist Gustav Metzger scurried through one hundred thousand newspapers piled up in the dark basement of T1&2 Artspace, a squatted building in Spitalfields, London.[1] With the newspapers filled with reports on the coming war in Iraq, Metzger's actions appeared especially charged. Here was a man who, in his own words, had dedicated his life "to the task of eliminating war and other social injustices."[2]

Metzger was born on April 10, 1926, in Nuremberg. His Polish Jewish parents had immigrated to Germany just eight years before. In January 1939 they sent the twelve-year-old Gustav, along with his brother, Mendel, to England as part of the Refugee Children Movement. They were just in time. Those members of Metzger's family that remained were subsequently killed during the war. After a brief period living in a commune in Bristol, Metzger decided to become an artist. His studies took him to Cambridge, London, Antwerp, and then back to London where he studied at Borough Polytechnic School under David Bomberg. By this time his terrible experiences of fascism in Germany and his horror at the nuclear destruction of Hiroshima and Nagasaki had already provided the foundations for his lifelong commitment to dealing with political and social issues through his art: "The atomic bomb is really the starting point of my own work. This is the point when I was an art student and I was very conscious that from now on everything was different, including art. From that point, I started to probe the limits of art, of what one could do and what one had to do in relation to society, in relation to helping society so that this could not happen again."[3]

Metzger's dedication to the anti-nuclear movement soon became the most obvious manifestation of his opposition to Cold War nuclear proliferation; it also informed his development of the concept of auto-destructive art. Metzger's first manifesto, "Auto-Destructive Art," appeared in November 1959. In this short manifesto he described auto-destructive art as a new form of "public art for industrial societies" and stated that auto-destructive art could be produced in collaboration with scientists and engineers and be machine produced or factory assembled: "Self-destructive painting, sculpture and construction is a total unity of idea, site, form, colour, method and timing of the disintegrative process."[4] His second manifesto, "Manifesto Auto-Destructive Art," appeared in 1960 and developed the idea further. Here Metzger described "man in Regent Street," rockets and nuclear weapons as auto-destructive, along with materials and processes such as acid, ballistics, cybernetics, electricity, explosives, feedback, human energy, mass-production, nuclear energy, and radiation. Auto-destructive art transformed technology into public art and mirrored "the compulsive perfectionism of arms manufacture—polishing to destruction point."[5]

Fittingly, given his involvement in the peace movement, it was Pat Arrowsmith, field secretary for the Direct Action Committee Against Nuclear War, who wrote one of the earliest articles on Metzger's work for *Peace News*: "I myself walked into London beside him at the end of last year's Aldermaston March . . . {He} stood up on a soap box to address the stall-holders of Watton market."[6] Metzger's activism led him to become a founding member of the Committee of 100, a group dedicated to nonviolent civil disobedience. In September 1961 at Bow Street Magistrates Court, Metzger, along with other members of the Committee, refused to be bound over to keep the peace for a year. For this Metzger was imprisoned for a month along with other Committee members including Alex Comfort, Bertrand Russell, Arnold Wesker, and Christopher Logue. At his trial he read out a prepared statement:

> I came to this country from Germany when 12 years old, my parents being Polish Jews, and I am grateful for the Government for bringing me over. My parents disappeared in 1943 and I would have shared their fate. But the situation is now far more barbarous than Buchenwald, for there can be absolute obliteration at any moment. I have no other choice than to assert my right to live, and we have chosen, in this committee, a method of fighting which is the exact opposite of war—the principle of total non-violence.[7]

In July 1961, just before his trial, Metzger organized a key auto-destructive event, an open air demonstration at the South Bank in London. Armed with a spray gun filled with acid and dressed in combat clothing and a gas mask, he attacked three large sheets of nylon attached to a metal frame. The accompanying manifesto contained Metzger's first mention of computers as a possible ingredient of auto-destructive art:

> Auto-destructive art and auto-creative art aim at the integration of art with the advances of science and technology. The immediate objective is the creation, with the aid of com-

> puters, of works of art whose movements are programmed and include 'self-regulation'. The spectator, by means of electronic devices can have a direct bearing on the action of these works. Auto-destructive art is an attack on capitalist values and the drive to nuclear annihilation.[8]

It took another four years before Metzger provided a more detailed proposal to create an artwork that included a computer as an integral element.[9] *Five Screens with Computer*, he wrote, would consist of five walls or screens made of stainless steel, each thirty feet high, forty feet long and two feet deep. They would be arranged about twenty-five feet apart in a central area between three highrise tower blocks. Each wall would be composed of ten thousand uniform elements made of stainless steel, glass, or plastic and be square, rectangular, or hexagonal in shape. Each element would be individually ejected from the screen over a period of ten years until the screens literally fell to pieces. Metzger still had to work out how the elements would be ejected but at this point he proposed the use of magnets and compressed air. The computer's job was to control—according to a program devised by the artist—the sequence of these ejections. This program would take into account the quality of light and shade, the revolution of the earth, the various seasons, the weather, and spectator participation via photo-electronic switches. Metzger claimed that the computer would link art, technology and society, and only through its use could the artist "achieve forms and rhythms that correspond to his aims." Through the work Metzger aimed to re-channel the destructive potential of the computer: "Today, death is fed into, processed and administered by the computers." Unlike his acid on nylon paintings, the computer also provided an escape from the connotations of "expression" usually associated with marks left by the artist's hand. This huge sculpture, in such a prominent public space, would make a spectacle of destruction and in the process, Metzger hoped, would "initiate a series of controversies that can become a kind of mass-therapy as well as educational programme."[10] You could imagine some viewers, especially those living in the nearby tower blocks, reading the random ejections of the units as analogous to the lack of autonomy and control in their own lives. The irony now, of course, is that it is the tower blocks themselves that are regularly demolished in celebratory and public spectacles of destruction and regeneration.

From this moment on, *Five Screens with Computer* became Metzger's greatest hope for realizing his ambituous ideas for auto-destructive art as "public art for industrial societies." The acid on nylon paintings had been taken as far as they could go and Metzger became increasingly fascinated by the potential of using computers. He never intended, however, to learn about such practicalities as, for example, programming. For such technical matters he willingly relied on his computer-literate collaborators. For him it was the future possibilities of computing that were important:

> I thought it was not even worth bothering to learn programming because it was so crude, so wasteful of time and energy. Everyone complained about it. To do anything you needed days. I decided I'm not going to do that. I also did not see the point of making very crude lines on a bit of paper—which was the computer art of the time. I knew in time that it would be so different. It was the future I was interested in.[11]

Metzger's interest in computers in 1965 coincided with a number of key events in the early history of computer art, most significantly the first computer art exhibitions at the Technische Hochschule in Stuttgart and the Howard Wise Gallery in New York. A year later IBM recruited its first artist-in-residence, John Whitney Sr., and the Museum of Modern Art purchased Charles Csuri's computer-generated image *Hummingbird*.[12]

Metzger's plans for *Five Screens with Computer* were temporarily put on hold as he spent much of 1966 co-organizing the Destruction in Art Symposium (DIAS) and much of 1967 dealing with its consequences.[13] But he returned to the project in 1968 for the exhibition *Cybernetic Serendipity: The Computer and the Arts*.[14] Curated by Jasia Reichardt, it was the first exhibition in Britain to demonstrate the creative potential of computers. Metzger's participation, however, did not prevent him severely criticizing the exhibition. His focus remained on issues of social responsibility for both the artists and scientists involved in the new technology, and he countered those who advocated the utopian possibilities of the coming computer age with sobering details of its origins in military research. *Cybernetic Serendipity*, he complained, provided "a perfectly adequate demonstration of the reactionary potential of art and technology. No end of information on computers composing haiku—no hint that computers dominate modern war; that they are becoming the most totalitarian tools ever used on society. We are faced by this prospect—whilst more and more scientists are investigating the threats that science and technology pose for society, artists are being led into a *technological kindergarten*."[15] Metzger's contribution to the exhibition took the form of a description of his latest version of *Five Screens with Computer*. Slight modifications included increasing the distance between the screens from twenty-five feet to thirty feet and also the introduction of a festive element when suggesting that the "frequency of ejections on holidays may reach 600 a day."[16]

The work's most developed description was revealed a year later during *Event One* at the Royal College of Art (March 29–30, 1969). The exhibition was the first public manifestation of the newly formed Computer Arts Society. Metzger's most significant modification saw the number of elements in each screen reduced from ten thousand down to twelve hundred. Metzger also provided more details on how the individual elements would operate: "These elements can be moved forwards or backwards within a frame at controlled speeds, and will finally be ejected at various controlled speeds, reaching a maximum distance of 30 ft." Metzger utilized the computer in three key areas: design, operation, and recording:

> *Design*
> Since all the decisions on the activity of the screens will be made before production begins it is necessary to have the most complete understanding of the work's potential at the design stage. A computer allied to graphic output will be used to plot the numerous possibilities for moving and ejecting elements, and for visualizing the possible shapes of the screens in transformation. 55% of the elements will be ejected on a pre-determined programme. The rest (including one entire screen) will be ejected in a random manner. These random ejections will be sparked off by intense sun or electric light, or by the assembly of people above a certain number in the vicinity of a screen. Random ejections are subject to a variety of controls such as structural considerations, and will be co-ordinated with the overall programme.
>
> *Operation*
> A computer will be in general control of the electro/mechanical activity of the sculpture—continuous adjustments (online) will be necessary. The computer will also direct peripheral activity such as the raising of the glass wall surrounding the site before ejections can take place.
>
> *Recording*
> The computer will be used to print out and draw the day-by-day development of the screens. This will be necessary to check on operational, structural, and safety factors, and will be an aid to maintenance activities. This graphic output, along with photographs and films, will be preserved as part of the documentation on the work.[17]

In another text from this period Metzger stated that when not being employed by the ejections the computer could be used by the inhabitants of the flats: "By means of telephone lines it can serve as a local convenient library for the inhabitants."[18]

Metzger's description of the project offered little explanation of how the artwork's immediate audience might be consulted or invited to interact with the sculpture. As Metzger clearly stated in the *Event One* text "all the decisions on the activity of the screens would be made before production begins." This point is significant because, if realized, such a sculpture would almost certainly have attracted great resentment from its immediate audience. Not only would there have been extensive and expensive construction and maintenance work, there would also have been considerable noise from the explosive ejection of the units, which in themselves would have posed a serious health risk (only belatedly allayed by Metzger's suggestion that a retractable glass wall should surround the site, protecting both the public from the sculpture and the sculpture from the public).

Metzger's plans for *Five Screens with Computer* were very much in advance of what the technology of that day could deliver. As such the project remained in a constant state of development right up until 1972 when Metzger decided to suspend any further work: "I stopped because I realised nobody was interested in producing it. I could have sat down with technicians and worked out ways of doing it. . . . But since nobody was in the least bit interested in making this piece of auto-destructive art or in commissioning it, I consciously said: 'That's it. Good-bye. I've done my bit in conceiving it.'" Metzger still remains convinced, however, that the work could and should be made: "The computer power is now so much cheaper. One of the reasons why nobody took it seriously was because the computing power necessary would have been so expensive. But now it would cost almost nothing. . . . It is perfectly feasible to do it now and the more we go into the future the easier, technically speaking, it becomes."[19]

After *Event One* Metzger's engagement with computers and art became increasingly bound up with the exhibition's organizers, the Computer Arts Society (CAS). The idea for the CAS was first mooted on the afternoon of August 7, 1968 at an informal session on computers and music at the IFIP (International Federation for Information Processing) Congress in Edinburgh. The CAS's aims were "to encourage the creative use of computers in the arts and allow the exchange of information in this area"; they were quite modest but still an important first step.[20] Alan Sutcliffe, then head of ICL's (International Computers Limited's) Programme Research Unit, became the CAS's chairman and R. J. Lansdown, an architectural partner at Ian Fraser & Associates, became its secretary. Metzger quickly heard about the group and became an active contributor to meetings and, as we have seen, a contributor to the group's first exhibition, *Event One*.

Shortly after the exhibition Metzger visited Sutcliffe at his home in Bracknell and was offered the opportunity to edit the Society's news bulletin. Metzger accepted and together they tried to think up a suitable name. Sutcliffe explained that they could not afford an extravagantly produced publication and that it would probably consist of just one page. At this point Metzger suggested "Page" as its title. Sutcliffe liked the idea, not least because "Page" was also a term used in computing. Thus *PAGE: Bulletin of the Computer Arts Society* was born. Metzger was given almost total editorial freedom and he quickly developed a strongly political and critical tone for the Bulletin. CAS paid him a small fee for his editorial work but this never really covered the many hours he put into each issue: "When there is a problem I'm prepared to spend weeks on it. And I spent weeks sometimes in preparing one issue."[21] Metzger was not proprietorial about the magazine and welcomed guest editors and special editions including, for example, Dutch and American sections.

CAS initially held its meetings in rooms donated by the British Computer Society at 29 Portland Place, London. In June 1971 it announced the establishment of its own permanent space, two rooms on the second floor of The Dairy in Camden, a large complex of artists' studios run by SPACE (though whether it was ever occupied or even used remains in doubt).[22] In 1971 the membership of CAS consisted of five hundred enthusiasts worldwide. At this time access to computers was severely limited because most were owned by scientific and military institutions. Artistic projects formed only a small and often informal element of their operation. To counter this marginalization CAS publicized and lobbied for artistic projects and set up events such as the Computer Art session at *Computer Graphics 70*.[23] Advertised as "More than a symposium—more than an exhibition—an international meeting of minds," the conference boasted key representatives from the military-industrial complex: General Motors, Lockheed Georgia, Mobil Oil Corporation, Royal Navy, Ford Motor Company, Space Flight Center, Boeing, Sperry Rand, and Unilever. At the conference Metzger presented a paper on "New Ideas in Plotter Design Construction and Output," and two months later, on June 24, he gave another paper, this time at the British Computer Society, entitled "Computers and Sculpture."

These activities formed a key part of Metzger's plan to seek out and collaborate with others who shared his interest in combining advanced art with the latest scientific developments. Two people he shared many ideas with were the writer on art and technology Jonathan Benthall and the scientist and mathematician Gordon Hyde. Together these three wrote the "Zagreb Manifesto" of 1969, in which they encouraged artists to explore and assimilate "the potential of existing computers and their peripherals." Artists should overcome the limitations of existing techniques and "seek an alliance with the most advanced research in natural and artificial intelligence."[24] Such information sharing also complemented Metzger's active membership in the British Society for Social Responsibility in Science (BSSRS). Metzger attended its first public meeting at the Royal Society in London in April 1969. Toward the end he stood up and made a statement suggesting that art and artists should provide some input into the BSSRC's work. Afterward, one of the leading members, Professor Maurice Wilkins, approached him and suggested they have a meeting to discuss the matter further. A small group, later named the Art and Technology Group, was invited to meet in Wilkins's offices at Kings College, University of London. This group included Metzger, Benthall, and another artist, Conrad Atkinson. Part of Metzger's deep commitment to the social responsibility of science eventually manifested itself in a two-page essay for *PAGE*. Here he listed every article that had appeared in the two main professional journals of the day that exposed links between computers and weapons of mass destruction.[25] For Metzger these references and selected quotations provided ample proof that the development of computers and armaments were both closely integrated with the capitalist economy.[26]

In that same issue of *PAGE* there was coverage of another of Metzger's activities at the time. It gave advance information of an event planned to take place on

October 20, 1970, when Metzger joined the International Coalition for the Liquidation of Art in an attempt to close down the Tate Gallery in London. *PAGE* carried the Coalition's manifesto:

> Art today is the end of the road / It is a result / It is a static thing / The final result (and we really mean final) of creativity today is art pollution.
> All artists who prostitute their functions in this way—
> All artists who use the title of avant-garde to help conserve the old elite—
> All artists who refuse to join in attacking the present system—
> Are shit.
> There is only one solution
> We must liquidate this crazy thing called art to make it possible for all people everywhere to be creative. . . . The artist must liquidate the art world by closing down art magazines, art councils and art museums because they are the tools of an irrelevant society.[27]

As such examples reveal, alongside his work on *PAGE* and *Five Screens with Computer*, Metzger never stopped developing new forms of political art, and these became increasingly important to him—so much so, in fact, that his involvement with *PAGE* ended with issue 26 in November 1972, when the bulletin announced he was too busy with other projects to continue.[28] Metzger's other projects included his participation in *3 Life Situations* at Gallery House, his assistance in founding the Artists' Union, and his preparations for the Art Strike from 1977 to 1980.[29] He published no further plans for *Five Screens with Computer* and for most of the 1980s kept an extremely low profile, working chiefly on research into art in Germany under National Socialism, Utility furniture, and the book jacket designs of John Heartfield. When he returned to exhibiting during the 1990s it was with proposals for artworks that focused increasingly on environmental issues, such as *Earth Minus Environment*, a sculpture project for the United Nations Earth Summit in Rio de Janeiro in 1992. More recently curators have included his work in important historical group shows, such as *Life/Live*, *Out of Actions*, *Live in Your Head*, and *Art & The 60s*,[30] and a major retrospective of his work took place in 1998 at Oxford's Museum of Modern Art.[31] To date, though, most attention has continued to focus on Metzger's spectacular acts of destruction, with little attention being paid to his seven-year engagement with computer science, from his talk at the Architectural Association in 1965 to his last issue of *PAGE* in 1972.

In retrospect *Five Screens with Computer* appeared at the height of what became the first false dawn of computer arts. These were the "Go-Go" years, the original boom time. Fed by the rising value of technology shares, supported by a seemingly everlasting revenue stream from defense departments, and effervescent with the missionary zeal of NASA's race to put a man on the moon, the computer age had arrived. By 1971 Colin Moorcraft boldly declared that "the heroic phase of modern art is well and truly over: no more lunatics burning their passions out on canvas; just a group of men in white coats deciding what next week's New Movement is going to be."[31] But the benign nature of computers and their manufacturers was always fiercely contested, not just amongst defenders of humanistic values but also amongst the most radical elements of the counterculture. Take for example Robert Smithson, who was invited by the MIT Center for Advanced Visual Studies to take part in the US section of the *X São Paulo Bienale* in 1969. He eventually withdrew stating that: "To celebrate the power of technology through art strikes me as a sad parody of NASA. I do not share the confidence of the astronauts. . . . If technology is to have any chance at all, it must become more self-critical."[33] This critical attitude also informed cinematic representations of possible future worlds in films such as *2001: A Space Odyssey* (1968) and *Alphaville* (1965), which Jean-Luc Godard had originally considered calling *Tarzan versus IBM*.[34] Exhibitions promoting the confluence of art and technology did little to instill confidence that a bright new future lay ahead. In late 1970 Agnes Denes was so disgusted by her treatment as an artist in the *Software* exhibition at the Jewish Museum in New York that she wrote to *Studio International* accusing the museum of supplying a malfunctioning computer and making false promises about the availability of technical assistance.[35] In support of Denes a number of artists (including Hans Haacke, Joseph Kosuth, and Lawrence Weiner) signed another letter claiming that the technical advisor assigned to her "told her at one point he would not do her work because he did not like her and did not like women."[36]

It would take at least another two decades for the development of personal computers and the growth of the Internet to allow digital art to once again achieve even nominal artworld status. Thirty-odd years on, however, Metzger's critique of the dubious techno-utopianism of some computer artists and his inconvenient pointing toward the military and state security sectors as the origin of much computer technology still holds true today. Also sadly prescient is his non-ironic assertion in 1971 that in terms of computer art, at least, "the true *avant-garde* is the army."[37]

Notes

1. The exhibition was entitled *100,000 Newspapers: A Public Active Installation*, and consisted of a large room filled with metal shelves and newspapers "much like the files of prisoners in Nazi libraries, reflecting their practical obsession with strict documentation. . . . The public will choose images from these papers while walking along metal gangways and corridors, they will then cut them out, according to what they believe to be relevant to our contemporary situation and paste them over the walls." From an undated press release by Wolfe Lenkiewicz of T1&2 Artspace. An earlier version of this essay first appeared as "Technological Kindergarten" in *MUTE*, no. 26 (Summer/Autumn 2003): 84–90.

2. Gustav Metzger, "The Artist in the Face of Social Collapse." In *Frequencies: Investigations into Culture, History and Technology*, ed. Melanie Keen (London: inIVA, 1998), 82.

3. Metzger in Kristine Stiles, "The Destruction in Art Symposium (DIAS): The Radical Cultural Project of Event-Structured Live Art" (unpublished PhD thesis, University of California–Berkeley, 1987), 74. For more on Metzger's early life and work see the essay by Andrew Wilson and the chronology by Clive Phillpot in *Damaged Nature, Auto-Destructive Art*, Gustav Metzger (London: workfortheeyetodo, 1995).

4. Gustav Metzger, "Auto-Destructive Art" (London, November 4, 1959). The manifesto accompanied an exhibition at 14 Monmouth Street of discarded cardboard packaging that Metzger discovered on Fulham Road.

5. Gustav Metzger, "Manifesto of Auto-Destructive Art" (London, March 10, 1960).

6. Pat Arrowsmith, "Auto-Destructive Art," *Peace News* (July 22, 1960): 11. The review was of a demonstration that took place at the Temple Gallery, London, on June 22, 1960.

7. Gustav Metzger in "Quotes from Bow Street," *Peace News* (September 15, 1961): 7.

8. Gustav Metzger, "Auto-Destructive Art, Machine Art, Auto-Creative Art" (London, June 23, 1961).

9. Gustav Metzger, *Auto-Destructive Art: A Talk at the Architectural Association* (London: Destruction / Creation, 1965). In the text Metzger acknowledged the assistance of Beverly Rowe, then Chief Applications Programmer at the University of London Computer Centre. He later became a founding member of the Computer Arts Society and subsequently introduced Metzger to the Society. Metzger had known Rowe since his days running a market stall in Cambridge in the mid-1950s.

10. Ibid., 6.

11. Gustav Metzger interviewed by Clive Phillpot, recorded at the National Sound Archive, British Library, London, 1997 (Tape: F5548 Gustav Metzger 25).

12. See Charlie Gere, *Digital Culture* (London: Reaktion Books, 2002), 100. Metzger was also well aware of the work of Roy Ascott and shared his interest in cybernetics. In December 1962 Ascott invited Metzger to give a lecture on auto-destructive art at Ealing College of Art. In the audience was Pete Townshend who later took some of Metzger's ideas into the realm of rock music with his spectacular auto-destructive performances with The Who.

13. DIAS ran from August 31–September 30, 1966. After the performance by Hermann Nitsch at St. Brides Institute on Fleet Street, on September 15, 1966, Metzger and his fellow organizer John Sharkey were charged with "having unlawfully caused to be shown a lewd and indecent exhibition." On July 19, 1967, the court found Metzger guilty and he accepted a £100 fine rather than spend four months in jail

14. The exhibition was held at the Institute of Contemporary Arts, London, August 2–October 20, 1968. See Jasia Reichardt, ed., *Cybernetics, Art and Ideas* (London: Studio Vista, 1971). For a recent reappraisal of the exhibition see Rainer Usselmann, "The Dilemma of Media Art: Cybernetic Serendipity at the ICA London," *Leonardo* 36, no. 5 (2003): 389–396.

15. Gustav Metzger, "Automata in History: Part 1," *Studio International* (March 1969): 107–109; italics in original.

16. Gustav Metzger, "Five Screens with Computer." In *Cybernetic Serendipity: The Computer and The Arts*, ed. Jasia Reichardt (London: Studio International, 1968), 31.

17. Gustav Metzger, "Five Screens with Computer (1963–69)." In *Event One* (London: Computer Art Society, 1969), unpaginated. Metzger accompanied the text with a schematic drawing of "the development of one screen (no. 3) in the first three years of its activity." The drawing is credited to Mr. D. E. Evans of the Computer Unit, Imperial College, London, and was produced on an "IBM 7094 11 (32K memory) with CALCOMP plotter."

18. Gustav Metzger, paper read (Metzger could not attend) at the conference *Computers and Visual Research*, Zagreb, 1969, transcript in *Bit International*, no. 7 (1971). The Zagreb Museum of Contemporary Art hosted four international conferences during 1968 and 1969, and nine issues of its magazine, *Bit International*, were published between 1968 and 1972. As a further sign of Metzger's commitment to computer art at this time he was also working on the translation into English of Herbert Werner Franke's seminal work *Computer Graphics, Computer Art* first published by Phaidon in 1971.

19. Metzger interviewed by Phillpot.

20. Mission statement and information from *PAGE*, no. 3 (June 1969).

21. Metzger interviewed by Phillpot.

22. PAGE, no. 16 (June 1971), unpaginated. Under the heading "Computer Arts Society News," it says "The Society now has its own premises at last. There will be an office and computing equipment. The accomodation [sic] consists of two rooms on the second floor of this very large complex of artists' studios run by S.P.A.C.E. The address is: The Dairy, 13a Prince of Wales Crescent, London NW1. Nearest tubes, Chalk Farm and Kentish Town. (Note: do not send correspondence to this address.)"

23. Hosted by Brunel University, Uxbridge, Middlesex, April 14–16, 1970. Information from conference program: *Computer Graphics 70* (Uxbridge, 1970).

24. Gordon Hyde, Jonathan Benthall, and Gustav Metzger. "Zagreb Manifesto," *Studio International* (June 1969): 259.

25. The two journals were *Computers and Automation* and *Communications of the Association for Computing Machinery*.

26. Gustav Metzger, "Social Responsibility and the Computer Professional, Part 1," *PAGE*, no. 11 (October 1970). There was no Part 2. This special issue of *PAGE* was printed in an extra large edition and copies were distributed at *Computer 70*, a trade fair organized by the Business Equipment Trade Association in Olympia, London.

27. Metzger, "Social Responsibility and the Computer Professional."

28. *PAGE*, no. 26 (November 1972). The text went on: "Gustav will remain as Executive Editor, looking after policy and continuing as our social conscience." This arrangement, however, did not last and subsequent issues of *PAGE* veered away from overtly political issues.

29. Metzger's announcement can be found in *Art into Society—Society into Art* (London: ICA, 1974), 74.

30. *Life/Live*, Musée d'Art Moderne de la Ville de Paris, October 5, 1996–5 January 5, 1997; *Out of Actions: Between Performance and the Object 1949–1979*, The Geffen Contemporary

at the Museum of Contemporary Art, Los Angeles, February 8–May 10, 1998, and travelling; *Live in Your Head: Concept and Experiment in Britain, 1965–75*, Whitechapel Art Gallery, February 4–April 2, 2000; and *Art & The 60s: This Was Tomorrow*, Tate Britain, June 30–September 26, 2004.

31. See the catalogue: Kerry Brougher and Astrid Bowron, eds., *Gustav Metzger* (Oxford: Museum of Modern Art, 1998).

32. Colin Moorcraft, "On-Line Nothings," *Studio International* (March 1971): 134.

33. Robert Smithson, "Letter to György Kepes (1969)." In *Robert Smithson: The Collected Writings*, ed. Jack Flam (Berkeley: University of California Press, 1996), 369.

34. Jean-Luc Godard, *Alphaville* (London: Lorrimer Publishing, 1984), 9.

35. Agnes C. Denes, "Open Letter to Jewish Museum," *Studio International* (December 1970): 228.

36. Undersigned, "Open Letter to Jewish Museum," *Studio International* (December 1970): 228.

37. Citing as evidence the success—in the first computer art competition organized by *Computers and Automation* in 1963—of the U.S. Army Ballistic Missile Research Laboratory. See Metzger, *Bit International*, no. 7 (1971): 28. According to Charlie Gere, the U.S. Army also won second place. See Gere, *Digital Culture*, 100.

14

Patterns in Context

Alan Sutcliffe

In this chapter I recount the stories, some anecdotal and some documented, of the development of my electronic music compositions and the parallel and related founding of the Computer Arts Society (CAS). In 1962 I went to Dartington Summer School of Music for a composition course taught by Luciano Berio, who was then at the electronic music studio RAI (Radiotelevisione Italiana) in Milan. Delia Derbyshire, from the BBC Radiophonic Workshop, was Berio's assistant. Delia, who had been studying math and music at Cambridge, was strangely beautiful and worked in electronic music: I became hopelessly enamored. I was apparently not the only one. In her obituary in the July 7, 2001, issue of *The Guardian* (July 7, 2001), Brian Hodgson wrote, "Shortly after Delia had arrived at the workshop in 1962, I was also invited to join. I was stunned by her beauty, awed by her talent." She was at once steely, ethereal, and vulnerable. At the time I was living in Yorkshire, and it was difficult for us to spend time together. The affair was soon over. In 1966 I moved south and made contact with Delia again; this time it was platonic. She told me there was a man I should meet. She took me to see Peter Zinovieff, then living in Putney, coincidentally a few hundred yards from the head office of ICT (which became ICL in 1968), the firm I worked for in Bracknell as manager of New Series Branch, for the company's next range of computers.

At the time of our first meeting the shed at the bottom of Peter's garden was full of his analogue electronic music equipment. The most novel feature for the time was voltage control of oscillators and other modules. Once a month or so I had a meeting at ICT Putney and got into the habit of going to see Peter afterward. He wanted to convert his studio equipment to computer control but was nervous about whether he could handle the programming. I reassured him, and soon a Digital PDP 8 was added to the studio, one of the first delivered in the United Kingdom.

Meanwhile, Stanley Gill was a professor of computing at Imperial College in London, and about to become president of the British Computer Society (BCS). He was preparing the program for the International Federation for Information Processing (IFIP) Congress 1968 in Edinburgh. Gill was president of IFIP that year. As a new graduate in the late 1940s he wrote programs for Maurice Wilkes's EDSAC computer at Cambridge and is said to have written the world's first subroutine. Another of his achievements was his dictionary definition: "recursion: see recursion."

In 1963 Gill was asked to write a program to compose music for a BBC production.[1] His program composed in roughly the style of Schoenberg. For each short section, several possible continuations were generated and an evaluation procedure was used to select one of them.

In the IFIP Congress program Gill included a competition for computer-composed music. In a 2004 program on BBC Radio 4 about his work, Zinovieff recalled a conversation we had had in 1967. I'd said that I could write a program on a mainframe computer to compose music and pass it to a program he could write for his newly computerized Electronic Music Studio (EMS) for treatment and realization. So Peter and I agreed to submit an entry. The piece we created was called "ZASP," which was composed by my program running on an ICT 1900 machine in a building just north of Putney Bridge, and the coded score was converted into sound, recorded on audiotape by Peter's program on the PDP 8 at the other end of the Putney rail and footbridge. "ZASP" was the first piece composed on one computer and realized on another. The first complete realization of the piece was finished just in time for the deadline at the end of January 1968. In the spring we heard that we had won second prize; Iannis Xenakis received first prize for his string quartet "ST-4."

There was to be a concert at the start of the Congress in August, at which some of the entries would be played and the prizes presented. However, there was no provision for a session where the pieces could be described and composition by program discussed. I suggested we have such a discussion and this was agreed, but it was too late for it to go into the printed program of the Congress. A small informal session took place on Wednesday, August 7. Lambert Meertens of the Mathematisch Centrum in Amsterdam spoke about his string quartet, which gained a commendation in the competition, although no third prize was awarded. Xenakis did not attend the Congress. I talked about "ZASP." There were questions and a discussion.

Although I later sent papers from this session for inclusion in the proceedings, they did not appear. (There was also a long article[2] about "ZASP" in the issue of *Computer Weekly* that came out during IFIP 68.) The following extract from the original documentation for the IFIP piece outlines my thinking at the time: "Our aim has been to produce music appropriate to the electronic means, not to simulate any existing instrumental music [or conventional method of composition]. The electronic music equipment used makes possible variations of pitch and timing, for example, not possible on conventional instruments."[3] It is a music of patterns and textures, more like the patterns and textures of nature, perhaps, than most music. In it there is a balance of control and randomness, uniformity and chaos. None of these alone is interesting. Moreover, this balance should itself change: variety must vary. A small number of random values make an interesting pattern, a large number do not. Surprise is an essential element of art, but the more it is used the less it is effective. These are some of the ideas underlying our work.

> What has been attempted is to give each section a distinctive character, and to relate these characters so that the whole is coherent. In the program simple means are used to obtain the different characters: some affect the overall character of a movement, giving generally long or short notes or a mixture, [while] some may have very little effect. Statements have been put in not wildly, nor yet with a full understanding of their effect. At this level too, control and chaos are in balance. The association between the parts depends on them being produced under similar controls.[4]

Each movement lies within a region of the multidimensional musical space defined by its parameters. "ZASP" was entirely within the tradition of the composer being in complete control. It was also entirely procedural: not surprising since I was a follower of the serialists in music.

There were many other ways of using computers for composition—in all the arts. Robin Shirley called his work computer-assisted poetry. In music, for example, Gill's program as well as composing roughly in the style of Schoenberg, produced several versions at each stage for the next few bars and then applied criteria to select the preferred continuation. The program of Xenakis composed in a style similar to that of his noncomputer instrumental works. Meertens's program also composed for string quartet but in a simple style using conventional rules for harmony and counterpoint and his own rules for melodies. In each of these cases output in a particular existing style was premeditated. No such style was sought for my ZASP program: what was desired was whatever emerged form the algorithm. Different approaches were more than tolerated—they were celebrated.

During the informal session, Stanley Gill suggested. At that I should consider starting a group for computer composition while so many interested people were assembled, many of whom had never before met anyone outside their own teams who had worked on computer composition. I immediately said that I would try, but that it should not be for music only but for all the arts, because I had already been thinking that the same sorts of approaches could be used for composition in other art forms. After the meeting I put up a notice on the Congress bulletin board asking for names and addresses. On my return to Berkshire I sent out a proposal for a "Computer Arts Society" to the list of names and addresses I had collected in response to this notice (figure 14.1).

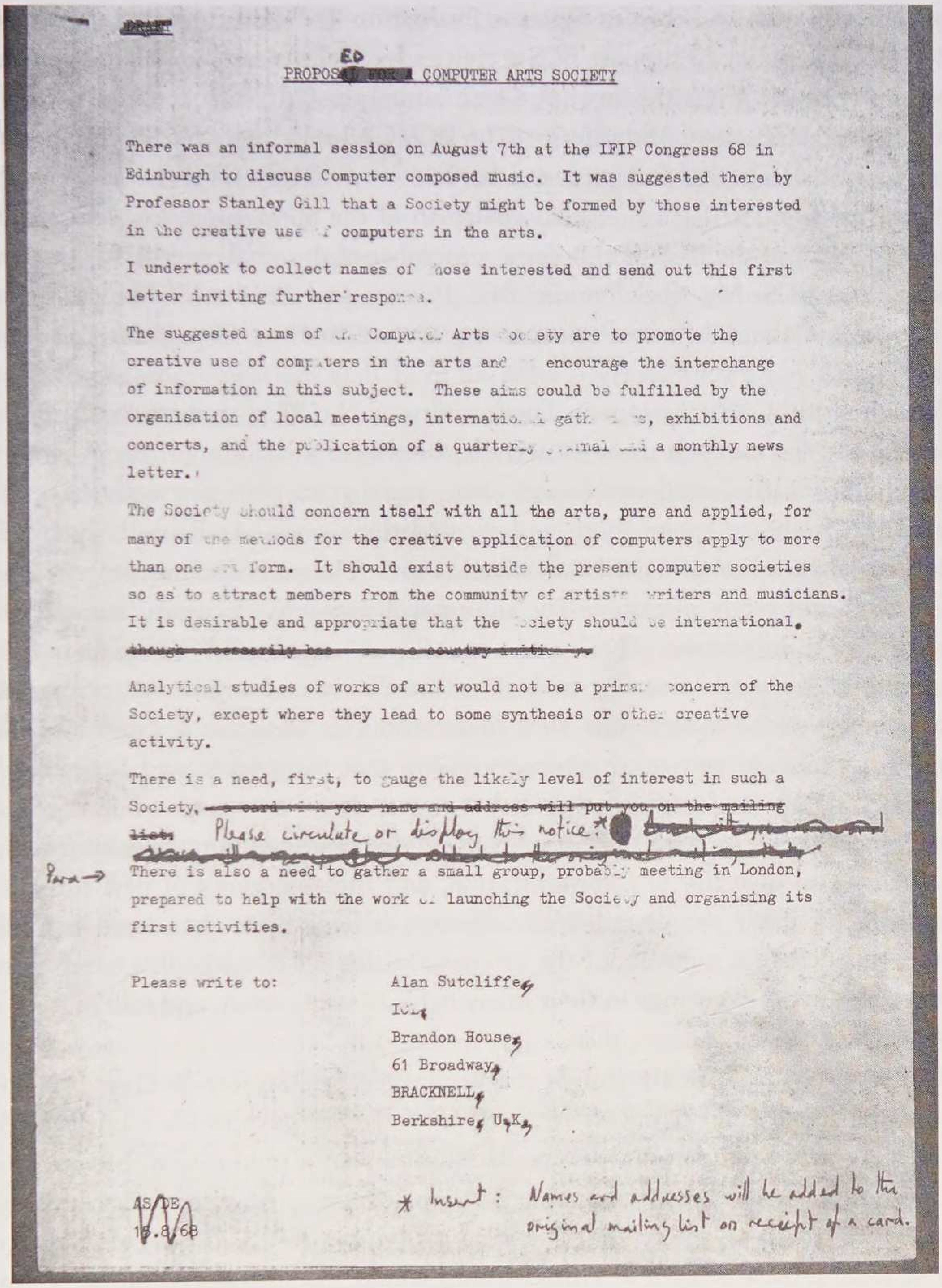
A first London meeting took place. George Mallen, Gustav Metzger, and John Lansdown were present. George became treasurer, John, secretary, and I was chairman. There was enough response to arrange a second meeting a few weeks later. There were six or eight of us at that meeting. None of us knew any of the others, but some lifelong associations developed from that seed.

I argued for a name that was plain and descriptive. "Computer Arts Society" says what the group is about. At our first meetings in late 1968 alternative names were suggested, more evocative but less informative: perhaps the name of a mythical beast or some such fancy. I was pleased that the name that was chosen combined the three overlapping domains that we operated in: computers, the arts, and society. We talked a lot over the years about how to spread more enlightened and intelligent uses of computers, first in the arts and then more widely in society.

The proposed aims remained almost unchanged for many years. They still underlie the wider and more diverse aims of the CAS that re-formed in 2005. My suggestions for fulfilling them were the obvious ones, and roughly what we did. There was only one publication, however, and not many concerts, but Electronic Music Studio made up for that by organising a series of concerts in London. Being concerned with all of the arts was my particular favorite goal and the mixing of people and ideas from all sorts of creative backgrounds was very fruitful and rewarding, and still is.

I had little idea how the CAS would become international, but we all believed it to be important, given its origin at IFIP, where a few names from overseas were collected, and given that the community was small, particularly in areas such as computer music. By April 1970 there were 254 members in the United Kingdom and 123 overseas members from sixteen countries, almost half of them from the United States. Soon there were branches in Holland and the United States, serving the communities in those countries as well as contributing to the international dimension. What made this happen was that the CAS filled an emerging need, and there was no similar international group.

I made a big mistake in suggesting that the group should be outside the existing computer societies. Becoming a specialist group of the British Computer Society (BCS) was proposed at an early meeting and I opposed it, thinking that it would deter some people in the arts from joining. The majority thought otherwise, and they were right. The benefits were and are substantial. There is no way of knowing if some artists were put off. Oddly, I think I was the only full BCS member among the initial group. At the time I worked at International Computers and Tabulators (ICT; later International Computers Limited, or ICL) in Bracknell, as manager of



~~DRAFT~~

ED

PROPOS~~AL FOR A~~ COMPUTER ARTS SOCIETY

There was an informal session on August 7th at the IFIP Congress 68 in Edinburgh to discuss Computer composed music. It was suggested there by Professor Stanley Gill that a Society might be formed by those interested in the creative use of computers in the arts.

I undertook to collect names of those interested and send out this first letter inviting further responses.

The suggested aims of the Computer Arts Society are to promote the creative use of computers in the arts and to encourage the interchange of information in this subject. These aims could be fulfilled by the organisation of local meetings, international gatherings, exhibitions and concerts, and the publication of a quarterly journal and a monthly news letter.

The Society should concern itself with all the arts, pure and applied, for many of the methods for the creative application of computers apply to more than one art form. It should exist outside the present computer societies so as to attract members from the community of artists, writers and musicians. It is desirable and appropriate that the Society should be international. ~~though necessarily bas [illegible] country [illegible]~~

Analytical studies of works of art would not be a primary concern of the Society, except where they lead to some synthesis or other creative activity.

There is a need, first, to gauge the likely level of interest in such a Society. ~~a card with your name and address will put you on the mailing list.~~ Please circulate or display this notice.* ~~[illegible]~~

Para → There is also a need to gather a small group, probably meeting in London, prepared to help with the work of launching the Society and organising its first activities.

Please write to:

Alan Sutcliffe,
ICL,
Brandon House,
61 Broadway,
BRACKNELL,
Berkshire, U.K.,

AS/DE
1[illegible].8.68

* Insert: Names and addresses will be added to the original mailing list on receipt of a card.

Figure 14.1 Alan Sutcliffe, original letter proposing the Computer Arts Society.

New Series Branch and then of Systems Evaluation and Development Department, and it was ICL policy to support BCS activities by staff. As well as getting computer time for my music programs, my office maintained the CAS membership list and the mailings of *PAGE*, the CAS bulletin. (The BCS/CAS relationship had a big effect on my life in the years that followed as I became increasingly involved in BCS activities. In 1978 or 1979 I was elected chairman of the Specialist Groups Board, was a vice president of the BCS, and became a member of the small executive committee running the BCS. My work on the BCS Privacy and Public Welfare committee led me to join the All-Party Parliamentary Committees on IT and on Freedom of Information.)

The monthly CAS meetings in London, first at the ICA, then at the BCS headquarters, and for many years at Russell Square, were a delight to me. A group of like-minded multitalented enthusiasts came together to plan new activities. Often a visitor from abroad spoke about and showed their work. At Russell Square, Dot Lansdown always brought generous refreshments. The activities we proposed were self-evident and rarely disputed. The informal discussions at committee and other meetings were important. There was enough commonality of views to maintain the group and enough diversity to ensure some lively exchanges. For example, we were opposed to the reductionist view that computers were just another tool. John Lansdown wrote an essay on this topic, arguing that computers used imaginatively go far beyond any earlier human tools.[5] It is wonderful to see how our vague and dimly perceived hopes have since been realized, for example by massively increasing the quality and quantity of communication, and the emergence of new interactive art forms. But many people still see computers as little more than another toolkit. To me, this debate is more about the extent to which we should allow computers to change the way we do things in their many fields of application, and talk of tools is a semantic diversion.

It was agreed to formally launch the Computer Arts Society at *Event One*, to be held at the Royal College of Art in March 1969. That gave us six months: plenty of time. At least as important was the decision to start a publication, because many members were outside London, some of them overseas. Most remarkably Gustav Metzger offered to be the editor. The publication was called *PAGE*, after the concept of paging (now known as virtual store), which was introduced on the Ferranti Atlas computer. *Event One* took place on March 29–30, 1969, and the first edition of *PAGE* appeared in April, edited by Gustav and including his review of *Event One*.[6]

During this period *Cybernetic Serendipity*, organized by Jasia Reinhardt, took place at the Institute of Contemporary Arts (ICA) in London. Some of the people who were becoming involved in the CAS also took part in this event. For example, George Mallen was working with Gordon Pask on his exhibit, and I was helping Peter Zinovieff, who had the PDP 8 and other studio equipment on exhibit. *Cyber-*

netic Serendipity helped the CAS to extend its membership, especially among people in the arts.

Who gets credit for supporting the CAS? First, the BCS. I cannot recall ever hearing, in over ten years and hundreds of meetings, a negative remark about the CAS by BCS members or staff. Our work was respected and supported. My only misgiving was that I occasionally felt we were being asked to contribute to an event for our novelty value, and that some took our work less seriously than we did. Many firms in the computer industry gave support of many kinds, including my own employer in the early years, ICT/ICL. It was wonderful to visit Cedric Dickens, sometime head of communications at ICL, in his office overlooking Putney Bridge in the new shiny tower block of ICL House. His office had a lovely Indian carpet, antique furniture, and a grandfather clock. Truly Dickensian: he was a descendent of Charles. He saw computer arts as good publicity, giving a human face to an industry that many people saw as threatening. He ensured that the CAS got good press coverage. The computer press was always interested and ready to help. Malcolm Peltu, when he was editor of *Computer Weekly*, had a particularly enlightened view and came to several CAS meetings. He allowed a lengthy argument to run in the correspondence column between Donald Michie and me about whether new information could be created by program, as I had claimed. At the point when Peltu finally said *Hold, Enough!* I believe Michie was saying that information could not be created, it was always there. I am still pondering that one. Peltu took part in and reported on a lively debate on computers in poetry at the Poetry Society in a joint meeting with the CAS.[7]

The national press were less enlightened. On February 20, 1969, I had the following letter published in *The Guardian*:

> The intensions of the Computer Arts Society were seriously misrepresented by Miscellany (February 13). Neither "theatrical outrage" nor "a day of programmed japes" are aims of Event One, which we are organising at the Royal College of Art on March 29.
>
> Our immediate aim is to show something of the possible creative uses of computers in a number of the arts. Equipment and programmes will be available for artists to use. There will be performances of works in which computers have been used. Naturally, some of what we can present will be more demonstrations than works of lasting value.

With one exception, the arts press largely ignored the CAS. Jonathan Benthall wrote several times in the now sadly defunct *Studio International* and elsewhere. In particular he criticized my view that the norms of critical assessment should be relaxed in relation to so new a phenomenon, to give it time to find its way. In his view any such indulgence would undermine critical integrity. While I never suggested a specific limit, I always thought the arrangement temporary, the suspect being below the age of responsibility. (The time of this special deal has long gone now.) I argued that whatever creative uses were found for computers were of interest and to be encouraged. I had in mind the works of Lloyd Sumner, the first person to earn a living selling computer graphics. Some of his works could be dismissed as only suitable for greetings cards and I think some were offered in that form. But others were not so different from the computer graphics of Herbert Brün, which he used as graphical scores for his music, which was his main interest. Are they to be judged by their uses? Not by me, and not at that time. I think the general philosophy in the CAS was to not be judgmental; "aesthetics" was a word never to be used. Sydney Paulden, then a journalist, became the publicist for the CAS, and ensured good promotion for our events. The Arts Council made a grant of £250 for *Event One*. The Scottish Educational Trust made a substantial grant for *Interact* in Edinburgh, an exhibition of interactive computer-based artworks and performances.

John Lansdown and I spoke frequently at CAS events and accepted many invitations to speak to other groups as well. A few of these were invited contributions to bigger events but they were mainly single shows, and were always an opportunity to promote the CAS. I appeared, speaking or performing, at a dozen or more locations across North America and Europe. Easily the most memorable for me was a talk at Aldeburgh Festival. Early in 1969 the CAS got an invitation, via ICL, to provide a speaker for Aldeburgh in June. It was agreed that I would go. It was for a morning weekday session in a modest hall near the seafront. Benjamin Britten and Peter Pears attended, and there was a reasonable-sized audience. I spoke about and played recordings of Lambert Meertens's Quartet, and works by others and myself. I was invited to lunch at the Red House where Britten and Pears lived. I remember the day for two remarkable things that Britten said. As we walked out of the hall together, Britten said that Meertens's piece reminded him of the sort of music that he wrote when he was eight. I said that that must be a great compliment, especially as Lambert was only a two-year-old in composition when he wrote his quartet. Britten was happy with this.

At lunch another guest asked Britten who he thought was the greatest living composer. Without hesitation or qualification he said Shostakovich. I was startled: Stravinsky was still alive. I suppose he was used to such questions. On the way home I thought about how I would have replied, uncertainly questioning the validity of the concept and probably offering a short list. I was impressed by the open-mindedness of Britten and Pears, compared with the indifference and incomprehension of most of the musical establishment.

The CAS had one memorable social event: the Mushroom Hunt as a tribute to John Cage. This was a coach trip I organized to Bracknell to see the junk farm for chaos, to Basingstoke new town center to see the boring architecture and on to Stonehenge, that ancient astronomical compute, and Silbury for its mystery. A grand day out. I would have liked to have more social events. In 1973 Kurt Lauckner, chairman of the CAS US branch, organized Circuit, a week of workshops at Eastern Michigan University in Ann Arbor, Michigan. Kurt, Bob Weinberg, Ken Knowlton, and I suggested and took part in projects. The students, mostly having an arts background, were taught the elements of programming and made works in text and graphics. There are photographs from Circuit on the front of issue 30 of *PAGE* (produced by CAS US), but I cannot find any review of the event.

My activities with Peter Zinovieff's Electronic Music Studio were also continuing during this time. In October 1968 (soon after IFIP) Peter and I went to the Internationale Woche der Experimentellen Musik at the Technische Universität in Berlin. I made two short contributions. At one general session, I made a speech in German: "Die Elektronische Musik ist tot." This was the sum total of the speech, all I wished to say, and reached the limit of my fluency in German. The two meanings were both intended: Electronic music is dead when compared to most other music, which is live, with all the uncertainty and excitement of performance. And for this reason electronic music was dead, finished, kaput.

Being a devout anti-intentionalist, though I did not know the term until 2004, I usually said little or nothing about what I did or why I did it. From that day to the present, Peter maintains that *tot* means *everything* so that what I said meant *Electronic music is everything*. It is one of his many teases, I think. These contributions in Berlin, like much else in my work, have been sparked by something like sibling rivalry with Peter.

One morning in Berlin I went into East Berlin on my own. I only had time to walk down Unter den Linden and back. I was upset at the military trappings of this seemingly still Prussian state, particularly the goose-stepping guards at the war memorial and the grimness everywhere: from the faces of guards and people to the dilapidated neo-classical buildings, reminders of the Third Reich. But back in West Berlin I was equally disturbed by the consumerism and the claustrophobia: The siege was palpable, but nobody spoke about it on the bright, prosperous streets or in the serious academic sessions. As a good tourist, though, I bought a set of slides showing the Wall with its watchtowers and defenses.

The next day I was scheduled to speak about my work on computer composition at an informal session. I gave the slides of the Wall to the projectionist and asked him to show them. I said nothing. I had no idea what the reaction would be. This was my piece. It got some applause. Jon Appleton from Dartmouth College particularly liked it: In the same session, I believe, he spoke on cultural politics. Another member of the audience was an organizer of modern music events in Berlin. He invited me to produce a piece and return to Berlin for its performance.

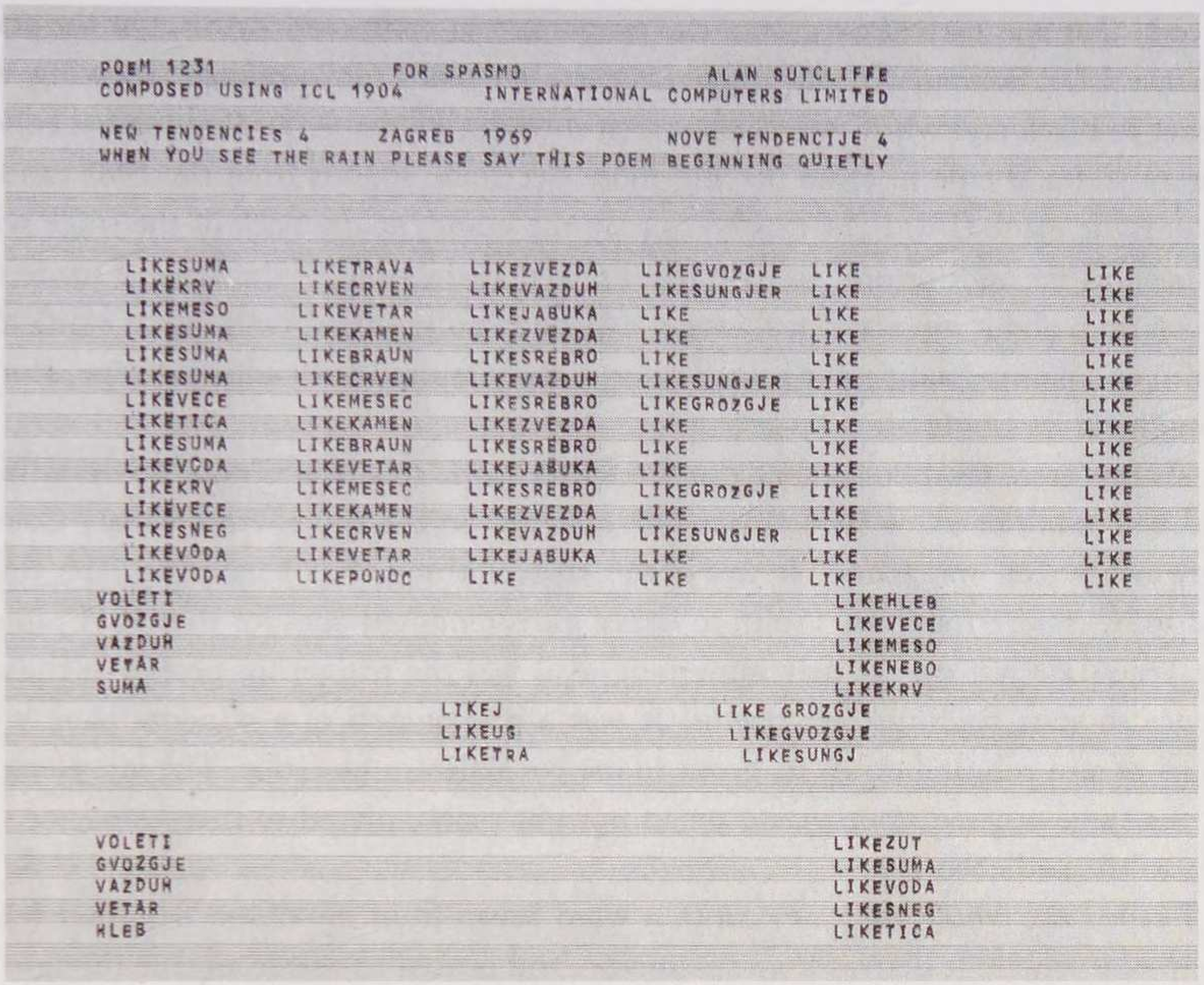
One evening Peter went with me to visit Boris Blacher, head of the music academy, top of the music hierarchy in Berlin, a position previously held by Richard Strauss. I had heard mumblings against him at the conference, so our visit was a bit subversive. I had got to know him slightly at Dartington summer school, though I did not study with him there. I was impressed when he hailed a taxi outside the academy to take to his home on the edge of the city; all the driver said was "Do you wish to go home, Herr Professor?" During the evening I mentioned my misgivings about electronic music and the use of computers. He said directly that I should continue with it, kindly, as though speaking to a faltering student. I had not been seeking his advice as much as wanting to hear his views. I had the impression he thought it would be good for my career, though I never considered having one, and certainly not in music.

On Friday morning there was a formal session on computer music and Peter gave his talk, "The Use of Small Computers in the Production of Electronic Music." Other speakers were Pietro Grossi from Florence and Godfried Michael Koenig from Utrecht, both at well-known studios in those cities. Then we left for home, unfortunately missing the afternoon session and the closing concert, which included the first performance of a work by Blacher, his only participation in the conference.

After my return home, I wrote a piece called *SLIDE SHOW* for speaker and computer generated sounds on tape, accompanied by some slides. I decided that the text should be in German and selected an item from my visit to East Berlin: a stirring but totally Orwellian propaganda handbill. The performance was in a small theater and I stood in the wings. The piece was no more than ten minutes long and as it progressed the audience became increasingly agitated. At the end there was uproar. My sponsor explained that they thought I was a communist, and that I should go on stage and explain. Explain what, I wondered—irony? random selection? Anti-intentionalism prevailed. They thought I was a communist. They would have to figure it out for themselves. I have often wondered if I should have confronted the audience, gone on the stage and ripped up the text saying "Es ist Scheiße," in English, "It's shit." I daydream of the acclamation. I was not invited to Berlin again.

In the autumn of 1969 I took three months leave from ICL to visit the Computer Music Studio in the University of Illinois, with side trips to see Ken Knowlton and others at Bell Labs in New Jersey; Charles Mattox at the University of New Mexico in Albuquerque (he was also US correspondent for *Leonardo*, having been a rocket scientist in the 1930s); Katy Nash and colleagues at the University of Minnesota in Minneapolis; Jerry Hiller in Indianapolis; and a visit to the University of Southern Illinois at Carbondale. Amazing hospitality.

After *SLIDE SHOW* my thoughts moved to questions of how to elicit audience participation for another EMS concert. To take place at the Queen Elizabeth Hall in London in February 1969. This was before *SLIDE SHOW* was staged in Berlin. I composed *SPASMO*. Every member of the audience was given a program with a front cover made of aluminium foil that was a little thicker than baking foil. By doing this, Peter as concert organizer, ensured that every piece would be accompa-



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POEM 1231               FOR SPASMO              ALAN SUTCLIFFE
COMPOSED USING ICL 1904       INTERNATIONAL COMPUTERS LIMITED

NEW TENDENCIES 4       ZAGREB  1969          NOVE TENDENCIJE 4
WHEN YOU SEE THE RAIN PLEASE SAY THIS POEM BEGINNING QUIETLY



    LIKESUMA     LIKETRAVA   LIKEZVEZDA   LIKEGVOZGJE  LIKE                LIKE
    LIKEKRV      LIKECRVEN   LIKEVAZDUH   LIKESUNGJER  LIKE                LIKE
    LIKEMESO     LIKEVETAR   LIKEJABUKA   LIKE         LIKE                LIKE
    LIKESUMA     LIKEKAMEN   LIKEZVEZDA   LIKE         LIKE                LIKE
    LIKESUMA     LIKEBRAUN   LIKESREBRO   LIKE         LIKE                LIKE
    LIKESUMA     LIKECRVEN   LIKEVAZDUH   LIKESUNGJER  LIKE                LIKE
    LIKEVECE     LIKEMESEC   LIKESREBRO   LIKEGROZGJE  LIKE                LIKE
    LIKETICA     LIKEKAMEN   LIKEZVEZDA   LIKE         LIKE                LIKE
    LIKESUMA     LIKEBRAUN   LIKESREBRO   LIKE         LIKE                LIKE
    LIKEVCDA     LIKEVETAR   LIKEJABUKA   LIKE         LIKE                LIKE
    LIKEKRV      LIKEMESEC   LIKESREBRO   LIKEGROZGJE  LIKE                LIKE
    LIKEVECE     LIKEKAMEN   LIKEZVEZDA   LIKE         LIKE                LIKE
    LIKESNEG     LIKECRVEN   LIKEVAZDUH   LIKESUNGJER  LIKE                LIKE
    LIKEVODA     LIKEVETAR   LIKEJABUKA   LIKE         LIKE                LIKE
    LIKEVODA     LIKEPONOC   LIKE         LIKE         LIKE                LIKE
VOLETI                                                  LIKEHLEB
GVOZGJE                                                 LIKEVECE
VAZDUH                                                  LIKEMESO
VETAR                                                   LIKENEBO
SUMA                                                    LIKEKRV
                           LIKEJ                LIKE GROZGJE
                           LIKEUG                LIKEGVOZGJE
                           LIKETRA                LIKESUNGJ



VOLETI                                                  LIKEZUT
GVOZGJE                                                 LIKESUMA
VAZDUH                                                  LIKEVODA
VETAR                                                   LIKESNEG
HLEB                                                    LIKETICA
```

Figure 14.2 Alan Sutcliffe, example of *SPASMO* poem.

nied by the sound of people trying not to make a sound. Each A4 program also had an individual copy on line printer paper of a concrete poem produced by my program running on an ICL 1900 computer. There were four controls affecting the layout of the words and each one had four possible values. Each run of the program went through all 256 possible combinations of these values, printing that number of poems per run. Over one thousand poems were needed for the concert. The content of the poems came from a passage in *Waiting for Godot*. The vocabulary was a development of this with words grouped by their number of letters. A line printer uses a fixed width font so the number of characters fixes the width of a word on the page (figure 14.2).

Each poem had a serial number made by the values of the four controls, so the numbers ran from 1111 to 4444 in a modified base four. Words of a required length were selected from the vocabulary somewhat at random. Random values affected the rules used to determine each layout, so that both the form and the wording of the poems changed from one run of the program to another, assuming the random number generator was seeded differently. The random number generator was the only bit of code that was carried over from the program that composed ZASP. On the stage was the PDP 8 (there for the whole concert), an 8mm film projector showing war scenes in black and white, the main screen showing my haphazardly updated collection of slides, a tape recorder playing more electronic sounds from the EMS studio, an upright piano (I was not trusted to play the grand) at the back of the stage with its back to the auditorium, and a colored screen at the front of the stage. I made the screen from about five six-foot sheets of expanded polystyrene, each cut to a different width and painted a different bright color, simply jointed with adhesive tape, sturdy enough for its single use.

To my great disappointment the fire officer came to the afternoon rehearsal and said he could not allow such flammable material on the stage. An ordinary dowdy brownish screen was found. It was better than nothing, but I hated it. The slides had to be transferred from 35mm to larger glass-mounted ones for the QEH projector. One slide was particularly important, as it was the trigger for people in the audience to start reading their poems. It was a photograph of a window pane with drops of rain running down it, given to me by Malcolm Le Grice. The last element on the stage was me improvising on an upright piano, placed so that I was not visible to the audience.

I called the whole work *SPASMO*, a word learnt from my oldest daughter when she was at school. It derives from spasmodic, and is used to deride anyone thought to be inadequate in some way. Art fails. Years later I mentioned the work to my friend in Wokingham, David Jackson. He was saxophone player with Van der Graaf Generator, who is now an improvising musician working mainly with children who have disabilities. David disapproved of the name; it reminded him of his own suffering at school. Unfortunately I cannot develop sensitivity retroactively, even if I wished to. The Oxford OED definition of *spasmodist* is one who affects a disjointed style.

In the months after the concert I used the poems on their own, sometimes under the name *LIKENESS*. One is reproduced in the catalogue of *Event One*. For *New Tendencies 4* in Zagreb I substituted a vocabulary in Serbo-Croat and sent a batch to Edvard Zajec for the *New Tendencies* exhibition in Zagreb.

The participation of the QEH audience was patchy and half-hearted. There were too many distractions; it was too easy not to join in. I resolved to make a work where it would be more uncomfortable to stay out than to join in. This was *BEHAVE: A Piece for Audience*. Each member of the audience was given instructions printed on an address label stuck to a piece of card. Each set of instructions had the same form but was different in detail. There were six lines of instructions on each card and the lines were labeled with the letters B E H A V E. This was a reference to the poem of the same name by Lewis Carroll, which mocks the authoritarian behavior of adults towards children, with couplets such as

```
B    SIT POINT SLOW SOFT   HUM
E STAND  WAVE FAST SOFT  SIGH
H    SIT   NOD SLOW LOUD SNIFF
A KNEEL  WAVE SLOW SOFT SPEAK
V  JUMP  GRIN FAST SOFT  SING
E  WALK SHAKE FAST LOUD GROAN
```

Figure 14.3 A sample instruction card from *BEHAVE*.

Close doors behind you
Don't slam them, mind you

The poem could be read in whole or in part, before or after the performance. Each instruction consisted of a body position, a gesture, and a vocal sound qualified by adjectives for tempo and dynamics: All were expressed in short words. The labels arose from a program which selected terms from a vocabulary roughly at random but weighted to ensure that, generally, later instructions would result in more movement than earlier ones: In the first line most labels were SIT or STAND, and in the last many were WALK or RUN (figure 14.3).

For a performance, a Leader explained the procedure. The Leader started the piece by shouting "B." When the Leader sensed that the dynamic of the group was flagging, or otherwise as seen fit, he or she would shout the next letter and the audience would obey the next line of instructions. The Leader could call "stop" after the last line of instructions or let the performance die out. Anyone who found it less embarrassing to sit out than to take part was ignored by the Leader: That is, no comment was made during the performance about their behavior, although the Leader did not explain this beforehand.

The Leader was sometimes replaced by output from a computer displayed on a screen. A performance of this version of the piece led someone to characterize my work as the Theater of Embarrassment: I like that, but have forgotten who coined the term. *BEHAVE* was often performed at CAS talks and other events. At a performance during a talk at Dartington Hall Summer School of Music around 1970, William Glock and his companion chose not to join in: After the talk he came to me and said that he realized he should have taken part. I thought well of him for that: He was musical director of the Summer School and controller of music at the BBC.

Another, similar work was *PEOPLE PIECE*, which I believe was first performed at *Interact* in Edinburgh in 1973, and has the following instructions:

Procedure for an audience:
    Start if you hear the Leader say START
    If you are not standing, stand up

A Stop if you hear the Leader say STOP
If you can, take a step forward: go to A
Else turn left by about a right angle: go to A

The Leader could arrange for other things to happen such as the playing of music.

In Edinburgh about thirty people took part in a conventional lecture theater. Gradually each one found his or her way off the row where started, into the aisles and around the platform, with fewer person-to-person confrontations, as they spread out into the more open areas. A door was open at the back of the lecture room and some people escaped. No computer was used in the composition or performance of this piece. One of my people procedures appears in *PAGE* 19. There was another on a CAS flyer for one of the EMS concerts. Neither involved the use of a computer but did embody the notion of a procedure. In a few years I went from the standard model with the composer in near complete control, achieved through a program in ZASP for a concert setting, to giving open instructions to a group of people in any setting and eventually not using a computer.

I was involved with many other musical activities in the 1970s, including playing in the Scratch Orchestra, making electronic music for drama and dance, starting Bracknell Play Group, involving improvising for amateurs, chairing a chaotic meeting of improvising musicians who wanted to start a National Musicians Collective based on the successful London Collective, writing articles for *Personal Computer World*, the *Computer Bulletin*, and *Video International*, and a remarkable trip to the New York Institute of Technology. During the mid- to late 1970s John Lansdown took on more of the running of the CAS as my interests turned elsewhere. By 1978 difficulties at EMS were a preoccupation. In 1979 I was elected chairman of the Specialist Groups (SG) Board of the BCS. This disqualified me from being chairman of a specialist group. John Lansdown represented CAS at the SG board that I chaired. In the same year, I left System Simulation Ltd., the company founded by George Mallen, where I had been working part time since 1973, and in 1980 EMS was liquefied.

The last notable project at SSL was in 1978. Ridley Scott and his colleagues wanted six or seven sequences for the film *Alien*. I got the job of making thirty seconds of animation for the terrain where the module lands. An article written at that time describes my part of the project. The work resembled ZASP, in several ways. It was all done in the evenings and on weekends; it was completed just in time, with the first complete output being the one used; it involved about the same amount of effort and programming; and it included a variety of processes to get interesting sounds or landscapes.

Only two of my sequences were chosen for the film. It was exciting attending the technical preview in Leicester Square in London not knowing which bits were in and which were not. Selection was clearly based on relevance to the plot or the editor's whim, not on intrinsic merit as animation. Some of what was left out was worth seeing and was used by Ridley Scott in other films. I learned only recently from George Mallen that soon after *Alien* was released, System Simulation Ltd. was contacted by a worried American intelligence agency claiming an uncanny resemblance between my animation and an "advanced" system they were developing. Had I infiltrated their network?

These were important years for me, both in the CAS and for the work I was doing at ICL, EMS, and SSL. I am indebted to all the remarkable people I met, and above all to Peter Zinovieff. This account, based on recollections of thirty years ago and biased by what was important to me, sometimes backed by documents that survive, is presented with my best wishes to those who think or know differently.

Notes

1. Stanley Gill, "A Technique for the Composition of Music in a Computer," *The Computer Journal* (1963): 129–133.

2. Alan Sutcliffe, "Programming to Make Music," *Computer Weekly* (August 8, 1968).

3. Unpublished paper.

4. Ibid.

5. John Lansdown, "Is the Computer a Tool?—The Question in an Art Context," in *Is the Computer a Tool?*, ed. Bo Sundin (Stockholm: Almqvist & Wiksell, 1979).

6. David Howarth designed and wrote much of the Supervisor (the operating system) for Atlas, and I believe that paging, the first form of virtual store, was his idea. Mike Baylis, David Fletcher, and David Howarth presented a paper (M. H. J. Baylis, D. G. Fletcher, D. J. Howarth, "Paging Studies Made on the I.C.T. Atlas. IFIP Congress 1968, vol. 2, 831–837) on the performance of paging at IFIP 68. At that time I did not know any of them. Each separately and subsequently joined the department I managed at ICL Bracknell. David Howarth left to become a professor at the Institute of Computer Science (ICS) at London University, based at 43 Gordon Square, later home of the CACHe project. In terms of computer storage hierarchies, cache is the name for a type of intermediate store. I did not favor the name *PAGE* when it was proposed. Having worked as a systems programmer for over five years, paging and its derivatives were well known to me. Paging was just another bit of systems jargon, while to some of the others it was evocative of an esoteric new technology. (Also I had no part in naming or starting the CACHe project.)

7. Malcolm Peltu, "Poetry by Program—Sans Emotion," *Computer Weekly* (May 3, 1973).

15

Bridging Computing in the Arts and Software Development

George Mallen

Beginnings

In 1969 the Computer Arts Society had been formed and held its first exhibition at the Royal College of Art. Also in that year the Society had been approached by the Business Equipment Trade Association to design a theme exhibit for its planned exhibition on computers in 1970 called *Computer 70*. Our response to that was *Eco-game*, which was first implemented at Olympia for *Computer 70* and then in Davos for the First European Management Forum in 1971.

In the early 1960s I was working in the mathematics department of the Royal Aircraft Establishment at Farnborough on digital simulation models of air traffic control systems. I had begun to discover the emerging subjects of cybernetics and artificial intelligence and came to understand that computer simulation could be an entirely new means of scientific investigation and that, particularly, it might help us understand thought processes. When it became clear I could not pursue such ideas at Farnborough I got in touch with my former mathematics tutor, Richard Goodman, who was beginning the process of creating a cybernetics department at Brighton Polytechnic. Goodman put me in touch with Stafford Beer who put me in touch with Gordon Pask, a leading member of the British cybernetics school. In late 1964 I left Farnborough, the world of "big science," to join Pask's System Research Ltd., a small freelance research group based in Richmond, Surrey.

I worked at System Research Ltd. from 1964 to 1971, as deputy research director from 1967 on. My main focus was a Home Office–funded project developing simulation methods for evaluating crime/criminal intelligence, but I also worked closely with Pask and Brian Lewis on the learning theories emerging from Pask's work on adaptive teaching machines. I also helped out on other projects such as the

Colloquy of Mobiles, which Pask designed and Mark Dowson and Tony Watts built for the *Cybernetic Serendipity* exhibition in 1968. This was my first involvement with the arts world and began a continuing quest into the nature of the two cultures. There was much discussion and speculation on things like the legendary *Fun Palace* with Cedric Price and Joan Littlewood. Through Mark Dowson I came into contact with the composer Peter Zinovieff and with Alan Sutcliffe. This led to my involvement with Sutcliffe, John Lansdown, and others in founding the Computer Arts Society.

It was a very stimulating period and I was privileged to be able to work with and benefit from the projects, discussions, arguments, and the many distinguished visitors who passed through the System Research Ltd. labs above the launderette in Richmond. However by the late 1960s it was becoming clear that the funding environment for System Research was becoming harsher. A substantial part of its funding had come from the U.S. military, via their several research offices such as the Air Force Office of Scientific Research, and this was shrinking. The United Kingdom environment also turned chillier. The research councils had decided to initiate artificial intelligence funding with Donald Michie's group at Edinburgh in spite of stalwart efforts by Donald Broadbent, director of the Applied Psychology Research Unit at Cambridge, and others, to get some of the AI funding into the kinds of thing we were doing at System Research Ltd. The Home Office's research policies began to focus more on equipment development and forensic science and moved away from operational research and decision modeling.

Eventually I moved on, setting up System Simulation Ltd. with Mike Elstob, who worked with me on the police simulation project. In 1970 I was offered and took up a part-time research fellowship in the Design Research Department at the Royal College of Art, and Elstob joined Frank George's new Cybernetics Department at Brunel University. Thus we tried to create a company that, following the System Research model, sought to work at the leading edge of our field with strong academic connections but at the same time applying these ideas in the real world. My first involvement with the art world was around 1967 when Pask drew up plans for his *Colloquy of Mobiles* installation for the *Cybernetic Serendipity* exhibition, well documented elsewhere in this book. Though my role in this project was minor, helping with wiring, transport, and assembly, the contacts made with the beginnings of a community of computer people seeking to explore the more playful aspects of the new technology were to be a big influence and last most of my professional life. A few of us were also attending the International Federation of Information Processing Societies (IFIP) Congress in Edinburgh in 1968 and it was there that a meeting was set up by Alan Sutcliffe and Stanley Gill at which it was agreed that a society to further the use of computers by artists would be useful. The Computer Arts Society was subsequently formed as a Specialist Group of the British Computer Society, with Alan as chair, John Lansdown as secretary, and me as treasurer.

At that time my access to computing resources was very restricted. My work at Farnborough had been carried out on the Ferranti Mercury using Mercury Autocode running under the CHLF compiler. CHLF stood for Cern, Harwell, London (University), and Farnborough, these being the main Mercury sites. One of the costs of leaving "big science" was that I no longer had access to such computing facilities; a usable digital computer was well beyond the resources of a small firm like System Research. My route to computing resources was to register for a PhD project under Richard Goodman at Brighton Polytechnic. That gave me access to the college's ICT 1301, which was a descendant of the Mercury, also using Autocode and paper tape. I developed models of Pask's learning theories on this machine. But I had to drive down to Brighton to use it. When I got to the stage in my Home Office crime intelligence project of developing a computer model detective decision making of that I was able to use the Home Office IBM 1401. This was easier to access—a twenty-minute train journey rather than a sixty-mile drive. By 1969 remote access computing was becoming available and I bought into the Telcomp time sharing service. This comprised a teletype and a large, slow, 110-bits-per-second, post office modem. I installed these at home, because night rates were cheaper, and continued developing the learning models. I cite this little bit of history because it meant that when it came to seeking resources and helping artists get connected I knew the problems from firsthand experience.

By 1970–1971 the Computer Arts Society was well into its stride: It had mounted the very successful *Event One* exhibition at the Royal College of Art in 1969; it had triumphantly executed the first version of the *Ecogame* project, described below; it was collecting works and loaning them out for exhibitions; its *PAGE* journal had established an international readership; it was running Sunday morning programming training session at Telcomp's office in London for artists; John Lansdown was writing regular columns for the BCS's *Computer Bulletin*; and it sponsored some music composition. At the same time, individual members were involved in projects of their own, John Lansdown with his CAD, graphics, and choreography, Alan Sutcliffe with music generation and performance, Tony Pritchett with graphics and animation, Robin Shirley with poetry and performance, Stephen Willats with his interactives, John Lifton with dance, and many, many others.

System Simulation Ltd. was very much on its learning curve at this time and beginning to make its way in the world. My time was split between the company, (which had a number of projects: several from the Home Office; the second implementation of the *Ecogame* project; some early computer graphic commissions for advertising, and the development of interactive financial planning and decision support software), the Royal College of Art (where I was continuing the development of cognitive models in research into design processes), and the Computer Arts Society. The next sections describe these various projects and activities.

Ecogame

Sometime in 1969 the creative phenomenon of John and Christine McNulty appeared at a CAS meeting with a device called an acoustic coupler. They told us that BETA (the Business Equipment Trade Association) wanted a stand designed for its *Computer 70* trade exhibition to be held at Olympia in September 1970, which would dramatically illustrate the way computing might affect our future lives. Acoustic couplers were devices for attaching a telephone handset directly to a modem for dial-up access to a computer, and Lansdown had the idea of installing a number of these in a small geodesic dome to illustrate online interactive computing. The photographer Antony McCall was also involved and the notion was to have computer-controlled 35mm slide projectors showing pictures in the small dome, producing an online photographic art show.

At this time, as a result of my work at System Research Ltd. on learning and teaching, I had become increasingly interested in the potential of computer simulation as an educational tool and proposed that we make a simulation model of an economic system and use that as the basis for an interactive game in which players would make decisions and have the results fed back via the slide projectors. There were some pretty robust discussions about whether this was feasible at the CAS meetings about the proposal for BETA. In the end the idea was adopted and BETA accepted it.

The project that emerged was very challenging. It brought together technologies that had never worked together before by a team of people who had never worked together before. Looking back it was very high risk but those of us involved were hopelessly optimistic and totally committed, which are key factors in an innovation. The McNultys were geniuses at conjuring support in the form of new equipment, and for the final installation at Olympia we had the first nine Tektronix graphics terminals in Europe with tracker ball interaction, acoustic couplers to link the terminals to a remote time-sharing computer, computer-controlled slide projectors from Electrosonic, and an Idiiom minicomputer-driven interactive graphics system with large screen and light pen interaction, which was also linked to the remote computer using an acoustic coupler (figure 15.1).

Figure 15.2 is a schematic of the economic model at the heart of *Ecogame*, which was shown on the interactive graphics computer screen driven by the minicomputer and could be set in motion and controlled using a light pen.

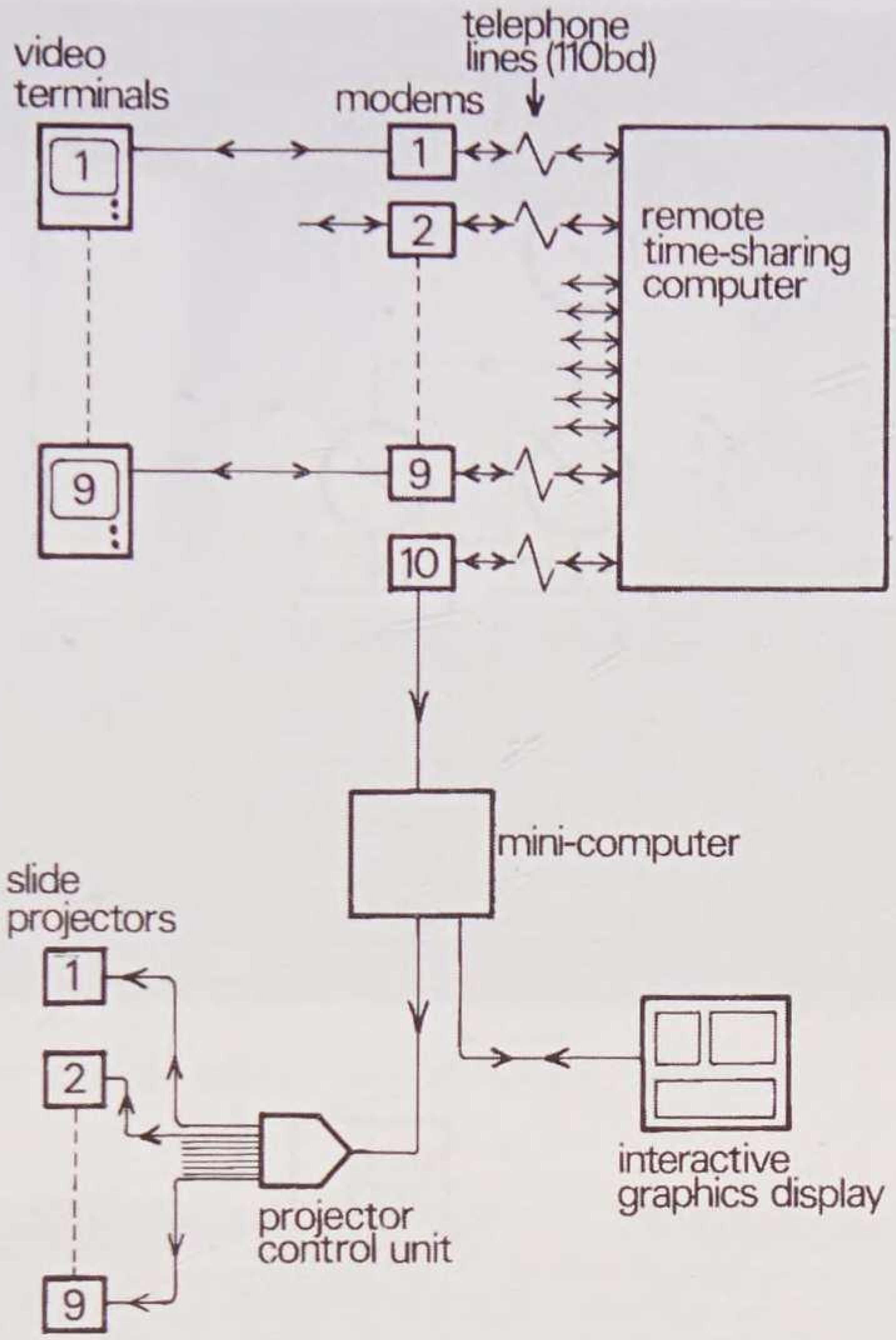


Figure 15.1 The hardware architecture for *Ecogame.*

Figure 15.3 shows the implementation inside the geodesic dome at *Computer 70* at Olympia in London in the autumn of 1970.

As part of the buildup to *Computer 70* we ran a version of the game in the offices of Time Sharing Ltd., which were providing the central computer to which the terminals were linked. The game was played by journalists from the main Sunday newspapers—the *Sunday Times*, the *Observer*, and the *Sunday Telegraph*. It got a good write-up, but there was a newspaper strike that Sunday so the story did not get wide circulation in the United Kingdom. Nevertheless, it did get some, and it caught the attention of a team led by Klaus Schwab at the Centre d'Etudes Industrielle in Geneva who were developing the program for the First European Management Forum, the forerunner of the World Economic Forum, scheduled for Davos in February 1971.

Happily the first installation at *Computer 70* (figure 15.3) was very successful and certainly met the requirement of showing how computers might be used in the

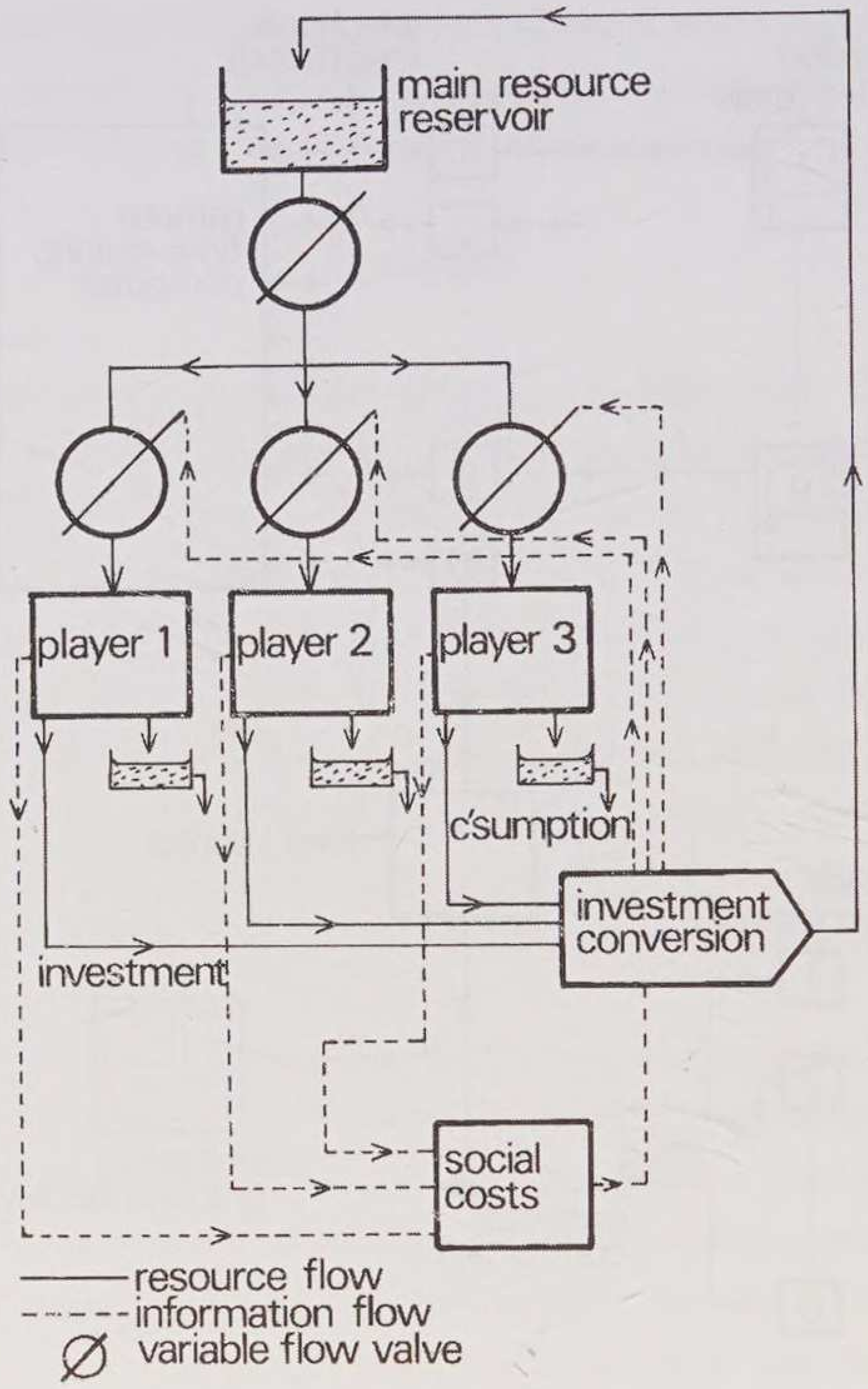


Figure 15.2 Schematic of the economic model in *Ecogame*.

future, with remarkable prescience. I believe it was the world's first interactive, multimedia, computer-controlled game and the result of an extraordinary collaborative team effort. The model's themes of competition and cooperation in economic systems and the impact on resources caught the beginning of the environmental movement. Norman Solomon from the Centre d'Etudes Industrielle came to see it and we immediately began negotiation to build a second implementation for the First European Management Forum. I took on the leadership of this project and SSL was contracted to implement it.

The Davos implementation used the same hardware team as for Olympia but without the geodesic dome. The game was set up in an auditorium of the Davos Kongresshaus where it was presented as part of the educational support program for the main conference (figure 15.4).

The game was played by many leading business people and politicians and was well received again, fulfilling its aim of showing what computing might be capable

Figure 15.3 *Ecogame* inside the geodesic dome at Olympia.

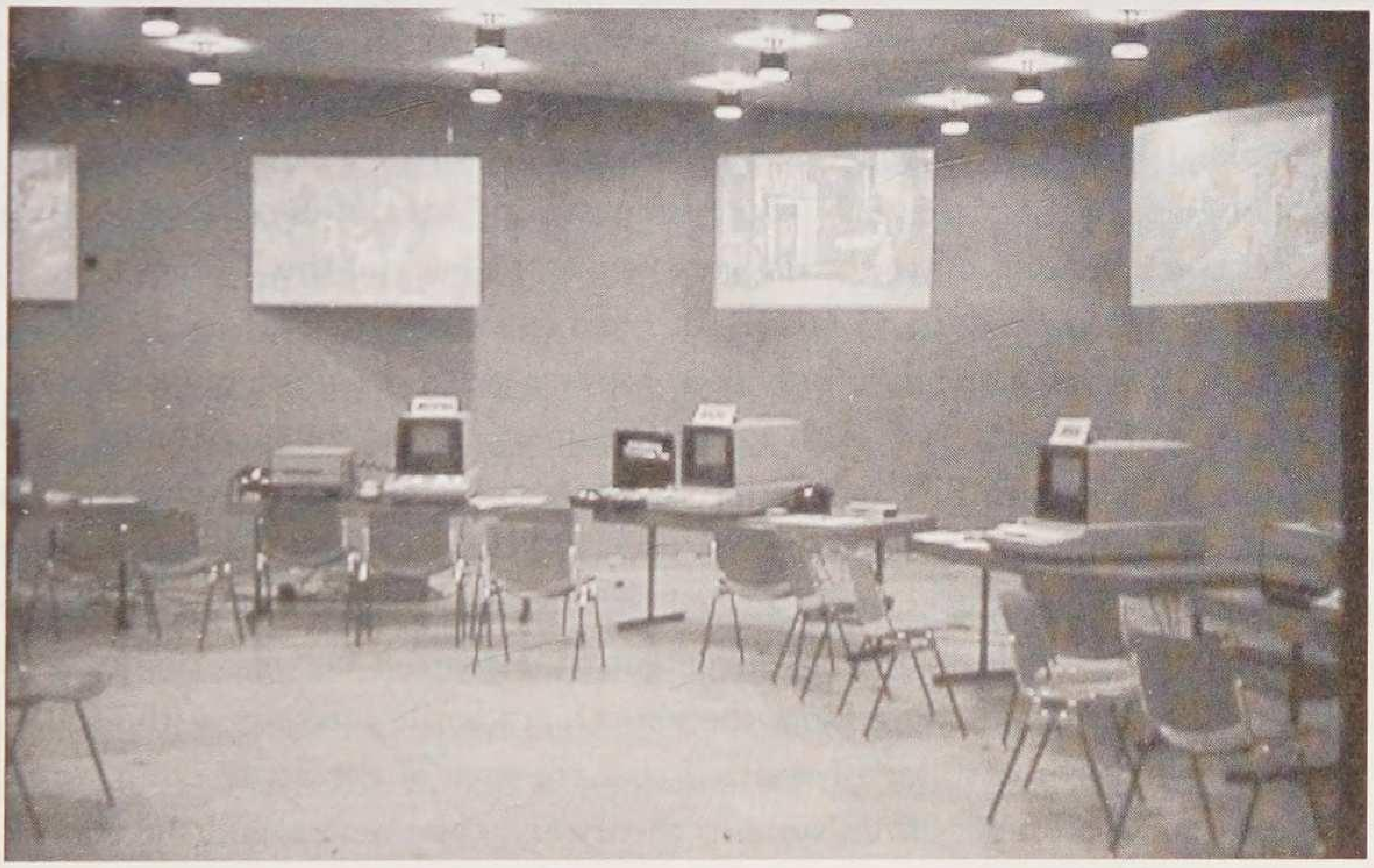


Figure 15.4 The *Ecogame* set up in Davos.

of. Stafford Beer was there and as a result the slide projection technology was used as part of the support infrastructure for the famous decision room for industrial planning in Allende's government in Chile. It was also seen by U.K. Treasury officials, following which we started discussions about its possible use in the Treasury and also with the Department of Environment about a possible version for the 1974 Stockholm United Nations Environment conference. Sadly both these United Kingdom initiatives were snuffed out somewhere in the corridors of power. A reduced version of the game was sold to IBM for use in its management education center in Blaricum in Belgium.

Ecogame encapsulated in one project what the ethos of SSL would be—a creative approach with state-of-the-art software engineering to make systems that were technically challenging, groundbreaking, and, above all else, delivered the results the project sponsors were seeking.

The Link with the Royal College of Art

The location of the Computer Arts Society's *Event One* exhibition, at the Royal College of Art in March 1969, came about through the efforts of the late Patrick Purcell, then senior research fellow in the Design Research Unit of the College's Industrial Design Department. Patrick was an early member of CAS and an influential advocate of interdisciplinary work. He forged strong links between the college and its neighbor, Imperial College, and with the Architecture Machine Group at MIT. Later, in the 1980s, Purcell moved to MIT to work with Nicholas Negroponte in the development of the Media Lab. One of my abiding memories of *Event One* is of a low loader truck inching up to the delivery bay at the back of the RCA with a PDP 9 computer and associated kit on board. This had been borrowed for the weekend by Patrick from Imperial College to provide computer-aided design demonstrations.

In subsequent conversations with Patrick it emerged that some of the methods I had been using at System Research Ltd. to study learning behavior might be applied in his research area to study how designers work. I was offered a part-time research fellowship on the Science Research Council–funded project Purcell had just started. This suited me very well, allowing convenient time-sharing between doing applied projects with SSL and pursuing more theoretical, academic interests at the RCA.

Once installed in the college I realized that the area of design research was ripe for the introduction of ideas from systems theory and cybernetics, and the team Patrick had assembled made some inroads into understanding creative design using modelling techniques. Eventually the Design Research Unit became an autonomous department in the college under Professor Bruce Archer. This was a multidisciplinary department with staff and students from a wide range of design and academic disciplines. Philosophers, psychologists, product designers, graphic designers, architects, computer scientists, and ergonomists combined to create a truly collegiate ideas framework challenging the master's and PhD students who found their way through the door. However such research work was alien to the rest of the college, which was founded substantially on the classical atelier principles of art education. There was a strong body of opinion that held that our kind of research into the nature of creative design processes would inevitably destroy the mystery and undermine the delicate nature of such skills. So institutional life was inevitably precarious and I was glad that I had work at SSL as well, though it did mean there was little opportunity for academic reflection or publishing.

Early in my tenure at the RCA we had, through the Computer Arts Society, made contact with the Rutherford Appleton high energy physics laboratory in Oxfordshire and got permission for RCA students to use its Atlas Computing Laboratory facilities. These facilities included microfilm plotters, which were used to visualize particle tracks from the physics experiments. There then followed a chain of events and developments that moved the embryonic fields of computer graphics, visualization, and animation substantially forward. Colin Emmett, a student in the graphics department of the RCA began a project on drawing with ouput on the FR80 microfilm plotter. This soon developed into an exploration of animation methods and then, with help from Alan Kitching and Alan Francis, grew into the Antics animation package, a library of FORTRAN routines for drawing and inbetweening. The Antics showreel of 1972 was, and still is, impressive. A film was then commissioned by the Science Research Council to use Antics to create explanations and visualizations of the Finite Elements mathematical techniques for analyzing engineering structures. This was made in 1973–1974 and was, I believe, the first wholly computer-animated film made for a purpose other than demonstrating that computer animation was possible. Antics was also used to make a limited edition of the rainbow snake silkscreen prints by Emmett and Kitching.

Following the launch of the film our department was approached by the BBC to make a titling sequence for the BBC science program *Burke's Special*. It became clear that the academic environment was not good for this kind of work. The process of pushing such project proposals through academic approval boards was time consuming, and the financial arrangements were cumbersome. Other projects loomed, so in due course this work was taken outside the college and managed through SSL, thus instigating a new phase in the development of the company, which I'll return to later.

Back at the RCA, computing was becoming increasingly prominent. In about 1973 the Natural Environment Research Council had installed its Experimental Cartography Unit, headed by David Bickmore, at the college to pioneer digital cartography. The Computer Aided Design Centre in Cambridge set up its London base in the college. The Department of Design Research acquired an Elliot 903 system as part of an SRC research grant into computer modelling of design systems to evaluate the potential impact of CAD on architectural design practice. The Property Services Agency of the Department of Environment installed a team with the Department of Design Research to develop a CAD system for building design. This team was led by John Chalmers and Brian Thompson and worked closely with Patrick Purcell. So from a standing start in 1970, the college had become a focus for a range of seminal computer projects by 1975. Sadly the computer culture was not entirely welcome in the college. There was a memorable occasion when the CAD Centre demonstrated the production of a 3D model of a vase. The image was black and white, heavily facetted, flickering and slow to build. Before it was complete a professor of ceramics had stomped out leaving a trail of white footprints, harrumphing, "Was that all it could do!"—so much for the leading edge of 3D modeling! However, by the late 1970s the senate of the Royal College of Art had sanctioned the creation of a computer activities unit and we acquired microcomputers, initially kit-form Altairs that we built ourselves, then later Research Machine systems, and we used these for teaching students the rudiments of computer graphics. Brian Reffin Smith joined as computer graphics tutor and he implemented courses for a number of departments in the college and for other computerless colleges such the London College of Printing. By this time I was spending most of my time at SSL and my time at the RCA was largely devoted to the politics of getting the college into the mainstream of university computing funding. During the Thatcher 1980s, and several changes of rector at the college, the Department of Design Research was closed down and the waters of history lapped quietly over a historic decade in both design research and computing development.

By the mid-1970s the growth of interest in computer animation by the film and TV industries had resulted in demands on the slender resources of RCA that really could not be met by the college. At this time (1975–1976), SSL had had five years of development since *Ecogame* and had carried out a number of projects to further explore the ideas of interactive computing for decision support in industry and government.

We then reached a major milestone in SSL's history. John Lansdown, senior partner in the architectural practice of Turner, Lansdown, Holt, and Patterson, as well as being secretary of the Computer Arts Society and very active on arts projects and writing, was also chairman of the Science Research Council's committee charged with developing CAD systems and skills throughout the land. This committee funded many important developments in computer-aided building design including Patrick Purcell's research at the RCA. Through this Lansdown got to know about the ideas I was working on and the practical developments in computer graphics at the college and at SSL. There was thus a rich set of interconnections—the Computer Arts Society, the Royal College of Art research and computer graphics departments, SSL's work on *Ecogame* and graphics, the still fermenting world of cybernetics and complex systems now spilling over into artificial intelligence—as well as a context of the increasing power and potential of computing in all areas of our lives. Lansdown and his partners offered to buy in to SSL. This was accepted, and in May 1977, SSL moved from its birthplace above an antiquarian bookshop in Twickenham to Turner, Lansdown, Holt, and Patterson's office in Russell Square in Central London. John became chairman, and Mike Stapleton, a research fellow in the Experimental Cartography Unit at the RCA, joined us as technical director. Mike Esltob left to pursue a full-time academic career in the cybernetics department at Brunel.

Almost immediately we were approached by 20th Century Fox to discuss the possibility of using computer animation methods in the film *Alien*. The approach actually came via Brunel University and soon we were heavily involved in that production. We were able to assemble a top flight team of computer graphics experts to create what were known as the read-outs on the spaceship flight deck computer screens. Colin Emmett and Brian Wyvill did the main orbit insertion sequence on the Atlas Lab's computer and FR80 plotter. Alan Sutcliffe did the 3D model of the mountain range as the spaceship landed. He used measurements from a polystyrene model of the mountain range. (Eerily, after the film was released we had an anxious enquiry from a U.S. avionics company, apparently Sutcliffe's output was very similar to the way they were representing terrain following radar outputs in a supposedly top-secret application!) Mike Stapleton, John Lansdown, and Tony Pritchett did myriad sequences as director Ridley Scott got into the swing of how CG worked, and story boards came at us in blizzards. Like *Ecogame* this project stretched all our resources, skills and ideas and, again, against the odds, was successful. Unfortunately we were a bit naïve and in the excitement of the early stages of the work we did not negotiate our credits into the contract! So the company's contribution was never acknowledged in the film's credits. Nevertheless there was considerable publicity surrounding the film as it progressed to cult status, and we benefitted greatly from that. There followed a continuous stream of animation and graphics projects, mostly in the advertising world but also for the film *Venus 3*, trial titling sequences for Jonathan Miller's *Body in Question* BBC series, and then an implementation of a "Brain Atlas" for the London Hospital (we digitized photographs of brain slices so that surgeons could see on a screen a contour map of the bit of brain they were probing).

Our final—though we did not know it at the time—big graphics project was the original Channel 4 3D tumbling 4 logo. Tony Pritchett was approached by Martin Lambie-Nairn's company to work on his design for the logo. Pritchett was a freelancer and asked SSL to take the project and manage it. The outcome was a very successful collaboration. Lansdown and Pritchett did the wireframe animation drawings on a Tektronix 4041 system, and some trial renderings were done by

Lambie-Nairn. The final color renderings with highlights were done in the United States by Pritchett using the Foonley supercomputer at III (Triple I) in Los Angeles. III had done the computer generation for *Tron*, the first Hollywood film about virtual reality.

During this time, 1975–1980, the Computer Arts Society had become well established. The *PAGE* journal had international circulation; Lansdown's "Not just Computing—Also Art" series ran regularly in the *Computer Bulletin*; we were accumulating a series of works from artists; and a new generation of artists was emerging led by Paul Brown and others from the Slade. But the first phase was over; graphics technology was developing with breathtaking rapidity and the early love affairs with random numbers and line drawings was giving way to newer interests in color, shape, and 3D. With the increasing availability of minicomputers and the early micros, the barriers to artists' access to computing resources were dissolving rapidly. Thus CAS had achieved what it had set out to do ten years previously, and, as the harsher world of the 1980s began to unfold, engagement and interest in CAS began to dwindle.

16

Two Cultures: Computer Art and the Science Museum

Doron D. Swade

A new gallery, Computing Then & Now, opened at the Science Museum in London on December 16, 1975. The exhibition, devoted to mathematics and computing, included a computer art booth with exhibits on the uses of computers in the visual and performing arts, including dance and poetry. The booth's exhibits were the product of a collaboration between the Science Museum and the Computer Arts Society (CAS).[1]

The computer art booth had pride of place as the primary point of access to the exhibition. The location of the booth, its contents, and messages can be seen as a position statement for computer arts by active practitioners and advocates of the time—a contemporary snapshot of perceptions, aspirations, and current practice by those active in the field speaking, as it were, through the internal process of public dissemination by a major national museum. The purpose of this article is to excavate meanings about computer arts in the 1970s from surviving evidence of the computer art booth's exhibits (the booth has long since gone) and the recollections and views of several of the original participants.[2]

Institutional Context

The Science Museum provided the physical and cultural context of the exhibition, and the social organization of the museum, its traditions, values, and mode of working, were determining influences in the realization of both the exhibition and, within it, the computer art booth. Science museums are concerned with science, technology, and their histories. So we might well ask how, in an institution devoted to science, art came to be featured at all, as well as how examples of art using advanced or state-of-the-art computers came to be included in an exhibition in an institution widely perceived to be preoccupied with the past.

The origins of the Science Museum are to be found in the Great Exhibition of 1851. The initial impetus to found what was called the South Kensington Museum was to promote the new "industrial arts," a label that was understood as a fusion of what we might now call art, craft, science, design, and engineering. Until 1910 education featured prominently in the rhetoric of institutional self-justification—referring not just to educating specialists, artisans, and craftsmen but educating the educators through teaching apparatus and the display of the latest machines and inventions. Manufacturers and innovators loaned or donated objects for display and demonstration and these were later disposed of once their public purpose had been served or when the devices were superseded. The growth of the Science Museum's permanent collections, now taken for granted as the essential purpose and justification for the museum, were at first the result of inefficiencies of the disposal process, and even then curators were exhorted by senior management to weed the collections of "inferior or obsolete examples" in favor of "more recent specimens."[3]

For most of its history there has been a shifting dynamic between the priorities of showcasing contemporary science and technology, and displaying historical collections. While the balance has shifted back and forth, the two bumped along, by and large, in a more or less easy rivalry. It seems that neither priority prevailed absolutely: A survey covering the period from 1910 to 1980 of special exhibitions in three categories (purely historic, purely about contemporary science, or a mix of both) shows that the distribution of exhibitions in the three categories did not change significantly over time and that the museum has maintained a largely constant balance over seven decades.

The upshot of this digression into institutional history is that featuring advanced computer applications was part of the museum's original mandate to display, for public benefit, innovation, invention, and products of new processes. Doing so was consistent with the practice, maintained throughout its history, of providing a platform for the new. So showcasing cutting-edge applications can be comfortably seen as part of an unbroken tradition.

But what of art in an institution devoted to science? With the rise of specialization since the early decades of the nineteenth century, the formal disciplines of knowledge had been progressively fragmenting. In South Kensington science and art publicly parted company with the opening, in 1909, of the Victoria and Albert Museum, which had specific responsibility for art, craft, and design.[4] The science collections were separated out and became the responsibility of the Science Museum. Exhibition Road ran between the two physically separate edifices of the two museums. Art and science, on opposite sides of the street. In the context of this brief history, featuring computer art in an exhibition at the Science Museum in the mid-1970s can be seen as an atavistic act of reintegration: the fusion of technology and art exemplified by computer art can be framed as a return to Prince Albert's original conception of the South Kensington Museum as being devoted to the "industrial arts" seen as an undifferentiated whole. But straddling the two cultures in this way was against the run of play.

The appeal of science, or the lack of it, to a non-specialist public is one that science museums and those marketing science have struggled with, often uncomprehendingly. While science, technology, its products and their consequences impact us all, there is a gap between the internal content of science and personal relevance. The "objective" truths of science, particularly in the hard sciences such as exemplified by physics and chemistry, have no immediate relevance to the specifics of personal experience. The world of science is a depersonalized one, both in the kinds of knowledge to which it has access and in the anonymization of its practitioners; there is no conduit linking what people care about in their personal lives to what the natural sciences can tell each of us about ourselves, our fate, fortune, or how to be.

In the 1970s, the curatorial culture of the Science Museum was still largely internalist, that is, concerned with the internal content of science and technology. Curators were professional subject specialists. The curator of physics would at some point have been a practicing physicist or at least a physics graduate. The movements of contextualization and relativism that began to occupy the methodological high ground in the 1960s had yet to filter through. For curators, recruited from the ranks of scientists and engineers, conscious or unconscious notions of what constituted knowledge were based on the empirical methods of science. In the model of science exemplified by physics, from which most of our explanatory paradigms still derive, the truths of science were regarded as objective (belonging to the object), generic, and supposedly universal. An unspoken tenet of faith was that science had privileged access to certainty through its methods, and these certainties were embodied in objective knowledge. Many of those who had imbibed the impersonal culture of science were uncomfortable with any form of subjective judgment. In this unreconstructed culture, facts were epistemologically unproblematic. Information was regarded as somehow neutral and therefore safe, while interpretation, which inevitably had a subjective dimension, was regarded as illegitimate and even indulgent.

The use of computers in the arts disturbed notions of creativity. Computers, as artifacts of physics, electronics, and engineering, are entirely deterministic. Their technology is exactingly and bindingly specified, and they operate in an uncompromisingly rule-based way. Yet their behavior in response to exact instruction is unpredictable, not because they are erratic, but because the complexity of the programs they execute defies human ability to foresee outcome. The romantic notion that prevailed at the time was that art was creative, and engineering, with which computing was culturally lumped, by virtue of being rule-based and analytical, was not. Engineering was seen as part of the desubjectivized world of science in which the practitioner is an impersonal agent. Art, on the other hand, at least in its romantic construction, cultivated and encouraged the individual subjective sensitivities of the artist and celebrated spontaneous connection and unassociated leaps; this was anathema to models of science, which embrace systematic procedure, rigorous deduction, reproducibility, and universality of outcome, in which the practitioner is a depersonalized agent. Art mirrors each of us in ways that science does not. Anything to do with the arts was exotically and provocatively attractive. In the internalist culture that prevailed, it was also threatening. Jane Randall (née Pugh), who was responsible for the curatorial content of the exhibition, had an interest in the arts and felt less bound than most by the prevailing internalism. Including the computer art booth in the exhibition was politically off-piste but was within the earlier traditions of showcasing the "industrial arts."

The exhibits featured in the computer art booth were heavily dependent on audiovisual equipment. At the time the Science Museum enjoyed a global reputation for its working exhibits and was widely known as "the push-button museum"—an ambivalent description used disparagingly by those who saw working exhibits as a frivolity, and in celebration of its popular appeal by others.

The museum's reputation for working exhibits was established by the now legendary Children's Gallery that opened in 1931 and pioneered the genre. The gallery was a popular success until it closed in the late 1990s. The push-button tradition continued well into the electronic era. By the early 1980s there were over six hundred working exhibits of varying degrees of complexity in 300,000 square feet of public exhibition space. In the mid-1970s, with in-house workshops still fairly well staffed, the Science Museum, which designed and custom built most of its exhibits in-house, led the field in terms of the number and novelty of its working exhibits.

In the 1970s there were four main audiovisual delivery media used in museums: slide shows, videotape, audiotape, and custom-built exhibits. Slide shows were typically back-projection systems sometimes with multiple projectors, invariably industry-standard 35mm Kodak Carousel systems. One reason for multiple projectors was to reduce or eliminate screen blackout when slides changed; the slide sets were interleaved and the projectors alternated so that one took over while the other prepared the next slide. Slides were sometimes cross-faded to soften the transitions. Some shows used multiple screens, with a sequence of changing captions slides on one and a series of illustrations on another, with the timing dovetailed.

Video was run on industrial U-matic players. Each tape had multiple copies of the same clip. Typically playback was on demand: the default rest state of the display was a blank screen and a single run of the clip was initiated by a visitor pressing an illuminated button. Exceptionally shows were run continuously; rewinding at the end of the tape was automatic.

Audiotape was used extensively. "Talking labels," as they were known, were typically voice commentaries running on commercial continuous-loop multitrack tape players with audio delivered either through speakers or more commonly through telephone handsets. Simple commentaries were available on demand and initiated by lifting a handset. Unused audio tracks were used to cue a sequence of display events triggered to occur at specific points in the audio track. Cue tones, inserted on unused parallel tracks at the appropriate point in the commentary, were detected on playback and used to initiate the requisite action, often a slide change, a lighting sequence, or an end-of-show halt.

Custom-built exhibits varied in complexity. The simplest were display sequences cued from the talking labels. At the more complicated end of the range there were complex display controllers custom designed using integrated circuits (ICs) on standard printed circuit boards, hand assembled and hand soldered using fine single-strand Kynar wire and mounted in standard racks. A single board had twenty to thirty ICs and took a week for a skilled wireman to wire. A complex display controller had up to four such boards and took four to six months to develop. The use of microprocessors as display controllers was a novelty and not yet part of the standard repertoire of customized AV exhibits.

Commercially available AV-delivery systems were primarily designed for trade shows and were unsuited to heavy continuous unattended use in museum environments. Equipment not specifically ruggedized was notoriously unreliable, and designers outside museum environments invariably underestimated both the intensity of use and the ability of overworked technicians to monitor and repair faults. Well-designed equipment reduced the mean time between failures. But even well-designed equipment made high demands on routine maintenance. Faded slides were duplicated from a master set and replaced on average every three to six months. Audiotapes became noisy with repeated use and display sequences lost synchrony with the commentaries when the cue tracks deteriorated. Audiotapes were duplicated from edited masters and replaced every two to three months. Filament lamps in the back-illuminated light boxes needed constant replacement even though these were under-run to extend working life, and there was a three-monthly rota of routine slide projector and tape player servicing. In the Science Museum the circuit and system design for the custom controllers and the production of the video and audiotapes were in-house operations, as was the maintenance of the equipment installed in the galleries, except for the U-matic players the maintenance of which was contracted out.

The Computer Art Booth

Exhibitions, especially themed ones, can be seen as ideas mapped onto public space. Decoding the geography of the exhibition might yield messages, intended and unintended, about contemporary perceptions and interpretation. So our first task is to locate the computer art booth in the overall gallery scheme.

The gallery is a simple rectangle of 10,000 square feet running east–west with a central boulevard dividing the space along its length into two 5,000-square-foot areas north and south (see floorplan, figure 16.1).[5] Access to and from the gallery was at both ends and there were no other entrances or exits. The décor was starkly simple and à la mode: matte black walls and ceilings, strident red plinths for the display cases, and glossy silvered colonnades lining a central boulevard.[6]

The central boulevard represented the analogue/digital divide with the north side devoted to analogue material and the south side to digital. Visually prominent on the north side were mathematical models (polyhedra and topological models including a Klein bottle and a Möbius strip). There were also exhibits on "Coordinates, Lines, Surfaces and Solids," and on trigonometry.[7] The south side contained "displays of digital calculating instruments and machines, and digital computers."[8]

The computer art booth was located at the entrance to the gallery at the east end of the central boulevard and formed the main portal to and from the gallery. The computer art booth was in fact designed as the exit. The main ground-floor entrance to the museum is on Exhibition Road, which is to the east, so the primary visitor flow was from east to west, which placed the computer art booth at the de facto entrance. However, the gallery design anticipated that the main entrance to the museum would be switched to the opposite end of the building with access from Queen's Gate. The switch never happened. Had it, the general migration of visitors would have been from west to east and the majority of visitors would have entered the gallery via the escalators and exited via the computer art booth (see figure 16.1). The anticipated but unrealized change in visitor flow explains the direction of the overall gallery timeline, which starts with early calculation aids at the escalator (west) end and moves from antiquity to modernity as you progress along the length of the gallery from west to east. The gallery guide specifically recommended starting at the escalator end and progressing from west to east, from the distant past to the present. Computer art is mentioned last. So in the original conception computer art stood as the last word in modernity.

It was not just that computer art was the first exhibit most visitors encountered. It was unavoidable. The structure of the booth straddled the central boulevard demarcating the analogue/digital divide: A visitor entering the gallery was faced with a darkened cavernous tunnel straight ahead and presented with the choice

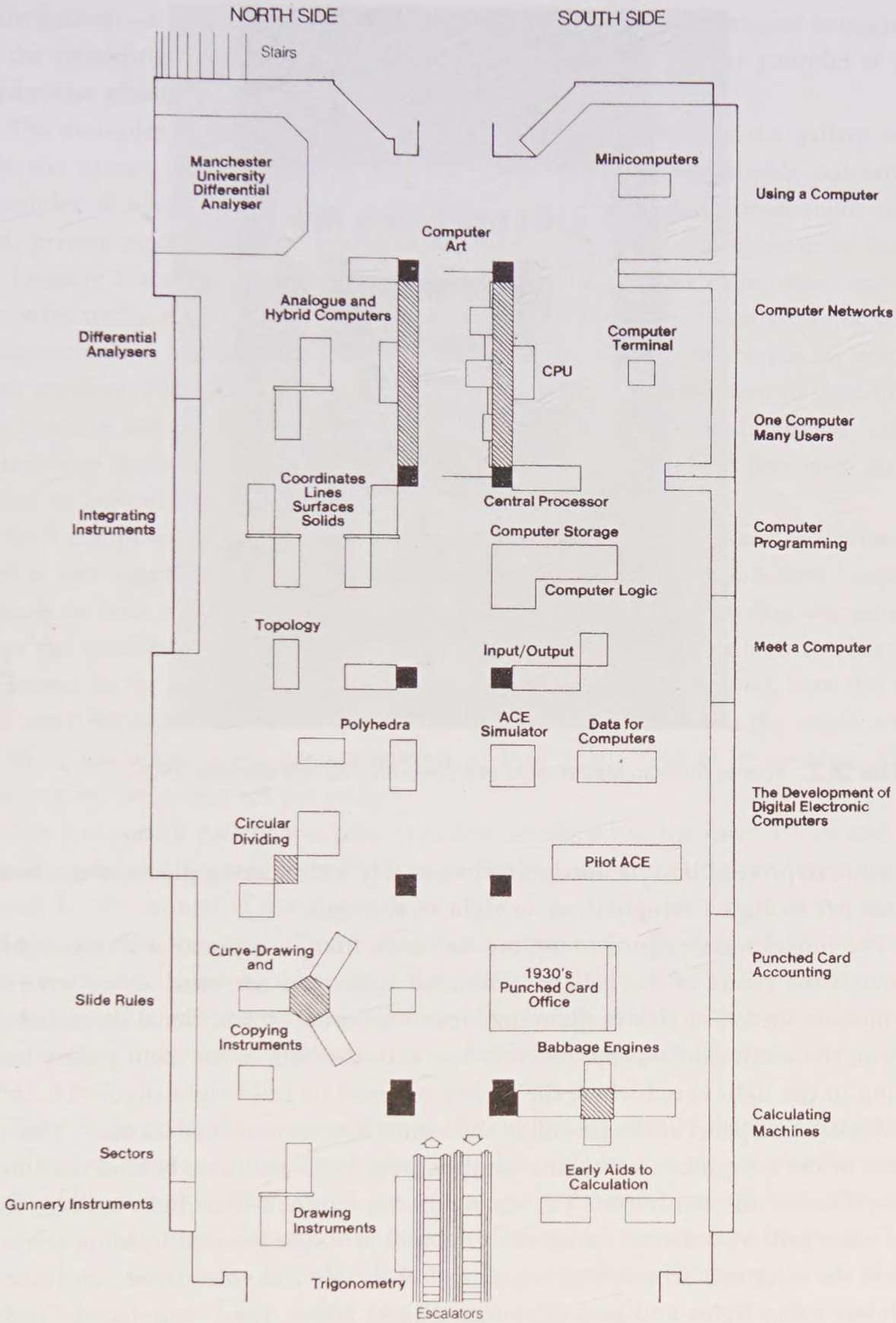


Figure 16.1 Science Museum Mathematics and Computing Gallery map.

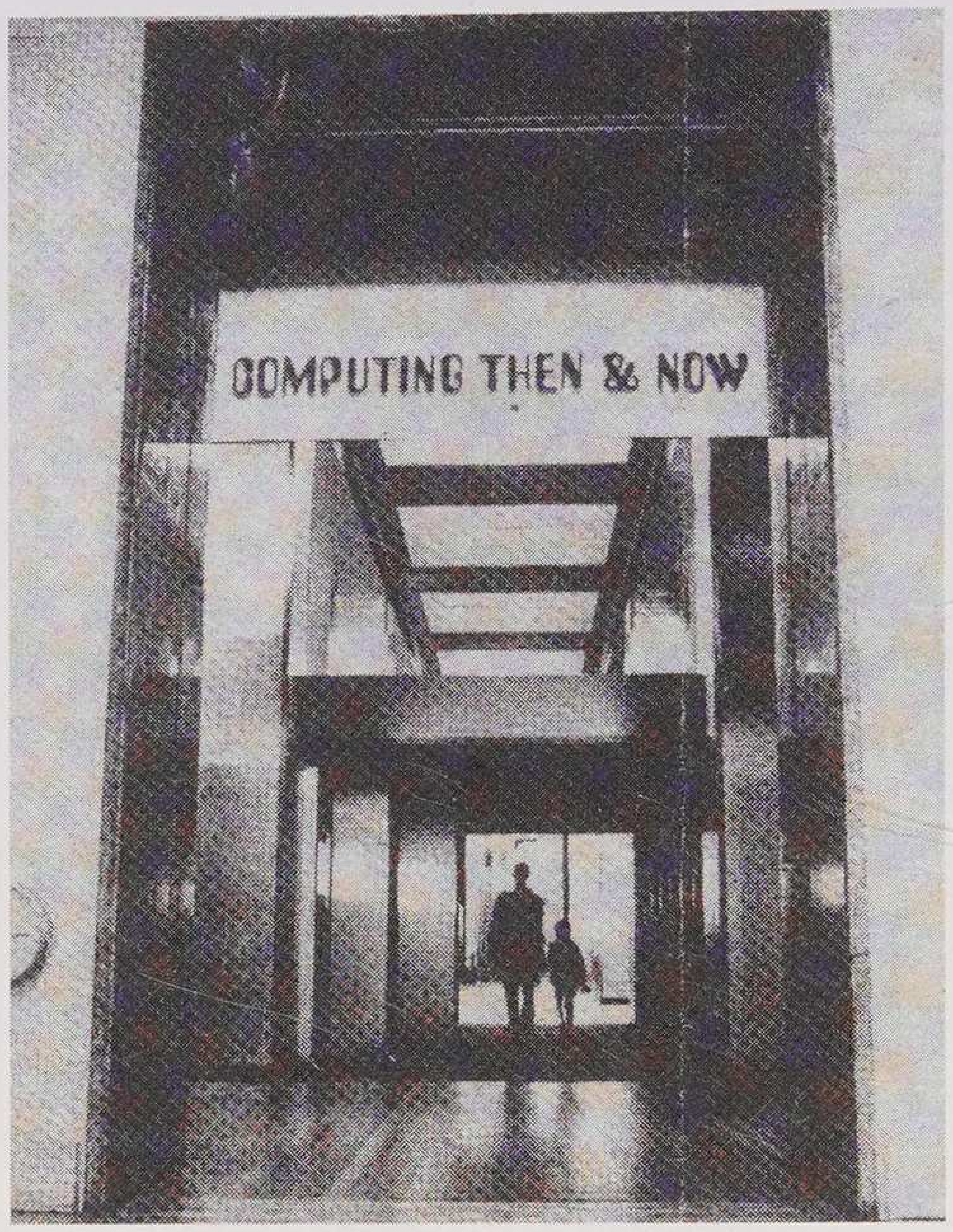


Figure 16.2 Science Museum Mathematics and Computing Gallery entrance, 1975.

whether to proceed into the intriguing or possibly intimidating gloom of the booth, break left to digital computation, or right to analogue.

The tunnel was designed to inhibit the booth from being used as a thoroughfare through the center of the gallery.[9] Dimmed lights and narrowed access were two techniques used. The slab of the tunnel roof, supported by additional shortened pillars on the south side, was oppressively low with the bulk of the main gallery beckoning in the light ahead where the gallery resumed its full height (figure 16.2).[10]

A glass half-panel at the far end of the tunnel further narrowed access.[11] The majority of the computer art working exhibits were in an enclosure behind the line of the pillars on the south side. The enclosed area, screened from light spillage from the main gallery, was even darker than the tunnel.[12] The lowered lighting levels favored the computer art exhibits, which included slide and video shows, and custom exhibits using lights and back-illuminated light boxes. These were located mainly on the south side of the tunnel; there were mostly graphics panels on the north side.

There were at least three features of the booth's location worth registering: It was in the section on modern applications; the booth bridged the analogue and digital zones of the gallery and in this it was unique; and the booth was a gateway to the main gallery—a kind of entry requirement if, that is, you were intrigued enough to by the twinkling lights, or otherwise committed enough to run the gauntlet of the mysterious gloom.

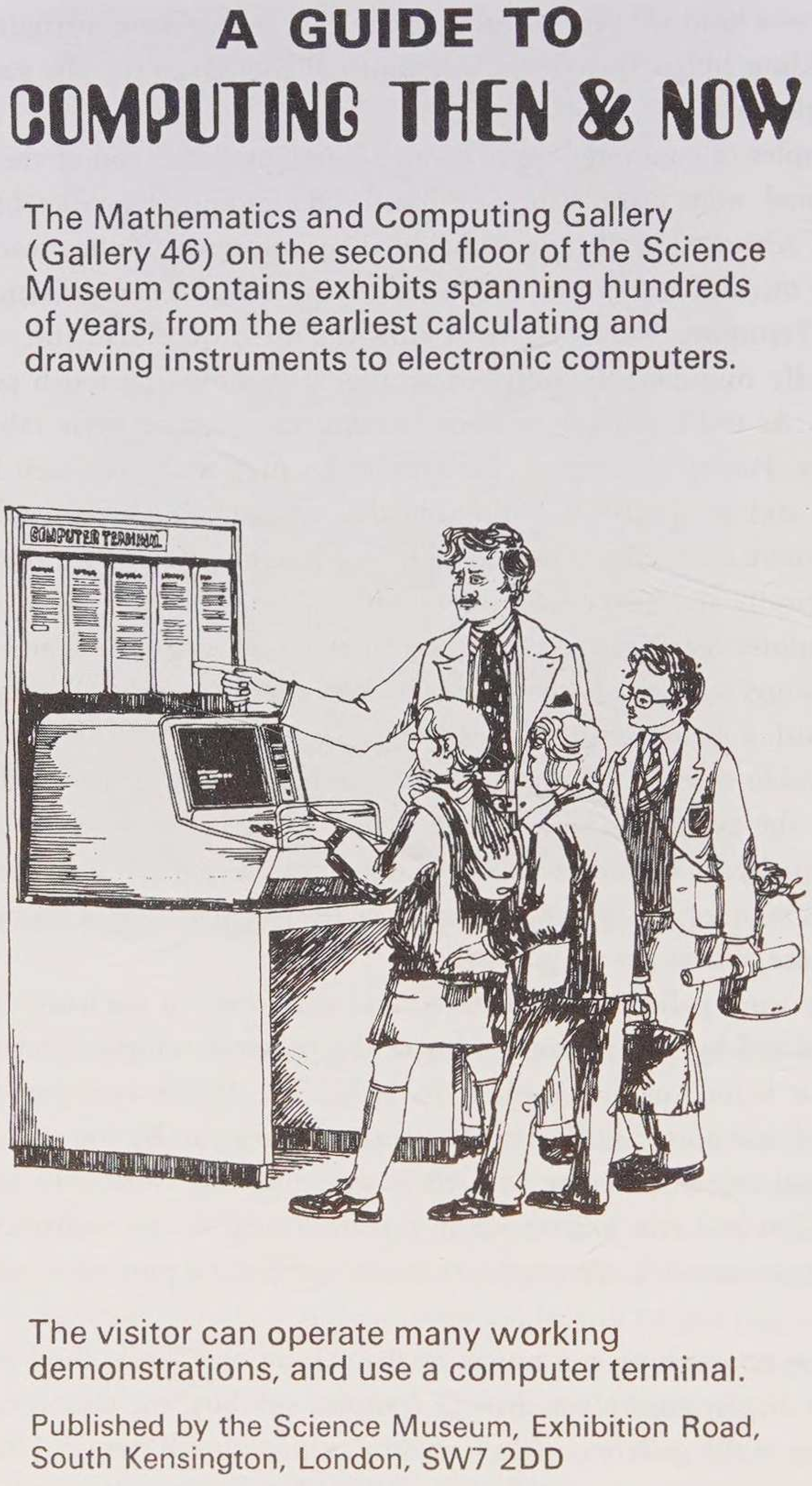
The examples of computer applications at the "modern" end of the gallery outside the tunnel were utilitarian, task-based, and produced predictable outcomes. Examples of advanced applications included payrolling, banking, road traffic control, private medical insurance, and, after the opening, the management of buses by London Transport. Whatever their importance to quotidian life, these worthy but admittedly mundane applications struggled to light the touch paper of wild imagination. As tasks, familiar in their human counterparts, their value lay not in their mystery. Part of the appeal of computer art may well have been in signalling implications and prospects for computing that were outside banal usefulness; computers were more than simply tools, and if they *were* only tools then they were interesting in logically and historically unprecedented ways.[13]

So if computer arts signalled a mixing of the worlds of people and machines as well as new suggestive prospects for uses of computers, then the booth served appropriately as both a gateway into the gallery and an exit from it. Entering the gallery from the outside world through the booth framed a question to which the history presented in the exhibition might offer insights: this is where we are, how did we get here? Equally, it served as an exit ramp from the gallery into the world with which it was seamlessly contemporaneous, at least at the time of its opening. This is where we are, where are we going?

The computing gallery was conceived and developed in the early 1970s and its opening predated by two years the start of the personal computer revolution milestoned by the launch of the Apple II in 1977. The 1970s were part of the era of mainframes that required skilled staff to run and maintain. By the mid-1970s minicomputers had begun to come into their own but they were still comparatively expensive and it was rare to find one in private hands. Access to live computers by those outside universities, commerce, or in the computing profession was rare at this time.

There were no working computers in the exhibition. While there were custom-made digital display controllers driving complex exhibits, the closest to a live computer a visitor to the gallery could get was by using a dumb terminal (monochrome) online to a mainframe computer in Imperial College in the adjacent building. The terminal was clearly seen as a notable attraction: it appears as the cover feature of the leaflet, which states: "The visitor can operate many working demonstrations, and use a computer terminal." Understatement was quite sufficient to convey the pride, novelty, and excitement of this exotic facility (figure 16.3).

The gallery guide describes the booth's contents and provides a summary of the scope of what was featured in the computer art booth:



A GUIDE TO COMPUTING THEN & NOW

The Mathematics and Computing Gallery (Gallery 46) on the second floor of the Science Museum contains exhibits spanning hundreds of years, from the earliest calculating and drawing instruments to electronic computers.

The visitor can operate many working demonstrations, and use a computer terminal.

Published by the Science Museum, Exhibition Road,
South Kensington, London, SW7 2DD

Figure 16.3 Science Museum Mathematics and Computing Gallery Guide cover page.

> Computer graphics, computer animation of films, choreography using computers, music, poetry and an ever-changing pattern of lights controlled by a microprocessor with a little help from you—all can be found here together with explanations of the techniques involved in their production.[14]

The special mention of an interactive exhibit in the booth "controlled by a microprocessor" is a clear indication of the rarity and novelty of microprocessor use at that time.

The specific contents of the computer art booth are difficult to establish in detail. Exhibitions are an essentially ephemeral medium and in their nature they do not serve well as media of permanent record. The booth is long since gone (it was demolished in January 1992) and the curatorial documentation was evidently disposed of after I left the museum in 2003. The official registered correspondence and project files that recorded the gallery's development seem to have met a similar fate at some unknown earlier date. The museum's Registry, the official institutional record-keeping department, appears not to have retained records of what was disposed of or when. However, the audiovisual material for the booth (35mm transparencies, audio tapes, and videos), preserved by the AV maintenance section, which ironically had no official responsibility to retain material after an exhibit was taken off display, is untouched in source and edited form. Thirty years on, the slides and audiotapes are usable, though the videos, in Sony U-matic format, are thought to be too fragile to run except as part of a recovery process yet to be undertaken.

From this material, supplemented by recollections of some of those involved, it appears that there were six to eight specific exhibits. Two of these were videos. One was titled *Touching* and illustrated computer-aided choreography using, as I recall, stick figure representation. The other was *Antics*, this probably a reference to the software animation package of the same name written by Alan Kitching that was used to produce it.[15] Neither of these videos has been viewed recently because of their fragility.

The computer music exhibit consisted of an audio track with examples of musical works.[16] The tape featured seven compositions lasting a total of just under twenty-four minutes[17]: the fourth movement of the Illiac Suite by Lejaren A. (Gerry) Hiller, played by the University of Illinois Composition String Quartet; third and fourth movements (*minuetto* and *finale*) of a piece in pre-Baroque style by Lambert Meertens, played by the Amsterdam String Quartet; title music to the film *Link*, a modernist piece by Arthur Roberts realized on a CDC 3600 at Argonne National Laboratory, Illinois; and a piece by Max Mathews called "Transatlantic Transformation" realized at the Bell Laboratories, New Jersey using Music V software.

"Transformation" starts with the recognizable melody of the military march, "The British Grenadiers" and, through what appears to be a series of wonky progressive transitions, morphs uncannily into "When Johnny Comes Marching Home

Again." The melody then morphs back into "The British Grenadiers." The piece is intriguing and witty, and recognition that the target tune is a familiar popular melody is gradual.

The fifth composition was "Computer Lotus" by Zaid Holmin, realized in the Electronic Music Studio of Stockholm, under control of a PDP 15 computer. The penultimate clip consisted of three movements of "ZASP" by Alan Sutcliffe and Peter Zinovieff composed on an ICL 1900 computer and realized at Electronic Music Studios, Putney, under control of a PDP 8 computer. Sutcliffe, a prime mover in the founding of the Computer Arts Society, commented in a recent interview that he had always been interested in composition. "It is hard," he said. "All those decisions." He reflected that he saw the computer as a way of "putting at a distance what should happen next," that is, of relieving himself of the continuous dilemma and burden of each next action.[18] The final clip was "A Lollipop for Papa," variations on a theme by Haydn also realized at Electronic Music Studios, Putney.

The visual arts were represented in four richly illustrated slide shows. One of these, titled *Machines that Make Art*, was clearly designed to provide an introductory overview of the computer art booth and, to some extent, the gallery.[19] The other three shows contained examples of artists' uses of computers and graphics devices interleaved with explanatory text slides that carried the narrative.[20]

The slide shows differed in kind from the other exhibits in the booth. Most, possibly all, of the exhibits in the booth were individual artworks, illustrative examples, or representations of artworks supplied by practitioners, innovators, and advocates outside the museum. The voice, or creative signature, of these individual exhibits was that of the artist. In contrast, the messages of the slide shows will have been authored by in-house curators bound by the protocols of a public service educational body. The illustrative material was provided by outside experts who will also have made representations about the content of the messages. But the responsibility for the positions articulated will have been that of the curatorial team. The shows are therefore particularly revealing of how the roles of computers in art were framed for general consumption by advocates of their use speaking through curators endowed with the responsibility of dissemination to visiting publics.

The format of the shows was that of the classic genre: a series of text slides with short simple statements each followed by several illustrative images. Of the 154 slides shared roughly equally between the four shows, fifty-one were text slides, and the rest were illustrations, many of which are intriguing and dramatic. The text slides (green text on a black background) appear to have been generated on a computer terminal and photographed directly from the screen. If they were simulations then they are a realistic capture of the slightly blurred disjointedness of the cathode ray tube displays and dot-matrix character-generators of the time.

Machines that Make Art argued a historical case for the use of computers in art. The gist of the case was that artists have used machines throughout history and computers are part of this continuum. Three categories of device were identified: those using existing technologies; specialized machines developed by or for artists "to exploit new ideas and technologies"; and machines designed for other purposes and commandeered by artists.

An example in the first category was the use, in early Egyptian civilization, of the potter's wheel to free the artist "to experiment with shape and decoration." Others were the embossing wheel used by leather workers, and the "rocking pole" used by etchers to roughen surfaces for mezzotints. The main example of a specialized device built to exploit new techniques was the camera obscura specifically developed as an aid to artistic reproduction and accurate representation of perspective. The third category (the appropriation by artists of technology developed for other purposes) was illustrated by a portrait of Queen Victoria created using a typewriter. X-ray scanners were cited as modern devices used in art, and illustrations included chromatographs and polarized micrographs "transformed in the hands of the artist."

The introductory show concluded with a summary position statement: "The question for the artist therefore is not 'Why use a computer?' but, 'What are its possibilities and limitations?'" Clearly the position taken was not based on a priori considerations of what a computer was or was not capable of in principle, but rather an encouragement to open-minded exploratory pragmatism.

The material in the other three shows falls loosely into two categories: graphics output devices used in art and artists' use of computers. Teletypes and line printers were described as the most common graphics output devices. Visitors were informed that line printers, capable of 160,000 letters per minute, had the facility for overprinting and this allowed grey-scale shading. X-Y pen plotters were featured and exemplified by the Calcomp 565.[21] CRTs were described as "a rapidly growing form of output"—a reminder to us now that their use was not yet widespread. Artists' use of light pens as a direct human-computer interface with a computer via the CRT was presented with some flourish.

The rest of the show was devoted to creative outcomes. Graph plots of mathematical functions were described as "one of the more common forms of computer art" and this was illustrated with several complex examples. The use of a single graphics element as a basis for modular patterns was featured, with the benefits conferred by computer cited as the ease with which generative rules can be iterated, the rapid exploration of variations of rules, and the introduction of randomness. Perhaps for the benefit of those concerned with the consequences to creative agency of rule-based generative processes, the last text slide in the sequence announced that "it is the choice of rules by the artist that determines the quality of the completed work." It is unclear whether this statement was intended to be didactic, patronizing, apologetic, or ingenuously informative.

Attention then turned to less mathematically oriented examples. Nine illustrations were given of paintings the design of which was aided by computer followed by images of computer-aided sculpture, including Edward Ihnatowicz's cybernetic sculpture, *Senster* (1970), and a sculpture since called *Ironwork* that has survived in physical form but whose authorship and origins remain obscure.[22] Illustrations of computer use in choreography, film animation, and 3D design followed, and the section concluded with five examples of artworks produced with the aid of a light pen.

The final section was concerned with transformations. Eleven examples of morphed images were given in works created using variants displayed separately and together. Purely abstract patterns, faintly recognizable patterns, and the human face were given as possible starting points, and the show billed the most dramatic results as those exploiting "the most advanced technology." What this technology was is not described, though the illustrative images appear to be false-colored medical scans, or images based on these.

A novel exhibit was *The Logical Mole* by Colin Emmett, designed to illustrate flowcharted decision making.[23] The exhibit invited the interactive participation of the visitor. A finely crafted cartoon mole holding a spade was depicted on a large panel. The exhibit allowed the visitor to influence the mole's tunnelling strategy in real time. The mole was set tunnelling and the path taken was influenced by interactive choices made by the visitor by touching several choice points on the panel as the mole progressed. Speed, direction, whether curved or straight, whether tunnels could cross, were some of the visitor choices. The logic was based on the *Random Walk*[24] and the mole left a lit trail of the tunnelled path that resulted from the interaction. The exhibit was technically novel in being among the earliest interactive exhibits controlled by a microprocessor.

George Mallen recalls a booth exhibit describing the *Ecogame* project implemented by the Computer Arts Society for a show at Olympia in 1970. He describes *Ecogame* as "a computer mediated interactive, multi-media, multi-user game using computer controlled slide projectors to create a visual environment reflecting the decisions players made about allocating resources in a simple model of an economic system."[25] *Ecogame* sought to highlight issues arising from the first oil crisis. It is not clear what form the *Ecogame* exhibit took in the computer art booth, whether a graphics panel illustration, a video, or an interactive.

The contents of the Science Museum's computer art booth serve as an index to attitudes, aspirations, hardware, practice, and the creative products of the computer art movement in the mid-1970s. In straddling two cultures, literally and metaphorically, the computer art booth was an anomaly. An intriguing one.

Notes

1. The Science Museum team was led by Jane Randall (née Pugh), Assistant Keeper responsible for the collections of Mathematical Instruments and Computers. Roger Mummery was the gallery designer. Computer Arts Society members or affiliates who were involved in material for the booth included Alan Sutcliffe, Tony Pritchard (animation), Colin Emmett, John Lansdown (choreography), and George Mallen, who guided the conceptual development and marshalled the CAS effort.

2. The computer art booth was removed in January 1992 when that section of the gallery was cleared for refurbishment.

3. For a fuller account of the evolution of the Science Museum, see Doron Swade, "Le Science Museum Face à ses Publics," *La Revue*, no. 33, Conservatoire des Arts et Metier (September 2001): 4–15.

4. Ibid.

5. "A Guide to Computing Then & Now," Science Museum, London, 1975. The guide is a fan-folded leaflet with five panels printed on both sides.

6. At the time of writing the gallery remains the Science Museum's computing gallery, though the original title, *Computing Then & Now*, was dispensed with. While several areas of the gallery have been updated piecemeal since 1975, many of the original design features remain intact, including the main boulevard, the black walls and ceilings, and the red plinths supporting the wall cases. The rows of pillars lining the boulevard are a structural feature of the building: the silvering was removed in 1992.

7. Many of the original exhibits, particularly those on mathematical instruments, were intact at the time of writing. The section on mathematical models was redisplayed and expanded in 1999 under the title "Strange Surfaces."

8. Contents descriptions are cited from the gallery guide. See note 5.

9. Conversation with Jane Randall, Science Museum, April 23, 2004.

10. The photograph appeared as an illustration in "Dp doors open at the Science Museum," *Computing* (January 8, 1976).

11. Personal communication, Jane Randall, September 14, 2005.

12. There are discrepancies between the floorplan and the contemporary photograph. For example, the floorplan shows a tunnel with the north and south tunnel walls in line with the pillars; the photograph shows the north wall in front of the pillars; the south wall (behind the pillars) is out of the picture. The floorplan is partly schematic and evidently not exact.

13. See Doron Swade, "Lessons from Dolphins." In *The Show 2005*, eds. Ros Sherwin and Aine Duffy (London: Royal College of Art, 2005), 100–101.

14. See note 5.

15. I recall a video animation exhibit on Finite Elements and the use of this mathematical technique in the design of bridges. An educational and promotional film, *Finite Elements*, was made in 1975 using Antics.

16. This material has been recovered intact from the original master tape. I am indebted to Cris Darby, Science Museum AV Technician, who maintained the exhibits in the booth from 1985 until the demolition of the booth in January 1992, for his efforts sourcing and re-recording this material, for scanning the 35mm transparencies from the master sets, and for additional information on the booth's setup and contents.

17. I am indebted to Alan Sutcliffe for guiding me through the compositions and for much additional information on the context in which they were created.

18. Conversation with Alan Sutcliffe, June 30, 2005. "ZASP" is described in chapter 14.

19. In an article, "Paragraphs on Conceptual Art," *Artforum* (June 1967), Sol LeWitt wrote, "The idea becomes a machine that makes the art." I am indebted to Paul Brown for drawing attention to the possible origin of the title of the main slide show.

20. The title of the introductory show survives as a title slide in the master set. None of the other three shows appear to have title slides. Projection screens were inset into the graphics panel and the titles of the other shows were probably printed on the panels. None of the panels survive, nor does any record of their content.

21. The Calcomp 565T was an 11-inch drum plotter first introduced in 1959 with 0.01-inch incremental drum control capable of 250 steps per second using stepper motors, and a single pen. It was a workhorse peripheral device also and sold with the IBM 1620 (1959) and later with the IBM 1130. Only a picture was featured in the show, with no technical detail.

22. See Alan Sutcliffe, "Linear Construction in Iron," *PAGE*, no. 56 (Spring 2004): 1–4.

23. Catherine Mason has excavated the history of *The Logical Mole* and retrieved the artwork. See note 15.

24. Conversation with Colin Emmett, October 18, 2005. The *Random Walk* is a statistical model that predicts the positional outcome of a number of random steps of fixed length.

25. Personal communication, August 5, 2005.

17

Never the Same Again

Malcolm Le Grice

This is a subjective set of comments and recollections based on my early involvement with computer or digital art. I studied painting but when I was leaving art school, like many artists in the mid 1960s, I began to consider other approaches to art and to explore alternative media. I had played jazz and was attracted by performance. During my time at the Slade School of Fine Art I had read quite seriously in psychology and philosophy, and under the good and strong influence of Harold Cohen, who was then a painter making large abstract works, I became very interested in semiotics, communication, and information theory. I read W. Ross Ashby's *Introduction to Cybernetics* and was fascinated and stimulated by his mathematical concepts of coding.[1] I connected this with other notions of coding in genetics and made paintings that explored connective forms drawn from electronics, genetics, and the nervous system.

I began working as a teacher at Ealing Art College just after Roy Ascott's revolutionary ideas about art and information had been "cleaned up" by a new regime and, within a few months, at St. Martin's School of Art with another major art education radical, Peter Kardia (then Atkins). I had already begun to experiment with film and, through another part-time teaching job at Goldsmiths College, with video. Kardia encouraged me to take up my enthusiasms for film and theoretical ideas about communication and information with the students. During this period, around 1966, film became my main but not exclusive medium. I continued to experiment with photography and video, also picking up on an earlier involvement as a moderate but not brilliant jazz musician, by taking part in a number of sound performances with the improvisation group AMM, which at that time included Cornelius Cardew.

My interest in communication theory was only part of a broader interest in science, but more accurately in the potential relationship between art and technology, especially electronic technology. With a few interested artists including Ken Adams, Philip Darrah, and Mike Thorpe I brought together a group interested in art and technology who met at St. Martin's School of Art. Also attending occasionally was George Mallen—I have a diary entry for July 5, 1967, that says "phone Mallen" and, among drawings of polar bears, the entry also says, "phone Harold" (this Harold was certainly Cohen). At this time I was trying to interest Cohen in the potential of computers. From the way he had talked about his work when he taught me at the Slade, I felt the potential of the computer would be of interest to him and at the time wrote him a letter expressing my enthusiasm. He replied kindly but declined to join our group as—ironically considering his later work—he did not believe computer technology could ever be of interest to an artist. I reminded him of this when I visited him in California some years later and he replied with some amusement, that as an artist he always reserved the right to change his mind completely. The art and technology group was short-lived, mainly because the establishment of the Computer Arts Society took over its most interesting aspect and promised practical collaboration with professionals in that technology. I became an early member of CAS—I think my membership card was number 006—and went to all the formative meetings set up by John Landsdown. Another scrawled diary entry for Friday, December 27, 1968, has a list of names including Lansdown, Sutcliffe, Mallen, Parslow, Reichardt, and John Lifton. I presume this was the first meeting I attended but am not certain if my list was of others at the meeting or simply people I intended to invite.

I quickly developed a close relationship with Alan Sutcliffe, then of ICT (International Computers and Tabulators, later to become ICL), and we began work on a computer program to generate instructions and dialogue for performing actors. This became *Typodrama* performed at the Computer Arts Society's *Event One*, held at the Royal College of Art on March 29–30, 1969. The concept for this work began with a broad system of component character traits that, when selected in any particular combination, provided the "weightings" by which the program generated actions and text. The program included sections that related both to tendencies in vocabulary and in grammatical construction, and used randomness held within limits imposed by the initial character weightings. The result was primitive; what the actors eventually spoke was a series of superimposed monologues rather than dialogue. There was no programmed interaction between the (three) actors, nor was there any dramatic development. However, the fragmented abstraction, caused in large measure by the invention from scratch of a "dialogue-engine," was not only true to the condition of computer art at the time, but matched contemporaneous artistic concerns about breaking traditional hierarchies. The aesthetic concerns were not unlike the found-footage, cut-up style I was exploring in my films of the time, particularly *Castle One* (1966) and *Castle Two* (1967). Alan Sutcliffe was the programmer on *Typodrama*; working closely with him on the detail of the program taught me the basis of planning and organizing a computer program and a broad grasp of FORTRAN code.

Tracing an exact chronology of influences, both on my personal development and of those events that were going on around me, is difficult. I was exploring a number of directions simultaneously and the rate of new developments in the field was accelerating. As well as pursuing my general interest in technology and computers, between 1965 and the end of 1969 I made and exhibited nine films, was involved in music performances with AMM at a gallery in Kingly Street (diary entries suggest 26 Kingly Street, on March 20 and 21, and April 16, 1967), and mounted a two-week video event, *Drama in a Wide Media Environment*. The latter took place in August 1968 at the first Arts Laboratory established in Drury Lane by Jim Haynes in 1967. I linked up with the Arts Lab through David Curtis who curated the cinema there. As well as the cross-art ethos that underpinned the Arts Lab, I had been attracted by the concept of a laboratory applied to experimental art. Specifically a filmmakers workshop began to emerge through discussions between myself and Curtis at the Arts Lab, and this rapidly led to my involvement with the London Filmmakers Cooperative. Meanwhile, in the same period, during the summer of 1968, there was the seminal exhibition at the ICA, *Cybernetic Serendipity*. Though impressed by this exhibition, and particularly by computer applications in music, I felt, as with my own *Typodrama*, the limits of the technology compromised the sophistication of the art. This was very evident in the visual and graphic work. At approximately the same time, I became aware of certain developments in the United States combining art and electronic technology. The information was secondhand and to some extent mythologized, but I was interested to learn of the exhibition *Nine Evenings of Theater and Engineering*, coordinated mainly by Robert Rauschenberg and Bell Laboratories' engineer Billy Klüver. Klüver also established, and was the driving force behind, the New York–based organization EAT (Experiments in Art and Technology). EAT had its parallel in the second incarnation of the Arts Lab at Robert Street in Camden, as IRAT (the Institute for Research in Art and Technology) largely driven by John Lifton.

While I was largely concentrating on film, I was attempting to develop theoretical ideas related to new technologies, with a central concern for the growing significance of computers in electronic and broadcast media. During 1966 I struggled to write a paper entitled "New Media—Education—Learning Behaviour." The paper was not well written but I did independently sell a few copies at five shillings. Unfortunately I failed to acknowledge my debts to Jean Piaget and W. Ross Ashby. I followed this with another, shorter, and only slightly less badly written piece, eventually published in *Cinemantics One*, titled "Outline for a Theory of the Development of Television."[2] Though neither of these papers was well written, some of the ideas they contained were, for the time, novel and politically challenging. In particular they envisaged combining computers, electronic data stores, communications, and video-media into a form of interactive system responsive to the user. They did not specifically envisage the possibility of more efficient compression systems for visual images nor the expansion of bandwidth that might make such ideas feasible, but I was discussing such ideas with people at the time. From the background research for my writing and awareness of new media systems I envisaged developments that were simply not achievable by the computer technology of the time. As was the case with *Cybernetic Serendipity* and my own primitive *Typodrama*, I felt that, however heroic it might be to struggle with computers, the technology would, for some time to come, lag behind what could be achieved artistically in other media.

Despite these misgivings, a curious opportunity presented itself to me out of the blue in 1969. Through some connection with St. Martin's School of Art, although I can find no reference to this connection in my archive, I met a man in a pub in Soho. Who asked if I was interested in making a computer film. Of course my answer was yes. It transpired that he had research funding (I assume from the Science Research Council—or whatever did that job in 1969) to explore possibilities of computer animation using the Atlas computer of the Atomic Energy Research Establishment (AERE) located at Harwell in Oxford shire. So, he asked, would I be interested in making a computer-generated film on this equipment? However unlikely, I found myself, a film artist with anti-establishment views, being offered access to the largest computer in Europe located in a high security government laboratory!

So for the next nine months, on and off, I visited Harwell and programmed the Atlas, which drove a device known as the Stromberg Carlson 4020 microfilm plotter. The SC 4020 comprised a 16mm camera mounted above a small, naked cathode ray tube (CRT). In order to make this system work I had to learn FORTRAN 4 and input my own program and data on punch cards. The program was then transferred to magnetic tape and was left to be run at an appropriate time in the computer's schedule. I would receive the inevitable error printout some weeks later in the post and make another trip. The system worked by digital control of the path of a flying spot on the cathode ray tube while the camera shutter was held open, transferring that path photographically to the film. The film was then digitally advanced one frame and the CRT activated to create 1 the next trace, with X and Y values incremented as appropriate to the animation. The setup was designed for making animated graph-plots for visualizing atomic processes.

Though it might have been possible to animate representational figures or shapes, I chose to work with the mathematics of the system producing a series of linear concentric ellipses that changed their forms in time. This was difficult to achieve but the abstract simplicity suited me better than any representational form of animation. Eventually after the nine months I had some eight seconds of 16mm negative film—black lines on white—or, rather, dark grey lines on a lighter grey background. The ratio between effort, time, and product was on a scale between idiotic and completely crazy, on top of which the output itself did not satisfy me artistically. I completed the eight seconds at approximately the same time as I had installed (with enormous help from another filmmaker, Fred Drummond) some old but professional film printing and developing equipment at the second Arts Lab (IRAT). With this equipment I was able to transform the film first by increasing its contrast, then by producing a positive image—white lines on black—followed by various forms of superimposure of the film with itself resulting in *Your Lips 1* (1970). The title was a pun on "ellipse" but also echoed the slightly mouth-like quality of the image. Then, by adding changing color through filtering the printer light, I made a film that now exists as *Your Lips 3* (I'm not sure why there is no *Your Lips 2*). I also looped and superimposed the black and white source material with military images in *Reign of the Vampire* (1970), as a section of a film series titled *How to Screw the CIA, or How to Screw the CIA?*, I suppose partly referencing the paradox of producing the material at the atomic energy laboratory. I used the color-filtered material again later, superimposed with other images in *Threshold* (1972) (figure 17.1). If you spend almost a year producing eight seconds of material, you might as well make full use of it!

I came to the conclusion that, while I remained interested in computers and computer film, as an artist I should put this on the back burner until more appropriate equipment was available (the Sinclair Spectrum in 1983 and the Atari in 1984). However, even if I chose to leave computer film alone it did not leave me alone. I was commissioned by 20th Century Fox to research the use of computer imagery in a production of a twenty-first-century detective story—a production named *Kyle*—

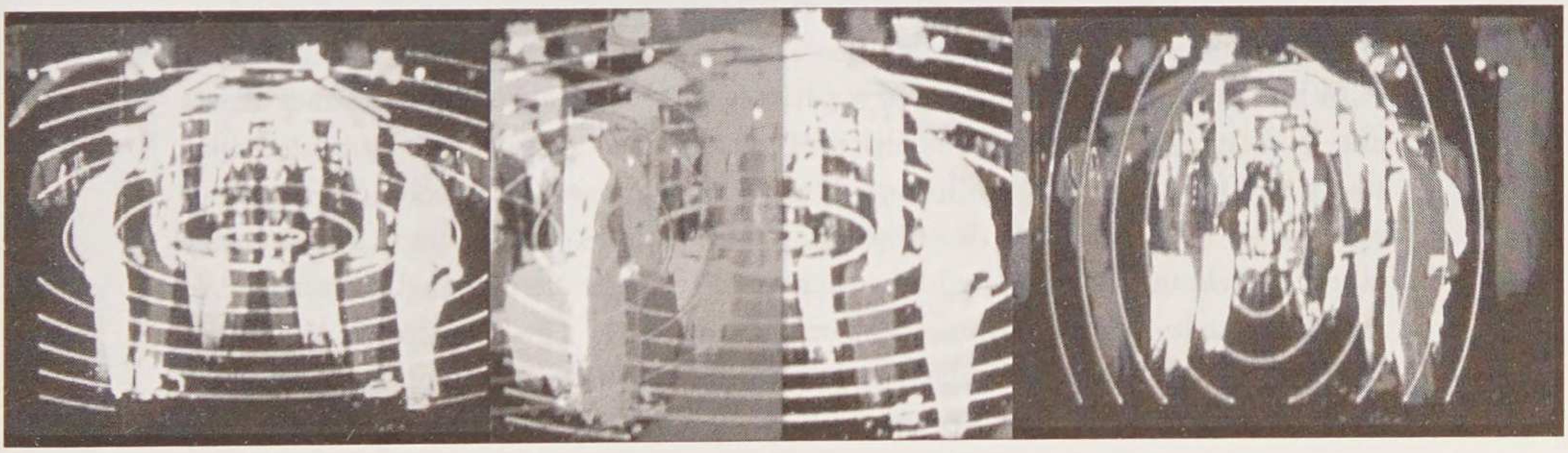


Figure 17.1 Malcolm Le Grice, image from the multi-screen projection of *Threshold*, 1972, including the reworked computer generated ellipses first screened as *Your Lips* in 1970.

directed by Sam Wanamaker. I was to advise them on the visual readout of various "gizmos" to be included in a *Space Odyssey*–inspired set. After research, including, as I recall, discussions with Bob Godfrey, I concluded that it would be cheaper and more convincing if the computer animation was faked by conventional animation techniques rather than attempting to achieve it by the then available technology. Fortunately the script was so bad that Fox pulled the plug on the production. The parties had been good (Campari sodas, smoked salmon, Parma ham); it was a great pleasure to have had some contact with Wanamaker who was always charming (I think he took the job to help finance his work on the Globe Theatre project); and I learned just how crass and infantile script production could be in that form of cinema (the executive producer worried more about the future merchandizing than the quality of the film).

Computer film would not leave me alone in another sense as well. From my involvement and research into computer film in the preparation of my book, *Abstract Film and Beyond* (1977),[3] by the mid-1970s I had become something of an expert on computer or electronic film art. I knew well the work of the Whitney brothers, Stan Vanderbeek, Lillian Schwartz, and others from the United States; I also knew about work being done in Europe by artists like Lutz Becker and Marc Adrian. Critically I was able to link abstract cinema with digital films (there were few examples in the early 1970s) and those using analogue or mixed electronic and photographic techniques, and I was frequently asked to write on the subject, including articles in *Time Out* and a chapter in Birgit Hein's German publication, *Film im Underground*.[4]

During this period the main debate around computer film was dominated by examining its potential for application to conventional cartoon animation. It was largely seen as a way to reduce the labor of animation by, for example, calculating in-between frames. Reducing the labor of animation, like its more recent equivalent computer-generated special effects and lifelike dinosaurs, was of no artistic interest to me. For me artistic concerns always had priority over technical innovation. However, I also understood that creative use of new technology could extend artistic language and meaning.

When I researched the history of experimental film I realized how abstract artists like Viking Eggeling and Oskar Fischinger had influenced postwar computer film artists like John and James Whitney. I began to take this idea beyond the notion of influence to a more general view that some of the formal concepts emerging in early experimental cinema prefigured what I came to see as fundamental characteristics of digital systems, like programmability and nonlinearity. These were only to become a technical reality through the much later development of computers. In John Halas's *Computer Animation*[5] I proposed that there was a historical continuity underpinning the emerging visual "language" of computer film. I wrote, for example, that *Diagonal Symphony* (1924) "is in many respects eminently suitable to have been made by a computer. It is largely linear and composed of simple abstract elements which are put together in a gradual formation of a single complex abstract unit. Not only is the image one that could be output on present computers, but, more importantly, the kinds of relationships and animated developments could have been analysed and programmed." By "largely linear" I meant simply that the images were made up of drawn lines. This was not a reference to the concepts of linear and non-linear.

Later I extended the idea that experimental cinema had sought concepts—philosophical notions not just techniques—that later became fundamental to digital processes. In particular I argued later (in essays such as "The Chronos Project"[6]) that the fundamental nonlinearity of digital memory processes was implicit in the spiraling repeat form of *Meshes of the Afternoon* (1942) by Maya Deren, a concept I have also applied in my recent video work.

My enthusiasm for computer films that was driven by artistic rather than technical motives also led to another slightly odd liaison during 1971 and 1972. In order to get work by John and James Whitney, Stan Vanderbeek, and Lillian Schwartz shown in the United Kingdom, I worked with the American embassy on a series of shows at the London embassy and other venues in Western Europe. The Vietnam war was ongoing and, as my title, *How to Screw the CIA*, suggests, I was not unaware of some of the problematic implications of this liaison. The shows were being organized by Bob Baker of the USIA (the U.S. Information Agency), funded by the U.S. government. It was clear that if this agency was not an integral part of the CIA they almost certainly worked closely together and had some of the same objectives regarding the spread of American influence through its art and culture. Even though those involved at the embassy were genuinely enthusiastic about the work, as America's actions in Vietnam became increasingly unacceptable, I broke the association in a letter of protest to Baker. On the positive side, however, the liaison had made me and others in London and Europe more familiar with the exceptional inventive genius of John Whitney.

As well as helping plan and exhibit the work in London, I shared a European tour with John's son John Whitney Jr. He showed work by John and James and new work by himself and his brother Michael. This series also gave me the opportunity to meet and work with Stan Vanderbeek. He was generous, expansive, friendly, and very good company. He was impressed by the production facilities we had established at the London Film Makers Co-operative (LFMC)—then in Prince of Wales Crescent—and particularly with the Debrie step printer. I had shown him examples of the re-colouring work I had done with *Your Lips* and this led to applying a similar process to some black and white linear output he had recently produced (figure 17.2).

We worked together making various colorfiltered prints. I assume, though cannot remember for sure, this was a film titled *Ad Infinitum*, which I described in my

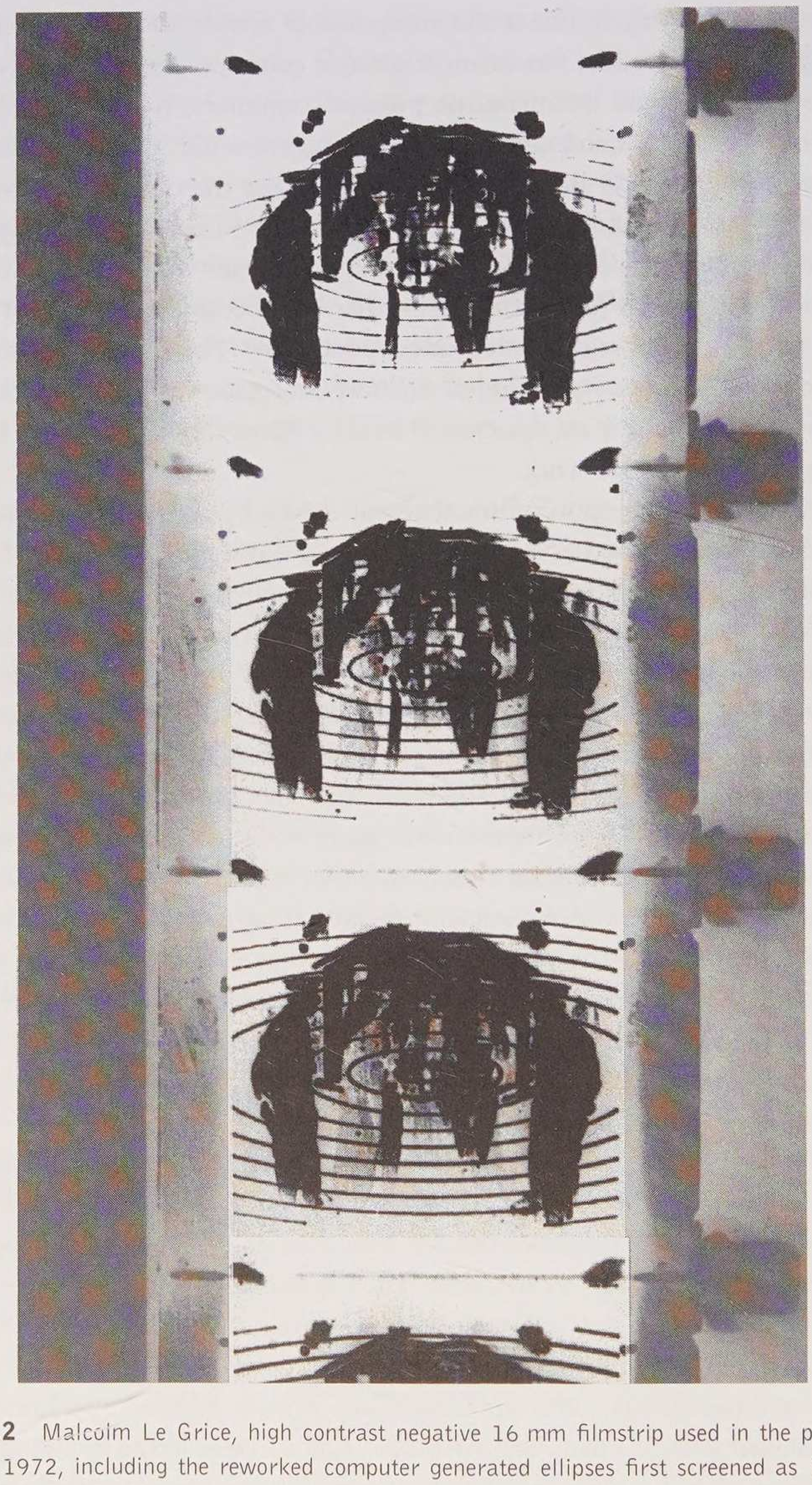


Figure 17.2 Malcolm Le Grice, high contrast negative 16 mm filmstrip used in the production of *Threshold*, 1972, including the reworked computer generated ellipses first screened as *Your Lips* in 1970.

Time Out article, "Computer Films" as exploring "a more fluid, linear, organic system using a light pen visual display, filmed on the spot in real time."[7]

My theoretical and critical interest in computers continued through the 1970s and 1980s but my practical involvement only resumed after 1984—the period during which I developed most of my digital artwork and theory. This falls outside the period covered by this book. However, my early attitude—that computers and computer art are only one component in a broader development of electronic media and technology—remains intact. Indeed, almost all subsequent developments related to computers have borne out and extended this cross- or intermedia tendency. In the essay, "Art in the Land of Hydra-Media,"[8] I suggested that it is now impossible to separate the computer from other systems to which it might become connected: the input or output hardware; the continuously developing types of interface with the human users; and its integral place in media transmission systems like broadcasting, satellite, telephone, or Internet. Even from its earliest period computer art combined a range of aesthetic and technical concepts. The computer was applied to the moving image, dance, theater, pictorial, and sculptural arts and architecture. It combined analogue and digital techniques and electronic feedback systems. From the start it not only mixed technologies but existed in a complex relationship to a range of artistic discourses or "languages." In this sense, the computer in art is not and never was a medium as understood in the other arts. If anything, the characterization as a many-headed Hydra has become even more true in contemporary digital art than in its early period. At the same time it has had critical repercussions on our understanding of the apparent stability of traditional art forms.

Fluxus first recognized that where artists may choose any combination of media in which to create a work there can be no historical stability in artistic form based on medium. While the material form in which a work is produced or encountered significantly affects its experience and meaning, crossing media limits inevitably draws on, or draws in, a range of histories and their related discourses. Through their ability to incorporate other media forms, computers and digital systems bring to an end any intrinsic link between discourse and medium. At the same time digital systems represent the basis of a new cross-media, cross-cultural discourse that began to emerge in the radical melting pot of the 1960s. There's no going back!

Notes

1. W. Ross Ashby, *Introduction to Cybernetics* (London: Chapman and Hall, 1956).

2. Malcolm Le Grice, "Outline for a Theory of the Development of Television," *Cinemantics*, no. 1 (January 1970).

3. Malcolm Le Grice, *Abstract Film and Beyond* (Cambridge, MA: MIT Press, 1977; 2nd ed. 1981).

4. Birgit Hein, *Film im Underground* (Frankfurt [Main], Berlin, Wien: Ulstein, 1975), 176–182.

5. John Halas, ed., *Computer Animation* (New York and London: Focal Press, 1974), 161–168.

6. Malcolm Le Grice, "The Chronos Project," *Vertigo* no. 5 (Autumn/Winter 1996).

7. Malcolm Le Grice, "Computer Films," *Time Out* no. 98 (December 1971).

8. Malcolm Le Grice, "Kunst im Reich der Hydra-Medien," in *Film & Computer—Digital Media Visions* (Frankfurt: Deutsches Filmmuseum, 1998).

18

Which Art in Heaven

Stan Hayward

Background

At school I had hoped to become a chemist, but national service in the navy put a stop to that. Around 1952 I became a lab technician, X-raying clay minerals. The work required much computation, and the transistor had just been invented so I became aware of computers and followed their developments.

Having failed to become a chemist, I tried writing and sold some ideas to the popular radio program *The Goon Show*, then became a scriptwriter in an animation studio in 1958 just when commercial television began. With my technical background, I worked on animated training films and could see this as an endeavor to which I might be suited.

In 1962 *The Flying Man*—a short experimental animated film I had written—won the Annecy Grande Prix, and on the basis of that I was invited to the National Film Board of Canada, which is famed for experimental film techniques. By chance this coincided with the Chicago Symposium on New Technology, and because of my technical background I was invited to New York to write a script about computers. At the time, the largest bookshop in New York had only one book dealing with the basics of computers.

I worked for a few weeks in a Madison Avenue advertising studio. It had a "state-of-the-art" office with an answering machine (large reel-to-reel recorder attached to a phone), a photocopier (heated crinkly paper), automatic phone dialer (plastic cards in which you punched holes for each number), and a radio-controlled TV. I went to the Bell Labs at Murray Hill to be shown films about computers, which included films by the Whitney Brothers using analogue computers to produce abstract designs. Most interesting was a weather map being plotted out by computer. It seemed to me that if a computer could draw a weather map, it could draw cartoons.

I asked the computer expert if it would be possible to draw animated cartoons in color with a computer. He nonchalantly said, "I don't see why not," and stated that anything, including color, sound effects, and music, could be computer-controlled if it could be converted to numbers. It was a "eureka" moment for me.

I was obsessed with the idea that computers could handle every aspect of animation production, but having little technical knowledge of computers did not realize that drawing pictures and making sounds required different types of computers and different programs and were incompatible with each other at every level; that is, I assumed that *any* computer could be programmed to do most technical studio production work. On returning to the Film Board and discussing the use of computers for animation, I discovered that in another department they were already making such a film, *Four Line Conics* by mathematician Trevor Fletcher; it was a mathematical film using wireframe drawings that were optically colored in the labs by coloring the white lines of the negative.

Animated films are usually short on script and long on production. To earn a living as a film scriptwriter, I had to either have a high turnover of scripts or work in some other capacity on production. I saw computer animation as an opportunity to sell scripts outside the studio system.

In the early 1960s other technological developments were finding their way into animation. For example, photocopiers could be used for tracing, scaling, and reversing images. The concept of using machines to eliminate production stages was a breakthrough, but the new technologies also offered creative potential. Computers were one aspect of this. I was now looking at three areas of development:

- Speeding up studio production methods
- Extending animation into new markets such as education and science
- Exploiting new technology for experimental films

I returned to the United Kingdom in 1963 and tried to get film authorities to investigate computer applications in film production. My arguments fell on deaf ears in every instance but one: the Halas and Batchelor studio. It was the largest animation studio in the United Kingdom at the time, and it produced all types of animation from feature films to TV commercials and educational films.

John Halas was a great enthusiast of new ideas who could see the potential of computers. At the time, the *Dr. Who* series used computer-generated sound and visual effects. The children's TV program *Thunderbirds* used puppets that had electronically operated lips. On the creative side, op art was popular, lasers were becoming artistic tools, and video was developing in leaps and bounds. The problem with video was that it could not record the single-frames necessary for animation, so it had no place in the animation studio.

A revelation came when I saw an Elliot Automation computer plotting diagrams at a computer exhibition. I suggested to John Halas that we use the computer for a series of math films on geometry, and I contacted Elliot Automation with the intent of asking the company to do the artwork. They invited us to meet fourteen staff members and to discuss buying one of their computers at the discount price of £110,000! We made the films using the studio animators.

It soon became apparent that animators hated the idea of computer animation; it was not just another technique like puppets or cutouts, which would extend their animation range, but a threat to their livelihood. This changed my approach to how computers might be used, but I continued to follow every lead I could find on computer applications to animation, whatever form they might take.

In a 1966 issue of *New Scientist* magazine, I thought I had found the answer in an article called "Film Animation by Computer" by Dr. E. E. Zajac. The introductory statement said: "By feeding a cathode ray tube with data from a computer it becomes very easy to make animated motion pictures illustrating a mathematically complex sequence of events. The technique has great potential, in enabling research workers to visualise the results of computation and in preparing educational films."[1]

The article began: "Supposing you are teaching a course in celestial mechanics." This was not directly applicable to the commercial market I was working in, but it was a start. I suggested to John Halas that we contacted Dr. Zajac and everyone we knew in the field doing any work related to computer animation regarding image generation and manipulation, and also machine control, sound synthesis, and applications that might find a place in the studio at another level. One of the people we contacted was Dr. John Oldfield, head of the computer-aided design project in the computer science department of Edinburgh University, as his department had equipment suited to computer animation as well as students working in this field.

John Halas had continued with the math series, one of which was *Ellipse*. I contacted Elliot Automation to do the artwork and produce the final drawings from the storyboard. These drawings were then traced onto cel, colored, and shot in the traditional way; this method integrated computer artwork with hand-drawn artwork. One major difficulty with computer animation was "the hidden line problem." When a 3D wireframe drawing such as a box rotated, the lines at the back still showed. It was a big problem that took years for programmers to solve. For the time being, plotted drawings had to be traced over and the hidden lines left out, or the drawings plotted directly onto cel and the hidden lines rubbed out. The final artwork could then be shot on a rostrum camera. *Ellipse* was complete in May 1967—my first computer-animated film!

Though animators hated the idea of computer animation, computer salesmen loved it; so I decided to approach computer companies for support rather than animation studios. In 1968 I wrote a film entitled *What Is a Computer?* for Halas and Batchelor, which I finished in 1970. The research on this film made me more aware of computer limitations; they were not quicker, cheaper, or better except for specialized work outside the studio, so were actually another industry in themselves. I had taken the computer animation path with the intent to increase my earnings in writing films, but I made almost nothing from this source; on the other hand, I was making money writing about computer animation for various magazines; not enough to live on, but it made me aware that promoting the concept of computer animation paid better than practicing it!

I had maintained an interest in science, and in 1970 a competition announced in *New Scientist* by Honeywell Computers asked for ideas on new applications for computers. I submitted the idea of "The Computerised Studio," saying:

> The plan of an animated film has a number of parallels with a computer program.
>
> 1. It is a step-by-step process
> 2. Drawings are coded sequentially, and composed of elements that are subscripted.
> 3. Animation cycles (walks, runs, wheels turning, etc.) occur through each film. These might be considered loops.
> 4. Transitions occur at the beginning and end of each scene. These may be considered subroutines.
> 5. There is an established system of coding and cross-reference for colors, field sizes, and movements that allow precise labeling of each drawing and instruction. This may be considered a machine language.
>
> The planning and charting of an animated film may be suited to data processing methods. There are three distinct stages in the production of an animated film:
>
> 1. *Creative* Ideas, research, script, design, storyboard.
> 2. *Production and Management* Costing, scheduling, charting.
> 3. *Technical* Animation, shooting, editing.

In June 1970 I was chosen as one of the winners of the competition, and, it gave me the opportunity to meet a number of others in the computer arts field. Around this time video-disk recorders, which could record short sequences of single-frames digitally, started to become available for line-testing. I realized that these would be the key to the commercial viability of animation becoming digital as these recorders would replace the film camera.

The Honeywell computer prize was a telex-like terminal that used punched tape. A timeshare system that worked between 8am and 6pm, it had rubber cups that fitted over the phone. Programs were written on punched tape then sent to be processed. I was given one free lesson on programming, a book of BASIC programming, and left to get on with it.

I learned enough BASIC programming to show that "A × B = C," which translated to "animator's salary" multiplied by "days worked" equals "cost of animation." I did this for the entire studio staff and produced a film-costing program. It was the only program I have ever written. I then invited three producers to test the system using their figures to cost a typical ten-minute animated film. They did so, and were amazed to see the printout. It was not the calculations that impressed them but the realization that all aspects of production costing could be automated.

My discovery was not that computers could save time or do anything clever, but how easily people were taken in by the computer hype. The costing program was of no use at all since producers don't estimate budgets on cost, but pick a figure out of the air of what they think the client will pay and then write a budget to justify it. The practical applications for an alphanumeric printout were rostrum camera movements and dope sheets. Both were beyond my skills, though Tony Pritchett did a basic camera movement program for me. The idea of making films by computer had caught the eye of the media who gave it much publicity in spite of my having nothing to show. The main benefit was to put me in touch with many people doing similar work. One was Ed Goldwyn, a producer on the BBC science TV show *Horizon* who had used computer animation produced at the Atlas Computer Laboratory in Abingdon. The head of Atlas was Bob Hopgood, who was developing the CAMP and CAMPER programs for animation and was to be a key figure in the field later. Another key contact was Peter Huhne, a businessman in the electronics field, who suggested that I start a company. He guided me through the formalities of writing and submitting a proposal to the NRDC (National Research and Development Company) for funding.

The NRDC was interested, and suggested it would cost around £100,000 to develop (a huge sum in 1970), but said it needed a technical organization to do the software and a commercial film/TV company to exploit it and put up half the funding. The NRDC put me in contact with several technical organizations, like the NPL (National Physical Laboratory) and various software houses, but they were all interested in selling computers and software to filmmakers rather than developing systems for filmmaking. It was a chicken-and-egg situation; no one wanted to develop it without a clear-cut market, and no studio would buy a system without evidence of it working. My mistake was looking at the concept of the computer studio as a whole, whereas at the time there was only one clear-cut market for computers in the animation studio—that of operating rostrum cameras. By now, the film and video industry had become a service industry, with people and facilities being hired on an as-needed basis. Camera operators previously housed in animation studios were now in "facility houses" and were competing for work, the best of which were advertising and special effects projects that required automated cameras.

By December 1970 Tony Pritchett had written a program for camera pans. It could only produce a printout, but as the keyboard also produced a punched tape version, the next step was obvious; approaching rostrum camera makers to see if the camera table could be computer-operated using punched tape.

The ACTT (Association of Cinematograph, Television, and Allied Technicians Union, now BECTU, the film and video union), which had previously been hostile to computers, now agreed to print my article on "The Computer Studio" outlining how each stage of an animation studio could be computerized.

In the meantime I had been going to art classes to improve my drawing for storyboarding. I discovered by chance discussion that a fellow artist was a technician and worked at Imperial College in South Kensington. He told me that the nuclear power department had just bought a D-Mac (Digitising Machine) flatbed computer digitizer and plotter. It sounded suitable for plotting on animation cels, unlike the drum plotters used at the time by engineers and architects. There were now two approaches to computer animation, using the wireframe approach of film, and plotting onto paper or cel and shooting the artwork on a rostrum camera.

The wireframe image used a "flying spot" system; you could only see a spot moving, not the line being drawn. A camera pointing at the screen would be exposed long enough for the complete drawing to be finished, and then move to the next frame. The final film was a white line on a black background. This could be transferred by telecine to video and then colored and other effects applied. By combining computer, film, and video, the shortcomings of each form could be overcome, but few people had access to film/video/computer equipment, and the cost and practicalities of working this way made it difficult to produce anything.

I went to Imperial College and met Dr. Colin Besant and Alan Jebb of the nuclear power department that had the D-Mac plotter. It operated from a PDP 8, which was one of the cheapest computers available at the time at around £8,000, but it did not include a monitor. The D-Mac plotter was about 6′ × 3′ and used a "puck," which was a primitive mouse with a cross-hair lens. You traced over your drawing by clicking on points. This was fine for engineering and architectural drawings as they were mainly straight lines, but curves were difficult to draw. There was also the problem that a point would occasionally register incorrectly, which would create spikes in the curve. These were not apparent until the drawing had been made, as the system did not have a screen to show the image being drawn.

Dr. John Oldfield also had a D-Mac plotter, as well as a microfilm plotter (cathode ray tube enclosed with a computer-controlled camera) in his department at Edinburgh. He invited me up to try digitizing a sequence of Muybridge drawings of a man riding a horse. The result looked very good, and apart from the problem of having to trace in the drawings, this method seemed to offer a way of line-testing animation even if it could not produce the final artwork.

It seemed to me that if the computer could show a horse moving, the technique could be applied to all animal movements, even nonexistent animals (such as those in cartoons). I contacted Dr. Charig of the South Kensington Natural History Museum and suggested that it might be possible to show how dinosaurs walked. He found the idea interesting, but said he did not know anything about computers so the movie *Jurassic Park* had to wait another thirty years to get made.

In March 1971 I met the people from the American company Computer Image who had the Scanimate system, an analog video synthesizer that was used to produce much of the video-based animation seen on television in the late 1970s. One advantage the Scanimate system had over film-based animation and digital computer animation was the ability to create animations in real time. The speed with which animation could be produced on this system, as well as its range of possible effects, helped it supersede film-based animation techniques for television graphics such as titles.

There were various video effects machines around at the time that could add chrominance to monochrome images. Typically the Cox Box, which could take a grey level of video and give it a color, was often used with character generators for titles and credits. Other machines enabled trailing images and applied Lissajoux patterns to live action images. These effects could be done in real time.

I thought that the Scanimate system might be combined with the system I had in mind, but on March 11 John Oldfield ran the "Muybridge horse" test on his computer system and it worked perfectly (figure 18.1). This boosted my confidence considerably in the digital as against analogue approach.

John Oldfield had previously done the computer artwork for the calculus film I had written for Halas and Batchelor, but now I could consider figurative animation; though only line drawings, "line-testing" was standard practice in studios (doing the animation as a pencil line to check movement and timing).

One company looking at the Scanimate system was Television International (TVI). The Scanimate system was physically large, requiring its own space and a full-time operator. The effects it could produce were similar for each job, so it quickly lost its novelty. On the other hand, digital animation could be done outside the studio as a service using computers that had the appropriate software and output devices of a cathode ray tube and plotter. I met with TVI executives to discuss the merits of digital animation, and I showed them the work I had done up to that time; they were impressed enough to put off the Scanimate decision. In June 1971 I was contacted by Julian Cooper, a director of the BBC science program *Tomorrow's World*. I showed him the Muybridge Horse we had done with John Oldfield, and the animation with Bob Hopgood at the Atlas Labs (figure 18.2), which had a stylus

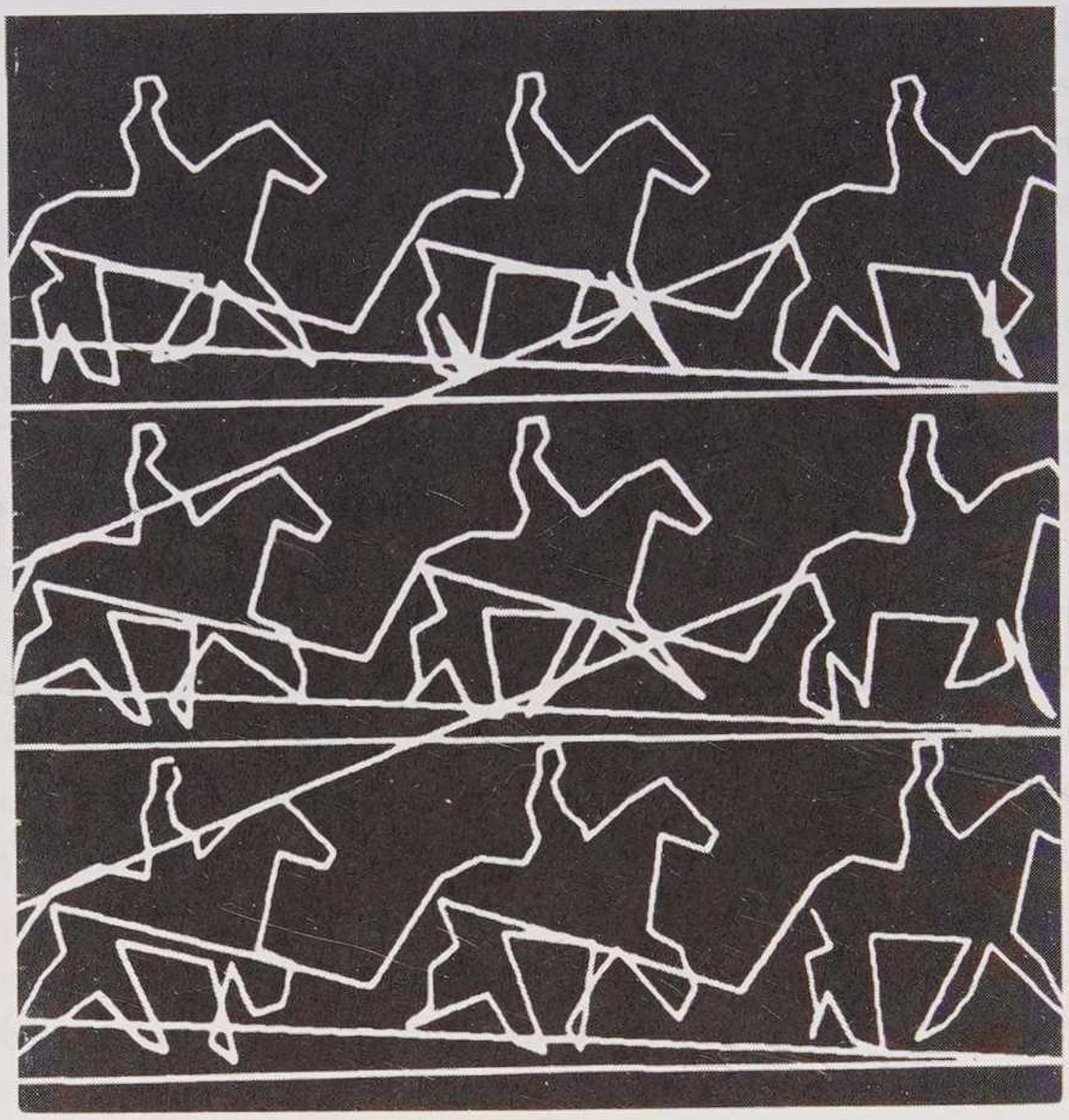


Figure 18.1 Muybridge Horse. First attempt of figurative animation using drafting puck.

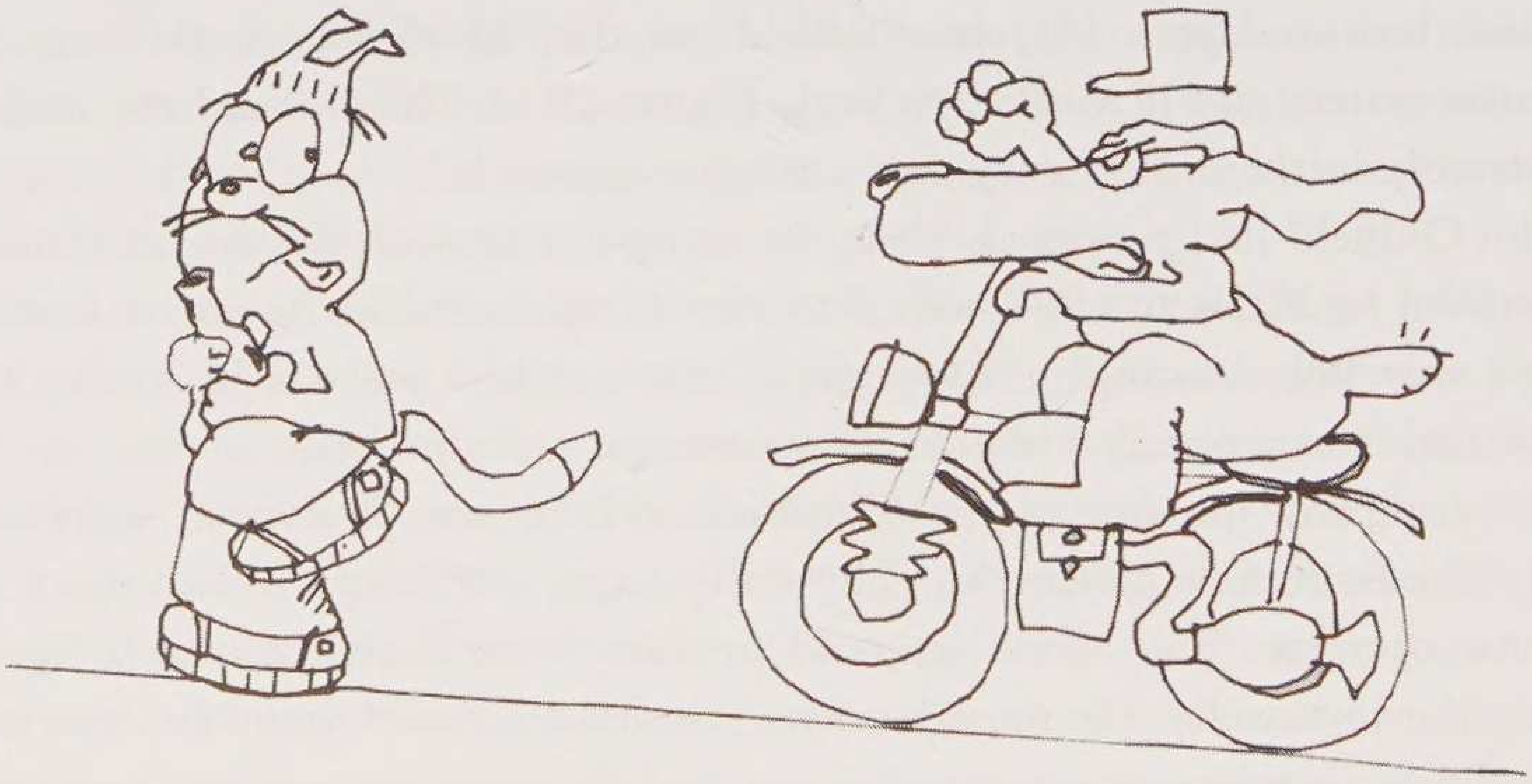


Figure 18.2 First attempt of figurative animation using a stylus.

that allowed figurative drawings to be traced; this greatly improved on the digitizing puck. Julian Cooper became enthusiastic and decided to make a long episode. The publicity supported my later applications for funding. We later produced the BBC's first computer-generated logo, and *Tomorrow's World* titles; the BBC's Open University became our best client.

While at the Atlas Labs, I met Paul Nelson who was organizing a symposium on CAD (computer-aided design) and computer simulation. He invited me to give a talk on computer animation. I set out the requirements of "The Computerised Studio" but extended it to include film and video techniques. Colin Besant and Alan Jebb were at the symposium, and they offered to collaborate on a project if I could set it up. I introduced them to TVI and NRDC.

Tony Pritchett invited me to the Computer Arts Society and introduced me to Alan Kitching and Colin Emmett, who were doing computer animation. I was particularly interested in John Lansdown's work on computerized dance notation as this was close to the idea I'd had of computerizing the Muybridge sequences of human and animal movements and linking them together so you could then link a run to a jump or a walk, and so forth, and construct a library of animation cycles.

In 1972 I was still earning my living writing traditional animation scripts. The computer work had to be fitted in when equipment became available. The Imperial College link enabled some of the programs to be done as student projects. Though in theory computer animation could be used for commercial work, doing commercial work in a college environment was difficult. Equipment had to be shared with students, and much of the development had to be done as student projects. But worst of all, academics do not recognize deadlines the way studios do, but I had no choice as there was no studio or commercial environment that had the necessary equipment available at the time. Moreover, software was being developed as students became available rather than as a priority.

If a machine did not work, it was in the hands of the college technicians rather than expert engineers. Minor items like a pen jumping during a plot could mean hours of work needing to be redone; such events were daily occurrences.

I put aside the idea of the computer studio for the time being and looked at machine control of the rostrum camera, as camera effects were now of major importance in the film world. A student programmer wrote a set of camera movements for me, which I tested with several studio cameramen. They all seemed enthusiastic and said they would use such a system and pay for the printouts. I felt confident enough to hire a Honeywell terminal of the sort I had won and go into business. I formed a company called The Computer Studio, with Colin Besant and Alan Jebb of Imperial College and two other directors, and set up at 82 Wardour Street in Soho. I then contacted all the animation studios and cameramen I knew to offer this service.

The media trade magazine *TV Mail* announced, "Computers Have Arrived in the Film Business." Not a single cameraman used it! Their enthusiasm had been for the concept, but in practice it required a computerized rostrum.

I had learned a very expensive lesson as I now had a computer, office, and staff, but no hopes of work. To start the company we had taken out a bank loan, and another director (who cannot be named) withdrew all the money and put it into his own company, putting us deeply in debt with no hope of recovery. It looked like the end of my computer animation dreams.

Luckily the considerable publicity we had gained enabled me to write and lecture on computer animation. The Imperial College project was still trying to put together the NRDC and TVI deal for funding, and in the meantime the college allowed me to use the equipment there when available.

I met a young animation student named George Borzyskowski who had made a computer film entitled *Crystal*. I asked him to make an animated version of the Computer Studio logo, which was a spiraling square I had designed as a tessellated pattern. Working with a programmer, he made an exceptionally good film called *Square*, which had the logo wrapped on a cylinder and spinning on three axes. Having four negatives optically colored and slightly offset it produced a 3D effect, and is to the best of my knowledge the first colored 3D computer animation done in the United Kingdom.

I applied for and got a grant from the BFI (British Film Institute) to make a computer-generated film called *The Mathematician*. The intent was to prove that computers could make figurative animation with budgets and deadlines suited to the commercial market and compete with traditional animation. I quickly regretted taking on the job as again it relied on students doing the programming. It was often beyond their skills, or had to be done between their studies, so they could never be relied upon. It was not finished until 1976 and was shown twice on TV. In spite of proving what I had set out to do, it made no impact at all on the computer animation world, and sank into obscurity.

Apart from being able to draw onto cel, another benefit of the plotter was that it partly replaced the camera. Where a camera would zoom in or pan on hand-drawn animation, the computer simply scaled or moved the image. The plotter working on the XY axis was similar to the rostrum camera table. I approached a plotter company with the idea of designing a camera table based on a plotter, but the company was not interested, though that became a successful project later.

I was now following several lines of development:

1. Using the plotter to draw onto cel and then shoot the cels on a rostrum camera. These cels could be overlaid on hand-drawn images. Flatbed plotting was good, but it took longer to digitize the drawings than to plot them.

2. Using a microfilm plotter to produce wireframe images that could then be optically colored. Microfilm plotting was only suited to certain types of film, was very expensive, and had to be colored in the laboratories.
3. Developing movement notation so it could be applied to animation. Movement notation was too complicated to consider further at the time, though I did look at various forms of dance notation including the works of Noah Eshkol and John Lansdown, which might have been used in conjunction with the works of Muybridge. I also discovered that NASA was using a movement notation to simulate astronauts' movements in space.
4. Using the computer to work out camera movements. This worked well, but cameramen used tables and standard routines to do most work, and calculating movements was a small part of the job; the whole rostrum camera needed to be automated for any significant gains, and that required controlling both camera and table movements. This was a huge problem as the rostrum table is very heavy and not easy to automate with prinpoint accuracy.
5. For studio administration, I considered applying PERT (Critical Path Analysis) to film production, but it was not suited to short films so I did not pursue this.
6. Making soundtracks. Other than special effects of analogue sound synthesizers, computers could not offer much to the animation studio, though there was the potential of doing soundtrack breakdowns, and bar sheets (the soundtrack breakdown that accompanies the dope sheet), as these are set out in rows and columns similar to a spreadsheet; I discovered later that spreadsheets actually were used for this purpose.

The NRDC was sold on the idea of "moving blueprints" for engineers and architects rather than the market for entertainment films or advertising. Technical animation was a predictable new market, but the NRDC deal was still not settled so no money was available to investigate this market.

The year had ended with not much to show for it, but by now I had contacted most animation studios in London and most film and video magazines likely to be interested in computer animation. I was now regularly writing and lecturing on the subject. TVI had decided to back the college system even without NRDC joining.

In February 1973 I discovered that the American company Computer Image had set up its system Scanimate on Wardour Street at Rank Film Laboratories, a few hundred yards from my own studio. I could not tell if this was good or bad in the sense of whether it would promote computer animation or be a competitor for the work I was hoping to get, but within days we had a microfilm plotter working at the college, aad this was a big jump ahead. We were also able to hire our own programmer instead of relying on students doing the work as projects.

Monitors with four colors were just becoming available, but they had huge pixels unsuited to animation. In May the NRDC finally agreed to fund our project, and the company Video Animation Ltd. (VAL) was formed, it operated out of the nuclear power department of Imperial College.

One of VAL's first jobs was to create a new logo for TVI. It had the words "Television International" made into two circles like two chainlinks with both links revolving. Hidden lines were on every frame so each circle had to be animated separately then both overlaid to check the hidden lines, which took weeks of work as each frame had to have hidden lines removed by hand.

We were now experimenting with microfilm and using an airbrush for coloring instead of getting it done optically at the laboratories. Projecting the microfilm for rotoscoping was considered at the time. Since microfilm could be made negative (black lines on a white background) with telecine, this was quicker and cheaper than getting it done at the labs, but we did not pursue this though rotoscoping was a commonly used technique in animation studios using back projectors on rostrum cameras.

In October, we finally got our own PDP 11 computer. It had 48K of memory and a 14′ removable disk drive holding just over 1MB, and it was linked to a monitor so we could see what we were plotting. A student made a library of lip shapes associated with phonemes so you could type in a phoneme and give it a number of frames to hold on, and so on to form a word. This would show the lips moving, but we had no way to put sound on it so we were never able to use it.

In November, Paul Nelson of Atlas Labs gave us a copy of the SPROGS program developed there. We now had a library of animation programs and all the hardware we needed, as well as NRDC backing. Things were looking up.

The year 1974 started well with a job for the college animating *Skyship*, an experimental concept for an airship designed in the engineering department at Imperial College. We also animated the blueprints of *The Great Eastern* for the Oscar award–winning Bob Godfrey cartoon *Great*, based on the life of the engineer Isambard Kingdom Brunel (figure 18.3). This was exactly the type of work I had hoped for.

The department technicians were working to build a "scan converter" to take the microfilm plotter output and put it directly onto video, and they were also building a "function generator" to produce Lissajoux patterns. But neither left the drawing board. At this time the first single-frame videos for security cameras were coming on the market, and I could see that these might be used to record animation. Rank Film Laboratories was now offering a "laser-scan" service for putting video onto film. This was useful because film was still the standard end product of animation, and although I never used the system, it was one of the many other areas of technological development that tied in with computer animation and promoted the concept within the film industry. In July I met Peter Neilson of Neilson-Hordell rostrum camera makers. He wanted to build a fully computerized rostrum camera, but he had had

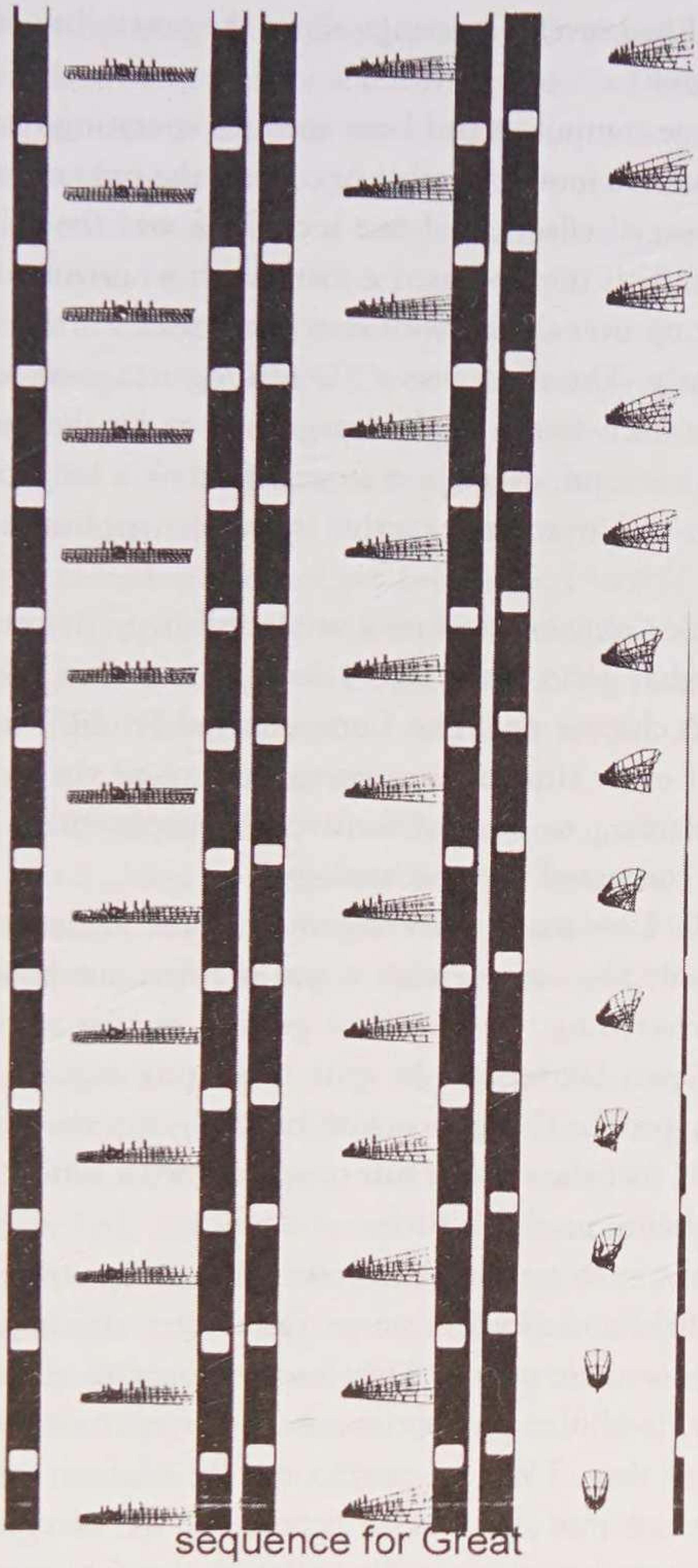


Figure 18.3 Sequence for Oscar-winning film, *Great*. First commercial film application.

problems doing so. I had several meetings about the possibility of working together, although we never did.

Although analogue computers had been used for operating rostrum cameras, they only did part of it such as move the table or control the camera itself. Optical houses were dedicated to special effects, and one technique was the "slit scan" method of producing 3D titles. This method used a mask with a horizontal thin slit in it that was moved down or up over the artwork after every shot. At the same time the camera zoomed in slightly. The effect was a 3D trailing image appearing to zoom forward. It meant that each frame of the image had to be shot many times, and at twenty-four frames a second, even short sequences took a long time to do, required much computation, and were very costly. It was an application ideally suited to computer control.

In 1974 the book *Computer Animation* was published.[2] It contained chapters by the various people that John Halas and I had contacted in the field of computer animation. My own chapter on "The Computerised Studio" was included among essays on a range of other similar ideas going on around the world. The computer applications were starting to become focused on people in the film industry who were not otherwise concerned with technology.

In September 1974 we made a TV commercial for Metro Radio animating the titles. Though not our first commercial, it was the first one broadcast, so we hoped for more work in advertising. we were now getting regular work, particularly from the BBC and the Open University. In spite of getting regular work, however, we were not making a profit. Things loooked hopeful, but then disaster struck, as a miners' strike meant that the college had to operate with limited power, preventing the machines from being used full time.

Another problem was that almost everyone in the company apart from myself was in the technology field and saw the project as a computer application that would either make money for them or not. They had no concerns about seeing the system opening up new fields of film production, and their attitude was sometimes unenthusiastic. On top of that, TVI was bought out by a larger company that saw the computer animation project as a loss; in September we were advised that TVI intended to put VAL into liquidation. We still had plenty of work and continued at the college while TVI looked for a possible buyer. One was eventually found with the EMI Music Group, which at the time was looking at the computer games market.

In March 1975 I was invited to West Surrey College of Art to give a talk on computer animation. I believe that the college was the first art college in the United Kingdom to teach this subject.

In May I had a meeting with Alan Sutcliffe and John Lansdown about using John's dance notation for animation, but nothing came of this. The NPL contacted me regarding two devices they were developing: SID (Speech Input Device), for doing automatic speech breakdowns for soundtracks, and a Datapad drawing tablet. Neither worked well enough to use, but the contact did indicate a growing interest in the media market by computer and software developers. I could see that eventually all these trends would merge into a computer system suited to moviemaking, and so followed up every development I became aware of.

By now colored CRTs existed, and many establishmnets had microfilm plotters and small digital plotters. The BBC and Open University regularly used our computer animation, but there was not enough work to make the company profitable. The miners' strike of the time and demands of the college on the system made it unworkable to run a company this way. But since the equipment and staff were still at the college and the company had not yet been sold, I looked for other sources of income in the hope the company could still be sustained. As the college had a management department, I asked if they could set up film databanks for film festivals and allow me to use their system. I made a databank for the Zagreb Film Festival of that year but could not find a way to get paid for it.

I then contacted CEEFAX (the BBC Viewdata system), which had just gone into use on the BBC. It was a character generator used for text news broadcast. The system used four colors, and I thought it possible that it could be used as a teaching aid and combined with animation. Although there was considerable interest, no funding was available.

With the equipment continually failing and our always having to beg, borrow, and collaborate to get work done, TVI felt the project was not going to be profitable and separated from NRDC. TVI then sent the Receivers in. In December I was fired from Video Animation Ltd. but was allowed to continue at the college. I was still earning my living from writing, and now from teaching animation, but with no salary from Video Animation Ltd. I had to look elsewhere for computer animation applications. It was now 1976, and I was still thinking about the idea of cheap computer camera controllers. Computers were made for such jobs, but rostrum cameras were huge, heavy, and mechanical, typically up to four meters high, and taking up a whole room. Working out the movements was simple, but machine control of a rostrum camera was another matter. It required stepping-motors that could accurately move the heavy table thousands of times and end up in exactly the same place. Even to be a fraction of an inch off would result in misalignment of images. The government was offering grants for ideas using the now cheap microprocessor units (MPUs) coming on the market. I approached the Department of Industry again with the idea of designing a cheap camera controller. This time I had a company to design and make it (Kins Applied Technology Ltd.) and an optical house ready to use it (Camera Effects Ltd.). It was a success, and six were sold. I was now acting as a computer consultant.

Although the government was promoting microchips and offering funding for ideas on applications, this funding was limited to paying for assessing the use of the chips. My proposal was for a camera controller. I researched the applications of MPUs and contacted Ed Goldwyn a producer on the BBC *Horizon* program, and I outlined a program on the coming of the microprocessor and its impact. He said he was not interested in computers as a subject, but a year or so later made a program called *The Chips Are Down*, which was seen by James Callaghan (then prime minister), who then appointed a technology minister, and put £100m into researching this field. I am not sure how much credit, if any, I might take for that.

The research on microprocessors applied to animation made me aware of a company Process Peripherals that sold a video disk that seemed suitable for line-testing, a stage of production used on all animated movies. It was unsuitable as it only stored about fifty frames as opposed to the several thousand required for animation, but Process Peripherals told me about Japanese single-frame video recorders used with security cameras that were perfect for line testing. A U.S. company Lyon-Lamb had made such a line-tester, but it was very expensive and not readily available in the United Kingdom.

I bought a single-frame recorder with animator Ted Rockley, and he had a controller designed that enabled the recorder to be set for any number of frames. The design was taken up by a rostrum camera company. It was the first cheap line-tester available in the United Kingdom, and it sold very well; I thought I had at last found a way of automating animation and making money. I put almost of my earnings from the line-tester into the development of a camera controller using the Apple II computer that had just come on the market. It worked, but the company went bankrupt, and I lost everything.

By then it was the 1980s and I was back to writing scripts for traditional hand-drawn animation, but I also had a children's TV series *Henry's Cat* running and a young daughter. Her school wanted to me to talk to the children about how cartoons are made. I set up a computer animation unit in the school, which in turn led to my getting several awards to run computer animation projects and websites for children; my original proposal had worked at last, but in quite a different environment to the one I had initially envisaged.

Notes

1. E. E. Zajac, "Film Animation by Computer," *New Scientist* (February 10, 1966): 346.
2. John Halas, *Computer Animation* (New York and London: Focal Press, 1974).

19

The Routes toward British Computer Arts: The Role of Cultural Institutions in the Pioneering Period

Catherine Mason

The unique position of early British computer arts can only be fully understood in relation to the central role played by cultural and, in particular, educational institutions. Due to the nature of computer arts, which required technical expertise and often involved persons from a non-traditional arts background, the specific conditions of access governing this pioneering work became an integral part of its origins.

The major route into computer arts in Britain during this period was through both artistic and scientific academic institutions. This was made possible by a reorganization of the art educational system and, for a brief time, a sympathetic governmental framework. Art with a technoscientific basis flourished, particularly within educational institutions supported by charismatic individuals, who inspired subsequent generations. These pioneers had a real vision of the arts and sciences coming together for greater understanding and creativity on both sides. The artistic counterculture of the 1960s encouraged an expanded notion of the art object, engendering an environment for artists and scientists to work well together, which contributed to the brief flowering that was this early period of computer arts.

The pioneers described in this volume forged alliances with academic institutions in order to gain access to the specialist equipment they required to further their artistic aims. This led to highly productive working relationships, enabling, for example, the production of Britain's first computer-animated film in 1967.[1] However, working with equipment designed for completely different purposes was a difficult task requiring long hours, dedication, and a particular type of mindset, which might as easily belong to an engineer as an art school–trained artist. Some of the resulting work was experimental in nature; some never reached complete fruition. Eventually, some pioneers, finding they had transferable skills, particularly in animation, graphics, and special effects, entered the commercial sector in the late 1970s and early 1980s.

Although a surprising amount of activity did take place, most of it existed largely outside what may be considered the mainstream art world of museums and dealer-gallery networks. The complexity and rarity of computers in the 1960s meant that any art form based around them was bound to be a specialized 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. Therefore the field of early computer arts is a rich example of interdisciplinary collaboration within art history. However, this diversity has a major bearing on how the art was and continues to be perceived by the art world. That it took place mainly outside of traditional art spaces is not surprising. Although artists throughout history have appropriated new technology and manipulated it to serve their own purposes, the specialized technology used in digital- and computer-based arts has traditionally been viewed by the art world as deriving from military applications, not art academies. This is one reason why the art world has been reluctant to embrace it. The issue is further complicated as many of these pioneers operated outside the framework of art history—either because they came from a technical rather than fine art training or because they were looking specifically for fields of practice and audiences away from the art world cycle of production, display, and sale. Ultimately, computer artists were forced to go in different directions in part due to a lack of mainstream institutional support, coupled with the changing nature of the art world throughout the period. However, the pioneers' work did have a lasting impact, both on the education of artists and their relationships to institutions, and on avant-garde art practice. In particular, their work produced a focus on interactivity, cross-disciplinary methods of working, and the practice of being an artist in the postmodern era.

The concept of using computers in art started in a sympathetic social and political climate in the United Kingdom. The computer manufacturing industry was reorganized, the use of computers in higher education was examined, and the education sector itself was reformed. Under Harold Wilson's "White Heat" government, post-war expansion of science funding was massive. Government expenditure in 1962 and 1963 was ten times that of 1945 and 1946, and at least half of this outlay was on technology that had not existed before the World War II. Science and technology seemed the talisman that would, through modernization, solve the problems of what had been perceived as relatively slow economic growth and decline.[2] To combat the strong market position of America's IBM, Wilson's Ministry of Technology (Mintech) assisted the development of British computer manufacture through mergers and acquisitions creating ICL (International Computers Limited), the largest non-American manufacturer of computers in 1968.[3] Mintech's Computer Advisory Unit stimulated the use of computers in the public sector.

The need for computers in the higher education sector had not been considered since the mid-1950s when the University Grants Committee (responsible for funding research at universities) became aware of computers as tools of academic research for which funds might have to be found.[4] By the early 1960s there was pressure to coordinate official policy. The Flowers Report attempted to assess the demands from British universities for the provision of computers and devise suitable structures to consider future policy.[5] Additionally, pressure was growing for change in the provision of higher education in the United Kingdom, due to increasing expansion. The Robbins Report in 1963 recommended a greater expansion of higher education, funded through additional public spending in order to, "avert the danger of a serious relative decline in this country's standing."[6] A few years later, recognition of the growing need for vocational, professional, and industrially based courses, which could not be fully met by the existing universities, led to the publication of the Government White Paper, *A Plan for Polytechnics and Other Colleges*.[7] This aimed to concentrate non-university higher education in thirty-one polytechnics in England, Wales, and Northern Ireland and fourteen central institutions in Scotland.

With advances in technology and the formation of the polytechnics, computers became more readily available. In certain institutions, a limited number of artists took up the computer as a tool, working method, or metaphor for practice. Due to these unique issues of access, both artists and persons from a technical or scientific background created work during this pioneering period. Far from being an isolated historical phenomenon, this early computer arts activity can be seen as a logical continuation of modern art and design pedagogy of the 1960s.

Early Influences and Basic Design Education

During the early stage in their development throughout the 1950s and early 1960s, computers were commonly thought of as "number crunchers" or referred to as "electric brains." Not only was it difficult to get access to this equipment, it was difficult to perceive of the computer as being an art method or material, let alone one with capacity for interactivity. But ideas such as cybernetics were widely disseminated and discussed. The Independent Group, the loose gathering of young artists and theorists who met at the Institute of Contemporary Arts (ICA), London, were among the first to recognize that visual culture did not exist in a vacuum, but was informed in direct relation to science and technology.[8] Their "affection for the new technology . . . broke sharply with ongoing British attitudes."[9] Many Independent Group members were involved with "Basic Design" education in the 1950s, which I describe in this chapter. This was to have a great impact on the future of computer arts activity in art schools. The influence of cybernetics spread from art schools into polytechnics, as those who had been students of technology went on to teach. Basic Design, a new type of art education influenced by European developments, was the most radical and progressive art education available at the time and was a crucial component in the development of abstraction in Britain. The influence of Basic Design on early British computer arts activity can be traced from tutor to pupil through art schools from its inception in the 1950s, with artists informed by cybernetics, through the 1960s, with artists working in programmatic ways using analogue devices, to artists who were able to access digital computer technology in the early 1970s. Further, Basic Design, while never a movement with a unity of purpose, did influence the formalization of art and design pedagogy, which was being reviewed by the government throughout this period.

The beginnings of Basic Design foundation courses can be traced to early initiatives by William Johnstone at two London art schools—Camberwell School of Arts and Crafts and the Central School of Arts and Crafts. As their names indicate, these schools had an emphasis on craft and the teaching of technique especially for the local trades such as printing. When Johnstone arrived at Camberwell in 1938, art education in Britain was at a low ebb, with a large number of technicians but few practicing artists actually teaching. Johnstone had trained and exhibited in Paris, where, "all the instructors were artists" and his vision was a school full of practicing artists rather than art teachers.[10] By engaging many of the leading practicing artists of the day, he was adopting the Bauhaus policy of employing fine artists to teach art to industrial and other craft designers. Bauhaus founder Walter Gropius stated, "The Practical Instruction [taught by two masters working in close collaboration] was the most important part of our preparation for collective work and also the most effective way of combating arty-crafty tendencies."[11] At Camberwell, Albert E. Halliwell, who had already had a career as a poster artist, set up a course of Basic Design in the commercial art (graphics) department. Reminiscent of the Bauhaus aim to train artists and craftspeople to participate in an expanding industrial society, Halliwell found, more immediately, that the course gave students the qualities wanted by employers. At the Central School (from 1947–1960), Johnstone determined to "shake it out of its 'arty-crafty' standards and to bring it in line with modern thinking."[12] He employed Independent Group members Eduardo Paolozzi in the School of Interior Design, Reyner Banham to teach art history, and architect Edward Wright to teach experimental typography. Richard Hamilton, William Turnbull, and Nigel Henderson all taught Halliwell's new Basic course in the department of Industrial Design, as did Victor Pasmore, himself an alumnus of the Central School.

Although more than three decades after abstraction was invented in Europe, Pasmore's shift of style in 1947–1948 from figuration to pure abstraction was considered by Herbert Read to be "The most revolutionary event in post-war British Art."[13] Pasmore's abstraction was influenced by Paul Klee's concept of "process" in his *Pedagogical Sketchbook*.[14] To further explore abstraction, Pasmore corresponded with the American artist and theorist, Charles J. Biederman (1906–2004).[15] However, abstract art was regarded as subversive in art teaching in the 1950s. Pasmore later commented that, "While [abstraction] was fine in design [at the Central School], it was in Fine Art that it caused an uproar!"[16] Abstract expressionism had only just reached Europe from America at this time, and was gradually changing the debate in Britain.[17] Young artists were becoming increasingly interested, so that finally an abstract foundation course became a viable alternative in some schools. When Pasmore left the Central in 1954 to become head of painting in the Department of Fine Art at Kings College, University of Durham, in the city of Newcastle upon Tyne,[18] he was in the unique position of being able to establish his experiments in a capacity that was not purely confined to the design departments, as it had been under Johnstone at the Central. Pasmore invited Hamilton (a lecturer in the school of textile design since 1953) to join him and together they set up and ran a Basic Design course, building on the Bauhaus concept of an integrated method of teaching by bridging the gap between the disciplines of the life room and the rigors of basic design.[19] Pasmore gave his reasoning behind it: "In the schools of painting and sculpture in London and throughout the country, there was no connection between the antiquated nineteenth century teaching and the revolutionary developments in modern art."[20] This course was designed to reference traditional academic training while taking into account the current art scene; as such it was a greater extension of the idea established at the Central. Although Pasmore and Hamilton were quite different in their approach and style, they both had a broad vision of the artist unconfined to one discipline who could think across old divisions between painting, sculpture, and architecture.

Like the Bauhaus, which placed emphasis on learning through experimentation and focused on the student rather than the curriculum and on the learning process rather than the results,[21] Pasmore taught that "any form, shape or process can serve as a starting point for abstract painting or sculpture whether it be a geometric square or a blot of ink, a rigid construction or fluid pigment. What was predetermined was not the end but the beginning."[22] This emphasis on process was a unique concept at this time—no more copying from plaster casts or using established works of art as paradigms, which had dominated art education since the founding of the Royal Academy.[23] The Basic course was taught to first-year students and included exercises based on natural science and technology, inspired by Hamilton's interest in D'Arcy W. Thompson's text *On Growth and Form* (1917) and cybernetic ideas developed in *Man, Machine and Motion* (1955), Hamilton's exhibition at the Hatton Gallery and the ICA. Hamilton and Pasmore's emphasis on creating an intellectual basis for learning about artmaking was a challenge to traditional art practices stemming from romanticism. However, it also coincided with a time when American abstract expressionism burst upon the scene in Britain. The manner in which abstract expressionism was promoted stressed the importance of free, creative, individual self expression. Many students found great inspiration in the new American painting at this time. These two approaches represented, on the one hand, by the self-expressive romantic and, on the other, by the logical constructivist (Pasmore) and techno-based conceptualist (Hamilton) were not as polarized as might be imagined. Trying to qualify the two approaches in his own work led Roy Ascott, graduate of the fine art department, to embrace cybernetics as a model for art practice, which he saw as a bridge between the two.[24]

Ascott, a student of Hamilton's and Pasmore's, was encouraged by the process-driven way of working taught in the Basic Design course. What might be termed a "next generation" basic course—Ascott's work at Ealing Art College in 1961—was formed from his experiences of the Newcastle model. Ascott's art work and teaching practice had strong social content, stressed inclusivity, and was directly informed by cybernetic principles of interactivity and feedback, as is discussed by Ascott in this volume. Ascott's "Groundcourse" emphasized, "learning from the ground up."[25] Behavior and process were the models for the course, which stressed media dexterity, interdependence, cooperation, and adaptability, as evidenced by the wide variety of artists and theorists brought in to give lectures, demonstrations and seminars in the fields of "cybernetics, semiotics, psychology, and such areas of study that seem pertinent to the general enquiry."[26] This was among the precursors of the new formalized Foundation Courses.

Foundation Courses came about as a result of the radical reform of education in the art and design sector put forward in the First Report (1960) of the National Advisory Council on Art Education under Sir William Coldstream.[27] This reorganization of the validation of art education raised standards and paved the way for the introduction of BA degree-level fine art courses in the mid-1970s. Crucially, the New Diploma in Art and Design (Dip.AD), which replaced the National Diploma in Design (NDD), was to be a university degree equivalent, given for completion of a program of three years duration. However, the Coldstream Council felt that three years of study was insufficient due to what they identified as the poor basis of preparation in the secondary schools. They favored a four-year course, to reflect the duration of the outgoing National Diploma. Therefore a one-year, pre-diploma course or Foundation Course as it became known, was formally instigated in 1963.[28]

Foundation Courses were unlike anything that had gone before; not validated by any central agency and often controversial, they became test beds for the innovation, experiment, and idiosyncrasies of teachers. They were never accorded any official or formal recognition, yet to this day remain an invaluable feature of art education in England and an essential requirement for entry into higher-level art education. Although Coldstream did give broad outlines for Foundation Courses, no syllabus or format was prescribed, thus allowing individual colleges considerable flexibility in the way they interpreted them.[29] However, there was no reference to photography or electronic media, the coming impact of computers, or conceptual art. The only, very brief, reference to photography is in the graphic design section. This demonstrates how radical Ascott's initiative, which directly employed cybernetic principles and analogue computing techniques, actually was. Coldstream's Council set out a definition of "fine art" within the Dip.AD course (which was to be a basis for any later specialization) as simply drawing, painting, and sculpture.[30] The major result of the Coldstream Report was that for the first time in the history of government-funded art schools, individual schools would be able to set their own curricula and examinations, albeit according to a national standard. Bernard Cohen, who had been a student under Coldstream at the Slade School, later described Coldstream's "greatest achievement" as being, "to rid this country of a system in which all art students were judged by such a committee. He put judgement into the hands of individuals within individual art educational communities."[31]

An early Department of Foundation Studies was formed at Leicester College of Art that acknowledged, "Our civilisation is discovering new ways of looking at things, both in art and science. The decline of the classical academies has required the revision of art school training and the necessity for evolving the artistic principles of this century." The interdisciplinary study program consisted of, "Courses and specialist lectures . . . on the central themes of the history and development of ideas and changing conceptions of form in art and technology and other disciplines, e.g., Science, Philosophy, Music."[32] Leicester was to play an important role in computer arts later in the decade.

As the new degree-equivalent Dip.AD qualification with its academic entry requirements and compulsory studies in art history and theory began to replace the NDD, Basic Design philosophy rapidly entered the canon of art school teaching—but this proved controversial. The two opposing philosophies in art education prevalent during this period were, on the one hand, Basic Design's abstractionism, industrial methods, and apparent impersonality, versus an approach that allowed "powers of feeling to oppose powers of knowing," based on the (dominant) notion of art as romantic ideas.[33] Student uprisings at, for example, Hornsey College of Art in 1968—defined as "a restatement of the spirit of romantic bohemianism"[34]—can be seen as an expression of discontent against the reforms put in place by the Coldstream Report as well as the process of coming to terms with modern art within British art schools. Those colleges that were not approved as centers for the Dip.AD either moved toward more vocational or adult education-type course provision or were closed down by local authority funding bodies.

In the 1950s a system devoted to conformity, to a sense of belonging to a classical tradition, and to a belief that art was essentially about technical skill, gave way to a general devotion to the principle of individual creative development.[35] Having been forced to carry out a review and development exercise gave teachers in Britain enormous advantages and a new measure of leadership in the world of art and design education.[36] The unique character of British art education was recognized during the period: "In England, the best in art education seems to happen of its own volition, independently of an administration, either benign or despotic. It happens when certain events, attitudes, indefinable moods, staff and students all come together at a particular time."[37] This appears particularly true in the case of emerging computer arts activity in Britain, activity that was largely incubated in the art schools and, to an extent, defined by their unique character. Ascott's important contribution to art pedagogy can be traced through the education of a generation of artists who developed an interest in the use of computer technology in art.

Stephen Willats's early diagrammatic works bear out Ascott's stated assertion that, "The studies of Communications including the making of charts and diagrams, the presentation of ideas verbally and with the written word and historical introduction to communications systems is an integral part of the Groundcourse."[38] When Ascott became head of the fine art department at Ipswich Civic College (1964–1967) Willats joined him on the teaching staff. His collective projects with students were continued at the Department of Fine Art at Trent Polytechnic, Nottingham in 1969, as discussed by Adrian Glew in chapter 3.

Stroud Cornock, who had studied sculpture at the Royal College of Art, also taught with Ascott at Ipswich during the mid-1960s (figure 19.1).

Cornock later moved to the City of Leicester Polytechnic, where he founded the Media Handling course in 1968. One of the main principles of this course was the belief that any medium had validity for artistic activity and that process rather than object was important.[39] In 1971, Cornock organized *The Invention of Problems II* event and exhibition at Leicester, described as "Concerts, Symposium, Exhibition . . . to examine some of the ways in which some artists and scientists are seeking to initiate a creative exchange between themselves and an unspecialised audience."[40] The symposium, *Creativity in a Machine Environment*, brought together speakers from the fine arts, academia, architecture, science, and engineering, drawn from around the country, including Edward Ihnatowicz, Ernest Edmonds, Stephen Willats, George Mallen, Cornock himself, and others. The dean of the Central Division

Figure 19.1 Stroud Cornock, *Game* participatory group project with students at Ipswich Civic College, 1965–1966.

of the Polytechnic, Albert Pountney (himself an artist), acknowledged the increasing importance of the cross-disciplinary aspect possible in such institutions. In the opening address Pountney stated, "Not only do we wish to see our artists share in the skills of their technical colleagues, and vice-versa, but we also seek some overall purpose in these activities through the joint application of such creative collaboration."[41] Such an admirable statement of intention must have been very heartening for the audience to hear. However, Cornock later encountered hostility when trying to raise funding for one of his multidisciplinary interactive art projects—a reminder of the inherent difficulties for artists working at the boundaries of disciplines, often using expensive equipment that required funds, and concepts that required further sustained research in order to realize. This attitude could prevail even within the polytechnic culture, one of the most hospitable places for computer arts activity during this period.

Initial skepticism displayed by the government educational awarding body toward the concept of "real" research being possible in the visual and creative arts centered on concern about how to accommodate art practice within the narrower definition customarily seen in academic disciplines. However, by 1978, the Council for National Academic Awards decided that "in appropriate cases, the Council may approve a programme leading to the presentation of a thesis accompanied by material in other than written form."[42] It is perhaps not surprising therefore that the first artists to undertake advanced research were located in polytechnics, using new media technologies, with a scientific bias. *The Invention of Problems II* event gave Cornock's student Stephen Scrivener, at the time working on kinetic and light pieces, the idea of using the computer in art. Scrivener went on to be among the first cohort at the new "Department of Experiment" at the Slade School in 1972, where he accessed computers and indeed constructed his own equipment. ("Department of Experiment" is the title used by Malcolm Hughes in his introduction in the *EXP at PCL* catalogue of 1979. The department is remembered by different names. Among those I have seen references to are: "Experimental and Computing Department," "EXP," "Department of Experimental and Electronic Art," "Experimental Media," "Experimental Studio," and others. There may have been a progression of names in use over the life of the department, but it has proven impossible to establish a timeline with any certainty.) Later, Scrivener became the first artist in the United Kingdom to commence work on a PhD, under Ernest Edmonds at Leicester.[43] Leicester became the first institution in the United Kingdom to award the PhD in Fine Art, in 1978, to Andrew Stonyer, an artist working in solar kinetics. Stonyer's supervisors were Leicester's head of sculpture and the reader in chemistry, with the Slade School of Art the collaborating establishment.[44] Arguably, such an accomplishment would not have been possible outside a polytechnic, with its collaborative research-based culture.

The polytechnics concentrated expensive resources into fewer but larger multidisciplinary centers, and many art schools were amalgamated into these new institutions. This move was not without controversy among some artists, with Patrick Heron, for example, lamenting the "Murder of the Art Schools,"[45] However, for computer arts, this proved to be a fortuitous move. The next generation of pioneers growing up in the climate of optimism culminating in *Cybernetic Serendipity* at the ICA in 1968 started coming through the art school system in the early to mid-1970s. One of the main characteristics of British computer arts of the 1970s was that it involved artists who either learned to write code themselves or built up a working relationship with scientists, engineers, or technicians, at a time when the computer itself was at a formative stage. By the early 1970s, the major route into computer arts was through a select number of art schools. These provided not only education and training but, in some cases, career incubation, employment, research facilities, and networking opportunities. In a few institutions, at least, the result was that artists had the opportunity to access expensive and specialized computer equipment and technical expertise (generally belonging to science and maths departments) for the first time. This was a unique feature of British education at this time—as an art student, one could learn to program. Thus, at a polytechnic, it was theoretically possible to study art and craft (technology) together, as in the first public art school at South Kensington in 1837.[46] Numerous examples of interdisciplinary collaboration at institutions across the country can be found throughout this volume.

At Coventry School of Art (then in the process of becoming Lanchester Polytechnic), practitioners from the two backgrounds of design and fine art were able to meet in computing. Clive Richards, coming from a technical illustration background, worked with Ron Johnson, head of the computer science department, to create *Spinning Gazebo* (1970) (figure 19.2).

This three-dimensional wireframe representation of a gazebo rotating in space was the first computer animation produced in a British art school. Richards later created the CACTI (Computer-Aided Construction of Technical Illustrations) software package.[47] The fine art side, with Terry Atkinson, Michael Baldwin, and Dave Bainbridge teaching at Coventry, saw the founding of the conceptual art group Art and Language (A&L) in 1968. Its use of computational methodologies resonated with similar uses of computing technology. The setting up of the Computer Graphics Studio at Lanchester Polytechnic in the early 1980s demonstrates an approach pioneered at Coventry to reconciling the conflicting requirements of educational needs and available finance. At a time when mainframes were still largely considered the best way to do things in universities, it was the art and design studio that was essentially the first to have personal computers in the institution. Assisted

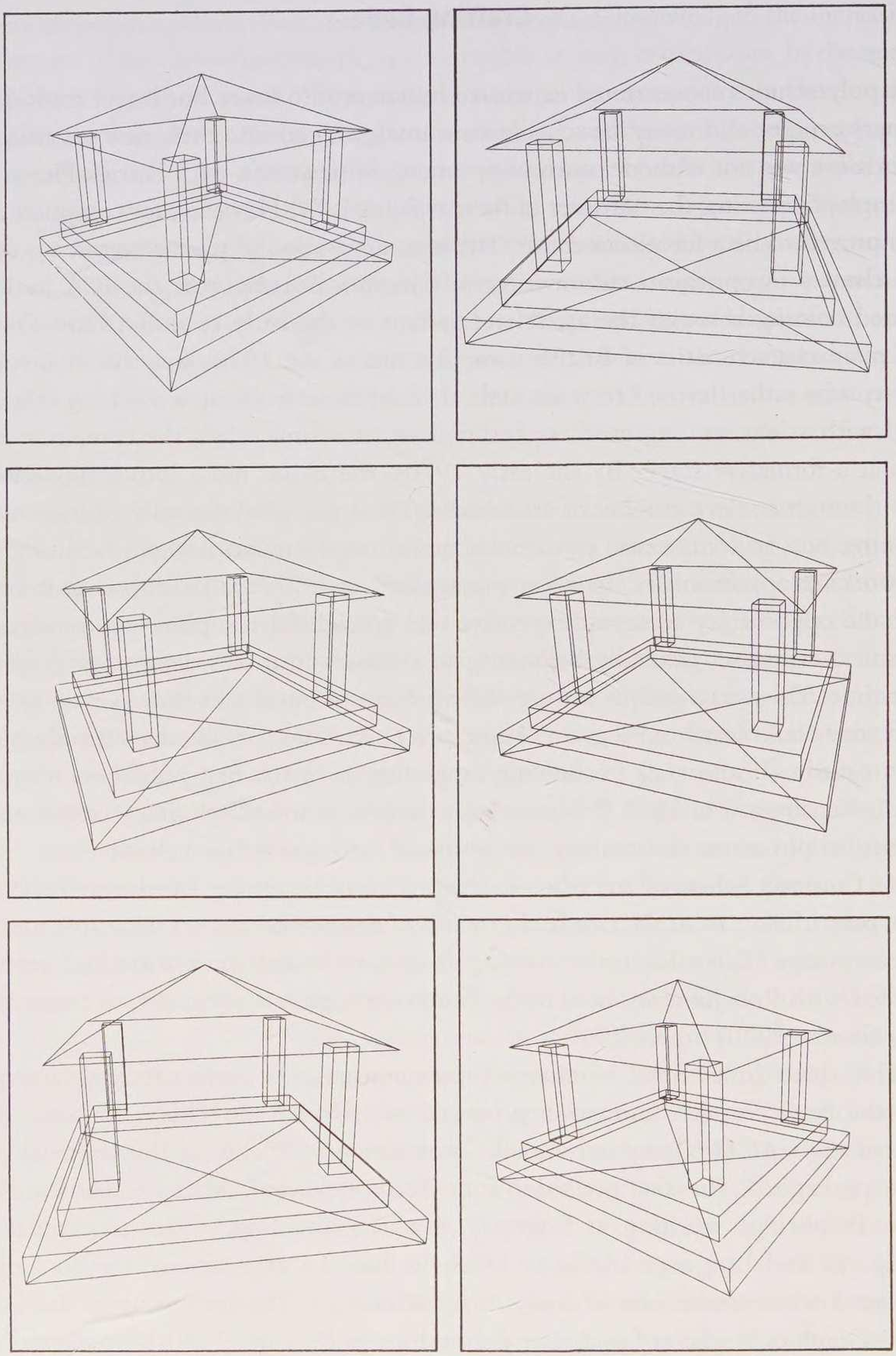


Figure 19.2 Clive Richards, stills from *Spinning Gazebo*, 1970.

by the appearance on the market of relatively inexpensive, powerful microcomputers, the Studio was based on IBM-PC-compatible equipment, equipped with a Pluto II frame store. This introduced the idea that large groups of students could work on relatively affordable desktop computer hardware, producing graphics to at least television standard.[48] In 1986 the linked Postgraduate Diploma and MA in Electronic Graphics was founded at Coventry (with the first student intake in September 1986). This was the first full-time postgraduate Master of Fine Arts course in computer graphics in Europe. Created within the Department of Graphic Design, its emphasis was on the graphic arts, including computer-aided drawing, design, modelling, video, information, text generation, and presentation.[49] It was closely followed by the MA in Computing in Design and MSc in Computing Graphics courses at Middlesex Polytechnic, as described by Paul Brown in chapter 21 (this volume).

At Coventry, artists and designers inserted themselves into computing, but at Middlesex Polytechnic, it was the converse—a programmer recognized the opportunities and inserted himself into the art community. John Vince, a programmer before becoming a lecturer in data processing, taught computer languages and technology to students studying a wide variety of courses at Enfield College of Technology, Hendon College of Technology, and Hornsey College of Art (which became Middlesex Polytechnic in 1973). Realizing that artists and designers were interested in this device but that they did not necessarily want to write high-level programing, Vince developed one of the first packages for artists—PICASO (Picture Computer Algorithms Subroutine Orientated). Darrell Viner and Julian Sullivan worked with him at Hornsey and later went to the Slade School for postgraduate studies. In the later 1970s, Vince and his colleagues ran training courses for the television industry. By 1980, PICASO contained about five hundred subroutines and, together with its complementary rendering system PRISM, was being used by over twenty-five academic institutes in the United Kingdom.[50] Many pioneers were associated with Middlesex, which secured an international reputation for computer animation and graphics.

As the beginnings of the application of computing technology to the arts tended to take place within the context of design and the applied arts, often in provincial institutions, the great pioneering role played by Malcolm Hughes at the Slade School of Fine Art is all the more impressive. The unique founding position of the Slade as part of a liberal arts university meant that it could, among other things, "think about learning rather than serving commerce."[51] The computing curriculum was founded in 1972 by Hughes, a co-founder of the Systems Group (described by Richard Wright in chapter 10, this volume), and head of postgraduate studies under Professor Coldstream. Hughes had a Renaissance concept of the arts; he felt that artists could be scientists too. Hughes, along with Chris Briscoe (a technician who later became head of the department), was instrumental in acquiring computer hardware for artists to use at this early date and persuading management to fund computing for art practice. Remarkably, at the Slade, this was driven by artists with training in fine arts, often coming from an undergraduate background in systems or kinetic art studied at regional polytechnics, rather than by scientists or technicians. Here at the Slade in the 1970s is the culmination of the line of computer arts activity traced from tutor to pupil through art schools that began with an interest in cybernetics and the Basic Design curriculum of the 1950s.

Into the Commercial World

In the early days, the notion of working with computers as an artist was quite groundbreaking. Almost the only access to computers for artists was in academic institutions. These pioneering artists had to learn to work within a research environment using equipment not originally designed for artistic purposes. Efforts in educational institutions impacted technological developments in the wider world. As the polytechnics had the equipment and the practitioners within had the expertise, they took on initially modest commercial work for advertising agencies and clients such as BBC Television. Into the 1980s, the field began to grow commercially. Computer animation techniques were in high demand. Artists and technicians, finding they had transferable skills, were able to pursue projects in the commercial sector. With the growth of television advertising came increasing demands for sophisticated visual effects. The motion picture industry was also interested in using the latest technology to create special effects. Although the polytechnic hierarchy was generally fairly receptive to computer work, occasionally even introducing concepts such as "study leave" for its practitioners, by the late 1970s it became clear that the level of investment these institutions could make simply could not match that made by the commercial sector. With changes in institutional management, it was all too easy for art/science crossover projects to find they no longer had a justifiable remit and several closed down. The downturn in public sector funding in the 1980s coincided with a rise in demand from the commercial sector for sophisticated graphics, which were rapidly becoming more easily produced by a computer than by traditional methods, thus encouraging a move for some artists into private sector freelance or part-time contract-type jobs.

Some pioneers migrated from educational institutions to found commercial production houses. The special effects company Digital Pictures was formed by Paul Brown and Chris Briscoe, two artists from Hughes's Experimental Department, initially in partnership with the Slade, as a way of running and maintaining the computing equipment at the school. Other ventures were set up to facilitate the commissioning process and to manage personnel, to work cooperatively with commerce, bringing knowledge and expertise gained from academic institutions. One such company, System Simulation Ltd., was set up George Mallen and is described by him in chapter 15 (this volume). Such ventures were driven by the service industry but they also made possible the continuation of research and development in this rapidly expanding field.

By banding together, artists found ways to overcome lack of interest within the formal art world. The role played by artist-led organizations, both formal and informal, during this pioneering period was immense. Numerous interdisciplinary events and exhibitions took place, which are discussed more fully in other chapters of this volume. The Computer Arts Society, for example, supported practitioners through a network of meetings, conferences, practical courses, social events, exhibitions, and occasionally through funding of art work production. The Society was able to attract publicity, even hiring a professional public relations consultant for a time.[52] Jasia Reichardt and Jonathan Benthall in particular championed the cause of this type of art in the press.

Most computer arts projects were expensive to create in terms of time and cost of equipment, materials, and specialist labor. However, it was not simply a case of funding; artists also had to overcome the fundamental difficulties of an art world that could not generally comprehend this type of art, and many pioneers had to struggle to realie their projects. Benthall lamented lack of support in Britain for such projects as Edward Ihnatowicz's *Senster* "at a time when most art-produce, including that using new technologies [is] buffered from public indifference by the support of art administrators with no more belief in what they are doing than has the most frightened commissar."[53] Although this work was privately funded (by Dutch electronics firm Philips) and exhibited abroad, it was Ihnatowicz's working relationship with engineers from University College London that enabled it to be produced. This is an extraordinary example of a classically trained artist, albeit one with a high level of self-taught engineering skill, working co-productively alongside engineers in an educational institution. This interdisciplinary approach is a unique example in the practice of sculpture in Britain at this time. The details of the *Senster*'s commission, difficulties presented during the exhibition of the work and its subsequent dismantling, are typical of the attitudes museums still have in dealing with this type of work. Ihnatowicz's constant search for funding is an indicator of the problems encountered by many artists working at the crossover of art and science during this period.

For a few pioneers, it proved too difficult a task to integrate art and science together in the truly comprehensive way they initially envisioned and they gave up. In some cases, the technology did not live up to its promise. Many artists refused to be termed "computer artists" and were reluctant to engage with computer art world activities. Even within the Computer Arts Society there were debates over terminology and approaches. In Britain, with its historically conservative attitude toward modernist art practices, it is not surprising that by the mid-1970s, activity which had not turned commercial became largely invisible. This had mainly to do with the nature of computer arts itself and its problematic relationship to the institutional structure of the art world. Lack of consistent mainstream support, especially from museums, galleries, and major funding bodies, together with production of artwork by practitioners without formal art school training, made it difficult for the field to be embraced wholeheartedly in any official capacity. Many of the exhibitions that pioneers participated in took place at computer trade shows or conferences venues, outside of the professional art arena and often unaccompanied by catalogues; thus they received little to no media coverage, particularly in the art press. Work not codified by museums tends to get written out of cultural history. Since the 1990s, the rise in popularity of multimedia installations and interactive, participatory art forms, including net.art, although only tenuously related to first wave pioneering developments, demonstrates that ground is being gained, although these forms have yet to be thoroughly integrated into mainstream museum culture.

Lack of mainstream support had repercussions on the future careers of many pioneers. Some artists who initially trained as painters or, more typically, sculptors found second careers producing computerized special effects. The commercial sector went on to develop its own approach and venues for practice and exhibition, including, for example, in the United States, the annual conference and art exhibition which began in 1981, organized by the Association for Computing Machinery's Special Interest Group on Graphics (ACM SIGGRAPH). Those who did not pursue commercial work continued their careers in academic environments. Institutions had to start focusing on training designers who wanted computer knowledge for their careers. Consequently, computer arts was forced to progress in a different direction —toward graphics, the commercial applications of which existed outside the traditional sphere of the art world. "First wave" or pioneering computer arts (now separate from computer graphics) receded further from view. Computer graphics, on the other hand, became increasingly visible on television and in motion pictures.

The story of Brown and Briscoe's Digital Pictures, starting in an art school and finishing in the private sector, marks the end of the early pioneering period in several ways. By the early 1980s, computing technology had changed radically. It was no longer an imperative to construct one's own hardware. Although many people continued to write their own code, proprietary software packages were becoming more widely available and user-friendly systems were gaining ground. Much of the technology used by pioneers became ubiquitous. It may now be rare for artists to be taught programming, but many of the pioneers' ideas became integrated into the mainstream; the rise of proprietary software such as paint packages for example, means that one no longer has to write code to achieve a wide range of effects.

The place of computer arts within the art world was changing too. Late modernism, with its predilection for geometric patterns and emphasis on process (which had suited the systems aesthetic of computer arts), was being subsumed by the eclectic, self-referential subject matter of the postmodern aesthetic, where demonstration of skill was not necessarily measured in means and method, but rather in the capacity to communicate a message. Ironically, many central elements of postmodernism, including the erosion of traditional distinctions between high culture and the market, the challenge to modernist claims of unilinear historical development, and the belief that mass consumerism constitutes a major break with the social and technological conditions of the first half of the twentieth century, were bred in the art schools during the 1950s and 1960s.[54] However, the cross-disciplinary work done in this period has proved of lasting impact on arts education, particularly with regard to notions of freedom of materials as well as a manner of working that takes into account institutional processes and the relationship between artist, audience, material, and environment. The interactive, responsive characteristics of much early computer art continue to dominate contemporary new media–based practice. With its emphasis on process and materiality, computer arts can be seen as a crucial part of the transition from late modernism to postmodernism.

Notes

1. Tony Pritchett's *The Flexipede*, created at the Institute of Computer Science, University of London, on the Atlas computer and output to 16mm film at the Culham Laboratory in 1967. Exhibited at *Cybernetic Serendipity*, 1968.

2. Ian Wilkie, *British Science and Politics since 1945* (Cambridge, MA, and Oxford, UK: Blackwell, 1991), 19, 56–57.

3. Murray Laver, "ICL: The Ministry of Technology and the Merger," *Contemporary British History* 13, no. 1 (Spring 1999): 183–185.

4. Jon Agar, "The Provision of Digital Computers to British Universities Up to the Flowers Report (1966)," *The Computer Journal* 39, no. 7 (1996): 631–642.

5. Council for Scientific Policy, *A Report of a Joint Working Group on Computers for Research* (The Flowers Report) (London: HMSO, 1966).

6. Committee on Higher Education, *Higher Education Report of the Committee appointed by the Prime Minister under the Chairmanship of Lord Robbins 1961–1963* (London: HMSO, 1963).

7. Department of Education and Science, *A Plan for Polytechnics and Other Colleges: Higher Education in the Further Education System* (London: HMSO, 1966).

8. Anne Massey, *The Independent Group: Modernism and Mass Culture in Britain 1945–1959* (New York and Manchester, UK: Manchester University Press, 1995), 54.

9. Douglas Davis, *Art and the Future: A History/Prophecy of the Collaboration between Science, Technology and Art* (New York and Washington, DC: Praeger Publishers, 1973), 61.

10. William Johnstone, *Points in Time: An Autobiography* (London: Barrie & Jenkins, 1980), 183.

11. Walter Gropius, *The New Architecture and the Bauhaus* (1935), quoted by Gillian Naylor, *The Bauhaus Reassessed: Sources and Design Theory* (London: Herbert Press, 1993), 74.

12. Johnstone, *Points in Time* 247.

13. Herbert Read, quoted in Jasia Reichardt, *Victor Pasmore* (London: Methuen, 1962), n.p.

14. Ronald Alley, *Victor Pasmore, Retrospective Exhibition 1925–1965* (London: Tate Gallery, 1965), Cat. Note 70, n.p.

15. Charles J. Biederman's *Art as the Evolution of Visual Knowledge* (Minnesota: Red Wing, 1948) is an exhaustive rethinking of art history from a perceptual rather than a stylistic perspective. Biederman advocates a severe form of abstraction dictating that artists should not copy nature's effects but follow structural processes and procedures. Neil Larsen, http://www.charlesbiederman.net/ (accessed April 11, 2005).

16. Victor Pasmore, unpublished letter to Richard Yeomans dated October 2, 1983; see Richard Yeomans, *The Foundation Course of Victor Pasmore and Richard Hamilton 1954–1966*, PhD (Education), 1987.

17. Willem de Kooning's work was included in the U.S. representation at the *Venice Biennale* in 1948 (Great Britain's entry was Henry Moore). Jackson Pollock and Arshile Gorky were exhibited at Venice in 1950. The ICA exhibited the first Pollock in Britain in the show *Opposing Forces* in 1953. The Museum of Modern Art's touring exhibition, *Modern Art in the United States*, exhibited twelve abstract expressionists in eight European cities, including at the Tate Gallery in 1956; a retrospective of Pollock's work toured to the Whitechapel Art Gallery in 1958, two years after his death.

18. Kings College separated from Durham University in 1963, becoming University of Newcastle upon Tyne.

19. Richard Hamilton, "About Art Teaching, Basically," *Motif*, no. 8 (Winter 1961): 17–23.

20. Victor Pasmore, unpublished letter to Richard Yeomans, October 2, 1983; see Yeomans, *The Foundation Course*.

Other Basic Design courses were subsequently started by Harry Thubron at Sunderland School of Art with Tom Hudson. Later, Thubron and Hudson both moved to Leeds College of Art, where they founded the Department of Basic Form and Research.

21. Hattula Moholy-Nagy, "Laszlo Moholy-Nagy: An Appreciation," in *Taken by Design*, ed. David Travis and Elizabeth Siegel (Chicago: University Press, 2002), 13.

22. Roger Coleman, in Victor Pasmore, Harry Thubron, Richard Hamilton, and Tom Hudson, *A Developing Process* (Durham: Kings College, and London: ICA, 1959).

23. A student in this course, John Walker, has pointed out that plaster casts were still in evidence throughout the building, including in the entrance hall and library. In his experience the so-called "Re-interpretation" of historic art project (taught by others) seemed to be at odds with the philosophy of the Basic Design course. John A. Walker, *Learning to Paint: A British Art Student and Art School 1956–1961* (Greenwich, UK: Institute of Artology, 2003), 10.

24. Roy Ascott interview with author, September 2, 2003.

25. Ibid.

26. Roy Ascott, "Introduction to the Groundcourse," *Prospectus*, Ealing School of Art (1962–1963), no page numbers.

27. Painter and educator William Coldstream was by this time Slade Professor at University College London. He became Chairman of the NACAE in 1959.

28. Robert Strand, *A Good Deal of Freedom: Art and Design in the Public Sector in Higher Education, 1960–1982* (London: Council for National Academic Awards, 1987), 9–10.

29. Ibid.

30. Bruce Laughton, *William Coldstream* (New Haven, CT: Yale University Press, 2004), 203.

31. Bernard Cohen, "Time, Timing and Bill Coldstream" (obituary), *Art Monthly* 194 (March 1987): 2.

32. Tom Hudson, *The Visual Adventure* (London: Drian Gallery, 1962), n.p.

33. These polarities of opinion were evidenced at the Society of Art Masters Conference of 1956 at Bretton Hall College, analyzed by Norbert Lynton, "Harry Thubron," and David Thistlewood, "The Formation of the NSEAD: A Dialectical Advance for British Art and Design Education," *Histories of Art and Design Education: Cole to Coldstream*, ed. David Thistlewood (Essex, UK: Longman Group United Kingdom Ltd., 1992).

34. Howard Horne, quoted in Alex Sego, *Burning the Box of Beautiful Things* (Oxford: Oxford University Press, 1995), 14.

35. David Thistlewood, "A Continuing Process: The New Creativity in British Art Education 1955–1965," *Histories of Art and Design Education: Cole to Coldstream*, ed. David Thistlewood, (Essex, UK: Longman Group United Kingdom Ltd., 1992), 152–168.

36. Tom Hudson, "Current Issues in Art and Design Education: Art, Science and Technology; Some Initiatives for Change," *Journal of Art and Design Education*, vol. 6, no. 3 (1987): 261–265.

37. Gerald Woods, Philip Thompson, and John Williams, *Art Without Boundaries 1950–1970* (London: Thames and Hudson, 1972), 24.

38. Roy Ascott, "Introduction to the Groundcourse," *Prospectus*, Ealing School of Art (1962–1963). See particularly *Conceptual Still Life* (1962) by Stephen Willats in the collection of the British Museum.

39. Stroud Cornock, interview with author, September 3, 2004.

40. Stroud Cornock, "Summary Account of Work by Stroud Cornock on Interactive Art Systems and Related Projects, 1968–1972" (2004). Cornock personal archive.

41. Albert Pountney, "Opening Address," *Creativity in a Machine Environment* (Leicester: City of Leicester Polytechnic, 1971), 2.

42. "Regulations for the award of the Council's Degree of Master of Philosophy and Doctor of Philosophy" (London: CNAA, 1978), quoted by Strand, *A Good Deal of Freedom*, 182.

43. Stephen Scrivener, interview with author, October 2004.

44. Andrew Stonyer, communication with author, April 10, 2003.

45. Patrick Heron, letter to *The Guardian*, October 12, 1971.

46. The Government School of Design, ancestor of the Royal College of Art and the Victoria and Albert Museum, together with the subsequently created provincial branch schools, was created to teach design skills using the latest tools in order to stop the decline of industrial art and to compete with Europe. The schools taught both fine art (based on the "high" art of figure drawing) and design (using the latest technology) in one place. See Christopher Frayling, *The Royal College of Art: One Hundred and Fifty Years of Art & Design* (London: Barrie & Jenkins, 1987).

47. Clive Richards, interview with author, July 22, 2003.

48. Alan Dyer, Graham Howard, and Clive Richards, "Art and Design," *Information Technology in the Humanities: Tools, Techniques and Applications*, ed. Sebastian Rahtz (Chichester: Ellis Horwood Ltd., 1987), 126–149.

49. Coventry Lanchester Polytechnic Faculty of Art and Design, "Application to CNAA for approval of a linked course leading to the award of the Postgraduate Diploma and Degree of Master of Arts in Electronic Graphics" (January 1986).

50. John Vince, interview with author, June 5, 2003.

51. Bernard Cohen, 1994 interview with Stephen Chaplin, *A Slade School of Fine Art Archive Reader*, 1998 (unpublished manuscript by Slade School Archivist 1990–1997), vol. 4, chapter 9, appendices 31 and 32.

52. Sydney Paulden was engaged by CAS for several years as public relations consultant, beginning in 1969.

53. Jonathan Benthall, "Edward Ihnatowicz's *Senster*," *Studio International* (November 1971): 174.

54. Howard Horne, quoted in Alex Sego, *Burning the Box of Beautiful Things* (Oxford: Oxford University Press, 1995), 14.

20

From Machine to Metaphor: Artists and Computers at Chelsea School of Art 1960–1980

Stephen Bury

The formative event in art education in the 1960s was the spread of the Bauhaus-influenced Basic Design course, sometimes known as The Developing Process.[1] Until this point, art education had fluctuated between the academic study and drawing of the nude (or its surrogates, casts) and applied art: the preoccupation with the latter was partly through Britain's fear of industrial rivals in France, Germany, or Austria. The Basic Design course bridged these two extremes and was extremely influential because it colored most of the art and design curriculum developments precipitated by the Coldstream and Summerson committees (1959–1964).[2]

The Bauhaus pedagogy owed much to the Moscow VKHUTEMAS (Vysshiye Khudozhestvenno-Tekhnicheskiye Masterskiye), founded in 1918, where Wassily Kandinsky, Kasimir Malevich, Antoine Pevsner, and (somewhat unofficially) Naum Gabo taught.[3] When the Bauhaus began in Weimar in 1919, Walter Gropius's overriding idea was that architecture had precedence in the arts, and that painting, sculpture, ceramics, and book and furniture design were either derived from or connected to it and to each other. Early Bauhaus staff included Kandinsky, Paul Klee, and other expressionists, and it was only with the 1925 move to Dessau that the Bauhaus became "constructivist": Teachers now included László Moholy-Nagy and Josef Albers, and its slogans were "truth to materials" and "cube, rectangle, and circle." In the political circumstances of the 1930s, many of the teachers and students dispersed, particularly to the United States. But it was in the 1950s and 1960s that much of their writing became available in English for the first time—Klee's *Pedagogical Sketchbook* (1953) and *The Thinking Eye* (1961); Moholy-Nagy's *The New Vision* (1955), *Theatre of the Bauhaus* (1961), and *Painting, Photography, Film* (1969); Johannes Itten's and Josef Albers's works on color were available in 1961–1963. Another important conduit of Bauhaus ideas into art education was through the work of György Kepes (1906–2001). Kepes had been a partner in Moholy-Nagy's design studio in London, where they worked together on advertisements for Simpsons and Imperial Airways before both artists left for the United States. Although Kepes was never a staff member or direct student of the Bauhaus, his seminal *Language of Vision* (1944) introduced Bauhaus thinking into American (and eventually English) art education. Subsequent publications and compilations included *Education of Vision* (1965), *The Nature and Art of Motion* (1965), *Structure in Art and Science* (1965), *The Man-Made Object* (1966), *Module, Symmetry and Proportion* (1966), and *Sign, Image and Symbol* (1966). A crucial impresario of Bauhaus ideas into Great Britain was the poet and critic Herbert Read (1893–1968) through his own writings such as *Art and Industry* (1934), but also through his introduction to the work of Klee, *Paul Klee on Modern Art* (1948).[4]

At Kings College, Newcastle upon Tyne, part of Durham University, Victor Pasmore, an admirer of Klee's theories of learning, and Richard Hamilton, himself an admirer of Moholy-Nagy, developed the Basic Design course in the late 1950s.[5] Hamilton added an interest in popular culture in all its manifestations—cinema, advertisements, comics, etc.

The painter and art historian Lawrence Gowing was a professor of fine art at Kings College between 1948 and 1958.[6] In 1959 he became principal of the new Chelsea School of Art, formed from the merger of the art departments of the Chelsea (formerly South-western) Polytechnic, strong in applied arts and sculpture, with Regent Street Polytechnic, which had a reputation in illustration, drawing, and painting (with an expressionist emphasis). A new purpose-built art school on Manresa Road, off Chelsea Square, formerly Trafalgar Square, where many of the workshops for the Great Exhibition of 1851 had been located, was planned, officially to open in 1964.[7] At the same time as he was choosing fixtures and fittings—was a Rietveld chair too expensive?—down to individual library books, Gowing was establishing a model for art education: Art history was integrated with studio practice, and often taught by artists; scientific studies were taught, including perception, study of organic form and structure, geometry and mathematics, and "physics and its imagery"; these studies formed a part of a wider program of "complementary studies" that could include music, poetry, philosophy, drama, media and cultural studies.

Many of these ideas were inspired by the Basic Design course devised by Victor Pasmore and Richard Hamilton at Newcastle. Indeed, some of Gowing's staff and students followed him from Newcastle to Chelsea. Ian Stephenson (in 1959) and Matt Rugg taught the Chelsea "foundation" course, which condensed the Basic Design course into a preparatory year for a diploma. Stephenson had studied fine art under Gowing at Kings College from 1951 to 1956 and was one of Gowing's star pupils. Between 1956–1958 he was a tutorial student, then a demonstrator in the Basic Design course, at one point sharing a garret with Richard Hamilton, whose influence on Stephenson can be gauged by a text (and the underlying interview) that William Feaver wrote for Stephenson's 1977 Hayward show:

> Hamilton's teaching-model exhibitions at Newcastle included "Man, Machine & Motion" (1955) and "Exhibit 2" (1958). These were incitements to break away from still-life study (plaster casts of Diana the Huntress etc) and take soundings in all directions. The combination of Journey into Space appeal and Voyage into the Unknown amazement (images under the microscope revealed as seething patterns, worlds within worlds) both opened up the possibilities of what should be attempted in painting and held Art in question. In a set of paintings based on the experience of passing by objects at apparently relatively varying speeds (the parallax effect) Hamilton used a variety of marks, arrows and flashes of illustrational style.[8]

Teaching the foundation course at Chelsea, Stephenson encouraged the devising of rules and their rigorous execution to produce art. He would return to Newcastle to be director of foundation studies from 1966 to 1970, and then back to Chelsea as principal lecturer for postgraduate painting. In the early years of the new school the staff would teach both foundation and diploma courses: Myles Murphy, who had studied at the Slade, taught at Chelsea from 1960 onward—students recall his experimental approach to the drawing of randomly scattered sticks in the foundation course, while the constructivist/systems artist Anthony Hill explored the topology of letterforms.[9]

The London art schools were a different experience from many other art schools that became departments of larger polytechnics, which gave their staff and students access to other departments and eventually to computer facilities.[10] The prospectus entry for the painting department claimed that "some practical work in the field of electronics also goes on in co-operation with departments of electronics in other institutions" but there is little evidence of this.[11] This is not to say that staff and students were not aware of developments in cybernetics, information theory, and computing. In the 1960s and 1970s most art schools employed visiting teachers who were practicing artists; they would teach in more than one institution, so it was possible for developments at Portsmouth Polytechnic (such as Cornelius Cardew's improvisatory group, the Portsmouth Sinfonia) or Roy Ascott's Groundcourse at Ealing (1961–1964), where Bernard and Harold Cohen, Ron Kitaj, Gustav Metzger (editor of *PAGE: Bulletin of the Computer Arts Society*, 1969–1972), and Gordon Pask taught, to have a much wider currency within the art school system.[12]

The Chelsea School of Art collection is revealing of interests and influences. The library had been set up by Lawrence Gowing and his personal assistant. The first librarian was Michael Doran, who was followed by Clive Phillpot. Gowing set the agenda for collection development: it was to specialize in post-1850 modern art, that is, Paul Cézanne's predecessors and successors. There were some pre-classes of material on form, color, visual perception, and illusions, perspective or the golden section; the writings of artists, including those associated with the Bauhaus, were well represented. There was very little practical material and the only book on electronic circuits in the library in 1978 had belonged to the hitherto separate Graphic Design Departmental Collection until 1977. On the other hand, periodicals included *Scientific American*, *Leonardo*, *Structure* (the missing issues provided by Malcolm Hughes), *PAGE* (1969–) and the German music magazine, *die Reihe*, which published articles on electronic music.[13] Students were interested in experimental music, expanded cinema, and information theory: Brian Chadwick, who had studied mathematics at Imperial College (and had used the University of London's computing facilities) wrote his 1966 Chelsea thesis on Monet and Léger using information theory.[14] But although the library possessed the English translation of Moles's *Information Theory and Esthetic Perception* (1966), it did not, until the early 1980s, possess the works of Claude B. Shannon, Benjamin Whorf, and Ludwig von Bertalanffy on general systems theory, or John von Neumann and Oskar Morgenstern on game theory.

Until 1976 it was Chelsea's painting school, as opposed to the sculpture or autographic printmaking departments, that was arguably the most hospitable within fine art to a nexus of ideas around systems, perceived by many at the time to be avant-garde. The painting school spawned a painting council where the leaders of studios—from life-room to systems—met regularly. The 1971–1972 Chelsea School of Art Prospectus refers to "workshops," but this probably describes something that had been in existence for some time although not necessarily formally recognized. In the 1980s these studio-workshops were described as "small close-knit groups of students and artists brought together by similar interests and by the need for similar resources." The 1986–1987 prospectus allocated the painting staff to studios for the first time, but this was also the last official reference, as the studio system gave way to year groupings.[15]

The systems studio staff included Malcolm Hughes, Anthony Hill, John Ernest, and Michael Kidner. Whether all or any of them would call themselves constructivist is debatable. For Hill: "I accept the appellation *constructivist* but am fully aware of the historical context of which I am clearly no part. Recently I have become aware of *Russian Formalist* Movement which I feel more drawn to than the schisms and subsequent developments of the so-called *constructivist art and ideas*."[16]

Elsewhere Hill described himself as a "constructionist" (a term also used by Charles Biederman) and Hughes spoke of a "systematic constructive art."[17] Inspired by the constructivist era of the Dessau Bauhaus and encouraged by Pasmore's adoption of abstract art after World War II, these British constructivists or systems artists explored the abstract, constructed, or assembled relief and rigorous and formal pursuit of mathematical laws, combinations, and variations: They experimented with new industrial materials—vinyl laminate, extruded or sheet aluminium with reflective or matt surfaces, polystyrene, polyvinyl chloride (PVC), Formica, Perspex, hardboard, etc.—and processes for fabrication. They aspired to architectural projects, whether Pasmore's Peterlee or Hill's installation for the temporary pavilion for the International Union of Architects Congress on the South Bank in 1961, commissioned by Theo Crosby.

Malcolm Hughes taught at Bath Academy of Art, Chelsea, and the Slade School of Fine Art. He began teaching at Chelsea in 1968, the year before he co-founded the Systems Group and worked at Chelsea with Anthony Hill, Michael Kidner, and John Ernest. But it was at the Slade and not at Chelsea that Hughes set up, with Chris Briscoe, the Department of Experiment, soon to be renamed the Department of Experimental and Electronic Art. The Slade used a bequest from the designer Eileen Gray to purchase a Data General Nova 2 minicomputer, and acquired teletype machines, oscilloscopes, and flatbed plotters, etc.[18] Hughes had stopped teaching at Chelsea in 1973 and the painting department workshops possessed no such equivalent equipment. Hughes's own works were concerned with coding—color levels or linear shape levels, primes or non-primes—and lent themselves to modelling on the computer, but, until he began to experiment with computer prints toward the end of his life, Hughes's artwork celebrated the artists' touch. A photograph in the catalogue, "*Painting Space, Gallery Space*," at Annely Juda Fine Art, shows Hughes at a PC: we are near the interest of the constructivists in architectural space, we are near their interest in abstraction, we are near their ambition to use formal variations to liberate the creative spirit, but we are far from "computer art."

Anthony Hill was a visiting teacher at Regent Street Polytechnic from 1955 to 1963, that is, before its art department formed part of the new Chelsea School of Art. He became a part-time tutor at Chelsea in 1964. In 1950, at the age of twenty, he had exhibited abstract paintings in "Aspects of British Art," at the Institute of Contemporary Arts, London, and met both Pasmore and Kenneth and Mary Martin. By 1954, Hill had turned away from two-dimensional work to constructions.

Influential on this development were the writings of the American Charles Biederman, whose *The Evolution of Visual Knowledge* was privately published in 1948. Biederman argued from an investigation of past art that the abstract relief was the only valid art form for the modern world, and from this point on Hill preferred the relief.[19] In the *This is Tomorrow* exhibition of 1956, Hill showed orthogonal reliefs, and from 1962 he began working on diagonals. Hill was a productive writer as well as an artist, and he contributed to *Structure* (1959), *Leonardo* (1968), *Studio International* (1966, 1969, 1975), "The Structural Syndrome" in Kepes's *Vision and Value* (1966), as well as editing *Data: Directions in Art Theory and Aesthetics* (1968). Hill also connected British art to the international art scene, corresponding with Max Bill (who had been a student at the Dessau Bauhaus in the late 1920s), Georges Vantongerloo, Charles Biederman, György Kepes, and Joost Baljeu, the founding editor of *Structure* (1958–). Mathematics—and topology, graph theory, and symmetry in particular—was of major importance to Hill. He was acquainted with the theories of L. E. J. Brouwer, Nicolas Rashevsky, and David Bohm—the latter lectured at Chelsea School of Art in 1971 and 1972 when Hill was a visiting Leverhulme scholar in the mathematics department of University College London.[20]

Hill met John Ernest at the exhibition *Artist versus Machine* in 1954. Both artists, with Denis Williams forming Group 5, exhibited in *This is Tomorrow* (1956), and in 1958 Hill and Ernest jointly published a conjecture on the crossing number of the complete graph. Beginning in 1964 they taught together at Chelsea—Ernest until 1987. He was a senior lecturer in painting and had acted at various points as a temporary head of painting.[21] Group theory, Klein bottles, Desargues configurations, and Möbius strips interested Ernest: In 1972 he exhibited a model of a negative Möbius strip at the "Systems" Arts Council exhibition. Whether graph theory of game theory, structure of viruses or the rules of chess and poker, Ernest was fascinated by the underlying rules of nature and felt that "every artist . . . seeks to discover the rules and principles which he considers important to his art."[22] The only evidence of Ernest's active involvement with computers is a series of incomplete computer programs based on geometry that he created in the mid- to late 1980s.

Among the many part-time visiting tutors in the 1970s and 1980s was the partner of Malcolm Hughes, Jean Spencer, who was one of the editors of *Working Information* 1975–1978: The publication included projects by Malcolm Hughes, Michael Kidner, Peter Lowe, David Saunders, and Jeffrey Steele. Issue no. 3, on artists who used computers, featured Darrell Viner. The Chelsea School of Art library subscribed to this magazine and this might have been Viner's introduction to Chelsea. He was a student at Hornsey College of Art from 1971 to 1974, where a fellow student was Shelagh Cluett, later head of sculpture at Chelsea, who employed Viner as a part-time tutor in the 1980s and 1990s. By 1972 Viner was already experimenting with computer-generated images and computer-animated films, which he showed in his *Inside Outside* exhibition at Coracle Press, London, in 1977. After Hornsey, Viner studied sculpture and mixed media at the Slade School of Fine Art from 1974 to 1976, and connected with the students in Hughes's and Briscoe's computer areas. When, from 1976, he taught at Portsmouth, he began to employ Chelsea master's students for a day a week there.[23] It was only in the 1990s, as a fractional lecturer in sculpture at Chelsea, though, that Viner's use of computers in interactive installations had significant influence.

In the late 1990s the Chelsea *grands projets* in computer printmaking and in virtual reality fine art were funded by the Research Assessment Exercise. At the same time undergraduate and postgraduate combined media students began to have access to Apple Macintoshes. Though there was a lot of interest in constructivism and the machine aesthetic, and although nearly all students had undergone a Bauhaus-influenced Foundation course, the first direct uses of the computer at Chelsea were in the school administration and the library. And although staff and students might have been becoming educated about computers and art through attending *Cybernetic Serendipity* (1968) or *Kinetics* (an exhibition organized by Theo Crosby, Caroline Tisdall, and Frank Popper in 1970), the use of computers within fine art at Chelsea is not evident until the 1990s.

A metaphor for this state of affairs may be seen in "Mundus" by John Stezaker, who taught part time in the art history department at Chelsea for a few years in the mid-1970s. The founder and editor of *Frameworks*, Stezaker's practice was in the area of what has been described as "theoretical art." "Mundus" (1973) was constructed from Perspex, film, wood, and electronics, and took the form of a wall-mounted learning game. Two control buttons could be used by the user in order to illuminate a series of square compartments in a quasi-Lévi-Straussian structuralist schema depicting action, custom, learning, and law. John Walker described "Mundus" in these terms:

> These generalities are made concrete by the most economical of means. Cutlery on a table indicates "custom" (the etiquette of setting a place at table); "learning" is indicated by a "tree" diagram which reveals the two routes—predictive and constructionist—by which nodal point "x" can be reached. The four categories are various kinds of sign—directive, iconic, indexical, symbol, all of which interrelate as the symbolic game is played; e.g. Successive questions in the "action" category are encoded in the other three; the term "law" encodes the inadmissibility of choice in "action" and moves in "custom"; actions are changed into "customs," by learning.[24]

It is symptomatic that this work was produced on the fringes of Chelsea by someone who taught in the art history department, rather than in fine art practice. The work owes more to Lévi-Strauss's structuralism than to computing, even in its analogue phase. Only after the personal computer made digital computing available to all after 1976 did Chelsea staff and students adopt it as they would any technology and medium available; as such, they would never be "computer artists," but artists who used computers.[25]

Notes

1. *The Developing Process* (Durham: Kings College, University of Durham, 1959), published on the occasion of an exhibition at the Institute of Contemporary Arts, London, 1959.

2. For the Basic Design course as an antecedent of developments in computer art, see Catherine Mason, "Routes towards British Computer Arts: Educational Institutions," *PAGE:*

Bulletin of the Computer Arts Society 57 (2004): 5–8. For Coldstream's influence on education, see Bruce Laughton, *William Coldstream* (New Haven, CT: Yale University Press, 2004).

3. Selim Omarovich Khan-Magomedov, *Vhutemas: Moscou 1920–1930* (Paris: Editions du Regard, 1990). For the influence of VKHUTEMAS on the Bauhaus, see Stephen Bury, "Were the Bauhaus Books Bauhaus Books?," unpublished lecture, given at Genesta (Gallery), London, 1997, transcript in Chelsea College of Art and Design Library Archive.

4. Read had "no other desire . . . than to support . . . the ideals . . . expressed by Dr. Gropius," who had read a paper to the Design and Industries Association in 1934, in which he said, "An artist must plan the distribution of cities within a region; an artist must plan the distribution of buildings within a city; an artist must plan the houses themselves, the halls and factories and all that makes up the city; an artist must plan the interiors of such buildings—the shapes of the rooms and their lighting and colour; an artist must plan the furniture . . . the knives and forks, the cups and saucers and the door-handles. And at every stage we need the abstract artist, the artist who orders materials till they combine the highest degree of practical economy with the greatest measure of spiritual freedom." Herbert Read, *Art and Industry* (London: Faber, 1934), 40. Read wrote an appendix specifically on "art education in the industrial age" (126–131).

5. David Thistlewood, *A Continuing Process* (London: Institute of Contemporary Arts, 1981). Thistlewood brackets Tom Hudson and Harry Thubron with Pasmore and Hamilton as the key figures in the new creative approach to art and design education. Hamilton was a lecturer at King's College from 1953 to 1966, and Victor Pasmore was director of painting from 1954 to 1961, continuing to work on the Peterlee New Town until 1977; this last project suggests Pasmore's adoption of Gropius's theory of the primogeniture of architecture.

6. Stephen Bury, "Sir Lawrence Burnett Gowing," *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004), v, 145–147.

7. Ironically, artists' studios were demolished to make way for the art school. This included the studio of Stroud Cornock, who created the "media handling" department at Leicester Polytechnic. Mason, "Routes Towards British Computer Arts: Educational Institutions," 7.

8. *Ian Stephenson: Paintings 1955–66 and 1966–77* (London: Arts Council of Great Britain, 1977), 7–8.

9. Brian Chadwick (at Chelsea, 1962–1966), personal communication, 2004.

10. Mason, "Routes towards British Computer Arts," 7–8.

11. *Chelsea School of Art Prospectus 1972/3* (London: Chelsea School of Art, 1972), 10.

12. Mason, "Routes towards British Computer Arts," 6–7. The activities around music and systems are described in Jeffrey Steele, "Collaborative Work at Portsmouth," *Studio International* 192, no. 984 (November/December 1976): 297–300; Michael Parsons, "The Scratch Orchestra and Visual Arts," *Leonardo Music Journal* 11 (2001): 5–11. Through the Portsmouth connection, the Scratch Orchestra formed links with the Systems Group—Jeffrey Steele, David Saunders, Malcolm Hughes, Jean Spencer, Peter Lowe, and Michael Kidner—and concerts were given in association with the *Matrix* and *Systems* exhibitions at the Arnolfini in 1971 and the Whitechapel in 1972. For Metzger, see *Gustav Metzger* (Oxford, UK: Museum of Modern Art, 1998), catalogue of an exhibition October 25, 1998–January 10, 1999.

13. *Die Reihe* was also influential on minimal art. Sol LeWitt was influenced by a 1960 article, "Mallarmé and Serialist Thought" by Hans Rudolf Zeller. Also see Alicia Legg, *Sol LeWitt* (New York: Museum of Modern Art, 1978), 34, 41–42.

14. Brian Chadwick (at Chelsea, 1962–1966), personal communication, 2004.

15. Prospectuses 1960–1986, Chelsea College of Art and Design Archive.

16. Anthony Hill, statement in *English Art Today 1960–1976* (Milan: Electa Editrice, 1976), catalogue of a British Council touring exhibition, shown at the Palazzo Reale, Milan, February–May 1976, 92–93.

17. *Anthony Hill: A Retrospective Exhibition* (London: Arts Council, 1983), 8. Hill's 1959 contribution to *Structure* was anthologized in *The Tradition of Constructivism*, edited by Stephen Bann (New York: Viking Press, 1974), 268–276. Bann's interest in concrete poetry is a possible link to the computer-generated/manipulated poetry sampled in Jasia Reichardt's *Cybernetic Serendipity* (1968).

18. According to a personal communication from Gary Woodley in November 2004, by 1988 all the computers in the Slade had disappeared without a trace and a new style electronic media area was established some years later.

19. This shift describes the changes within only one of Hill's practices: Hill as Redo or Rem Doxfud (a contraction of Rembrandt's Doghsfoodt) had another dadaist/Duchampian aspect.

20. David Bohm, "On the Relationships of Science and Art," in *Data: Directions in Art Theory and Aesthetics*, ed. Anthony Hill (London: Faber, 1968), 171–172.

21. See the obituary by Alastair Grieve in *The Independent*, July 28, 1994.

22. *Construction: England: 1950–1960*, an exhibition at the Drian Galleries, London.

23. See Darrell Viner, *Eight Times Three: Dilston Grove* (London: Café Gallery, 2000). Gary Woodley (a master's student at Chelsea, 1977–1978) recounts: "My early computer conversations were usually with Darrell Viner, as he came out of the Slade '70s research area and then had good connections with Chelsea sculptors," personal communication, November 14, 2004.

24. John Walker, "John Stezaker at the Nigel Greenwood Gallery," *Studio International* (December 1973): 248.

25. In a personal communication in November 2005, Gary Woodley confirmed: "My interest did not get going until about 1994, when 3D programs started to get more useful. John Law at Bath got me started, but he had only begun around 1990." Jake Tilson was a Chelsea Bachelor of Arts painting student and edited and produced (as Woolley Dale Press) *Cipher Magazine* (1979–1981) and subsequently *Atlas* (1985–), using black and white and color photocopiers. He went on to publish on the Web with *The Cooker* (1994–), www.thecooker.com/.

21

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, "Paragraphs on Conceptual Art," *Artforum* 5 (Summer 1967): 80

In 1968 I was one of a generation of young artists who visited London's Institute of Contemporary Arts (ICA) at its then-new premises in The Mall to see the *Cybernetic Serendipity* show[1] that had been curated by Jasia Reichardt. Like other exhibitions during the foment of the 1960s, *Cybernetic Serendipity* challenged many long-held attitudes about 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 artifact, between these "two cultures." Like many of my contemporaries I was enthralled by the show and, after a period of 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 Alan Kay termed "the computational metamedium."[2] Rinaldo saw the show as a child and only later when he discovered the *Cybernetic Serendipity* catalogue[3] in a second-hand art bookstore did he recognize what he had seen and acknowledge the influence it had had on his development as an artist.

One of the works shown at *Cybernetic Serendipity* was Edward Ihnatowicz's *SAM* (*Sound Activated Mobile*).[4] Later Ihnatowicz worked on the ambitious and high budget *Senster* for the Philips Evoluon Museum in Eindhoven, Netherlands. Kees Stravers maintains a website about the Evoluon[5] and videos of Ihnatowicz's robotic artworks are available from Alex Zivanovic's *Senster* web site.[6] 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 Malcolm Hughes, who was a member of the Systems 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 1970s 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 Marvin Minsky and Seymour Papert published their critical review of the connectionist field.[7] 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 (such as evolutionary and adaptive systems) are often astounded to learn of Ihnatowicz's work, especially considering its early date. Ihnatowicz died in 1988.

Another regular visitor to the Slade's Experimental and Electronic Art Department was Harold Cohen.[8] 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 Harold began working at the University of California at San Diego (UCSD) where he became interested in computers and programming. In 1971 he became involved in the AI Lab at Stanford University, where Edward Feigenbaum was developing expert systems. These systems sought to address 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 1960s and early 1970s who suggested that this could be overcome by limiting the scope of what was to be understood to small, well-defined areas in which ambiguities could be sufficiently reduced to enable contextual cross-referencing. Researchers at Stanford developed many valuable expert systems, such as MYCIN, which was used to diagnose infectious diseases and prescribe antimicrobial therapy.[9] As a guest scholar and artist-in-residence from 1971–1973 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.[10] 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 that have to do with cognition and drawing in general, his major achievement has been the externalization 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. It's interesting that they also epitomize the two main approaches to AI. Cohen's work builds on 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 Alan Kay's computational metamedium. This definition contrasts with the later insistence by some post-modern commentators that the computer has no 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 recognized by the mainstream art world when it became increasingly dominated by the post-modern aesthetic paradigm during the 1980s. The idea of intrinsic nature was confused with modernist ideas of "truth to the medium," while more important concepts like emergence, which should have been acknowledged as central to post-modern concerns, were too far ahead of their time and consequently either misunderstood or ignored.

Throughout the late 1960s and early 1970s self-expression was perceived as an outdated romantic notion, and many artists were exploring methods for removing themselves from the production process. What later became known as the computational paradigm complemented other paradigms that dominated aesthetic debate during this period. Principal among 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 described by Lucy Lippard.[11] Anton Ehrensweig offered an alternative interpretation[12] by psychoanalyzing the process of artmaking rather than the resulting artifact. Hierarchies were being undermined by heterarchies and concepts of equipotent interdependent networks were beginning to emerge. Today's Internet took root in 1969 when the ARPANET connected UC Los Angeles, UC Santa Barbara, the University of Utah, and the Stanford Research Institute. Not long afterward artists like Carl Loeffler, Roy Ascott, and Kit Galloway and Sherrie Rabinowitz (who later founded California's influential Electronic Café) created intercontinental artworks using both computer and video networks.[13] 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 audiences. Time was reconsidered as the early experiments of Moholy-Nagy, Duchamp, Calder, Malina, Schöffer, and others were formalized 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 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 United Kingdom (along 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 sought 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 six-foot cabinet that held the main chassis with around ten 15 × 15 inch circuit boards that composed the computer itself. It also housed a high-speed paper tape reader and was interfaced to an electromechanical teletype console via a 300-baud serial line. Compared to a modern computer the Nova was exceptionally primitive: it had 16K 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."[14] He designed and built a general-purpose interface board that output analogue signals to a modified Tektronix 10 × 8 centimeter 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 electromechanical devices. A couple of visits each week to check out new arrivals were mandatory for many of us. Figures 21.1 and 21.2 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 1978, a Tektronix 4016 green-screen vector graphics terminal was added, then in 1979, a bequest from the estate of Slade alumna Eileen Gray purchased an AED 512 color frame store. With a resolution of 512 × 512 of 8-bit memory (which offered 256 simultaneous colors from a palette of 16 million) the AED was one of the first commercially available color graphics displays in the United Kingdom.

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 hands-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 department of engineering at Liverpool Polytechnic who let me use their Digital Equipment Corporation PDP8 mini). So despite its limitations the Nova was like heaven on earth for most of us. We booked blocks of time and worked the system twenty-four hours per day seven days a week. I often booked the night shift when I didn't have anywhere to stay so I could sleep on the floor while the Nova worked away. Those who were confident enough to develop their own hardware could interface it to the Nova, and several wire-wrapped their creations directly to the motherboard because they couldn't afford the £1500 interface boards. (About £6,500 or over US$12,000 at 2005 value—and this was just for an unpopulated printed circuit board!) For an artist this was 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 United States Chuck Csuri had built up a powerful computing facility at the Ohio State University but he had done this independently and largely unsupported by his

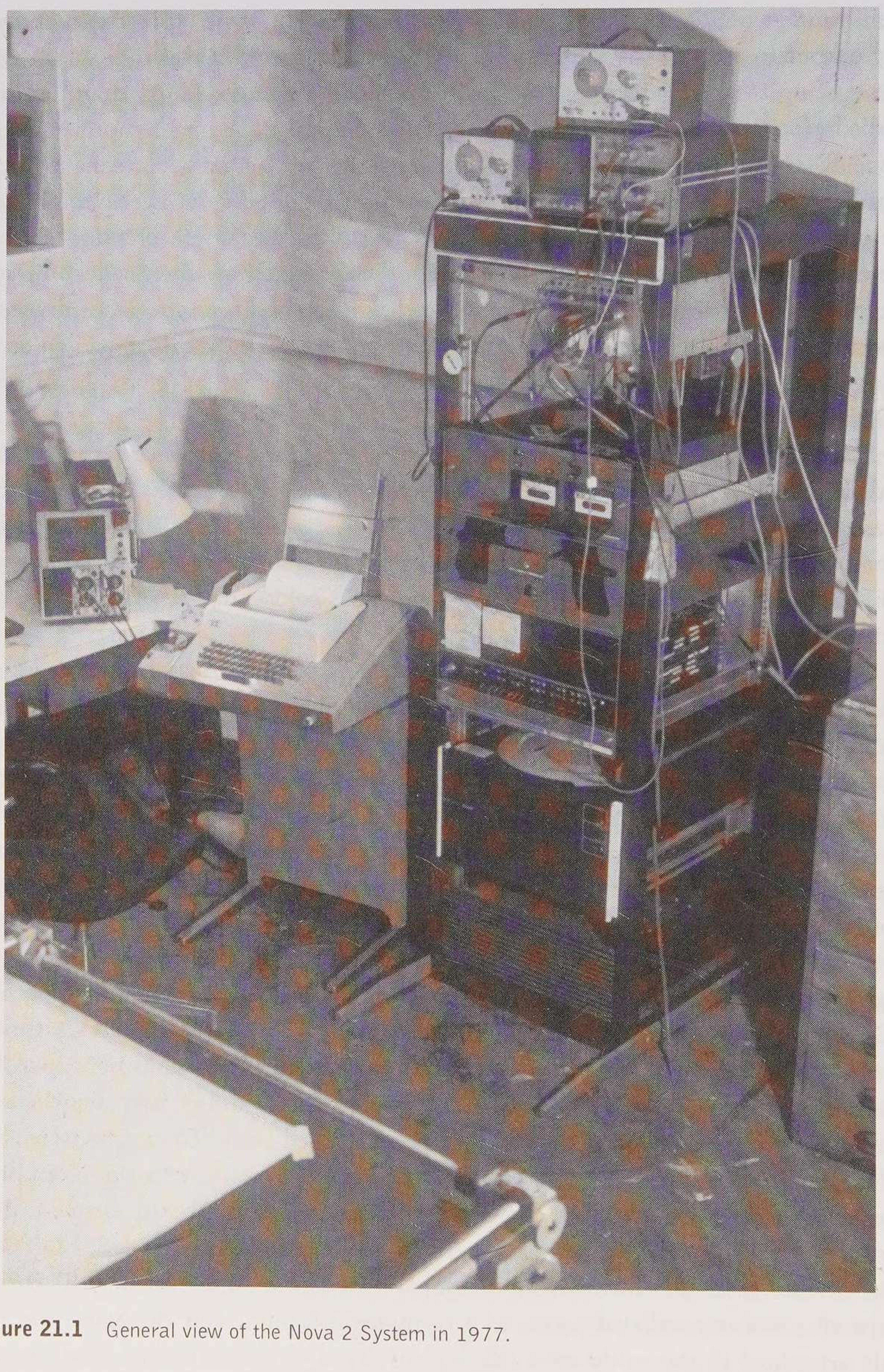


Figure 21.1 General view of the Nova 2 System in 1977.

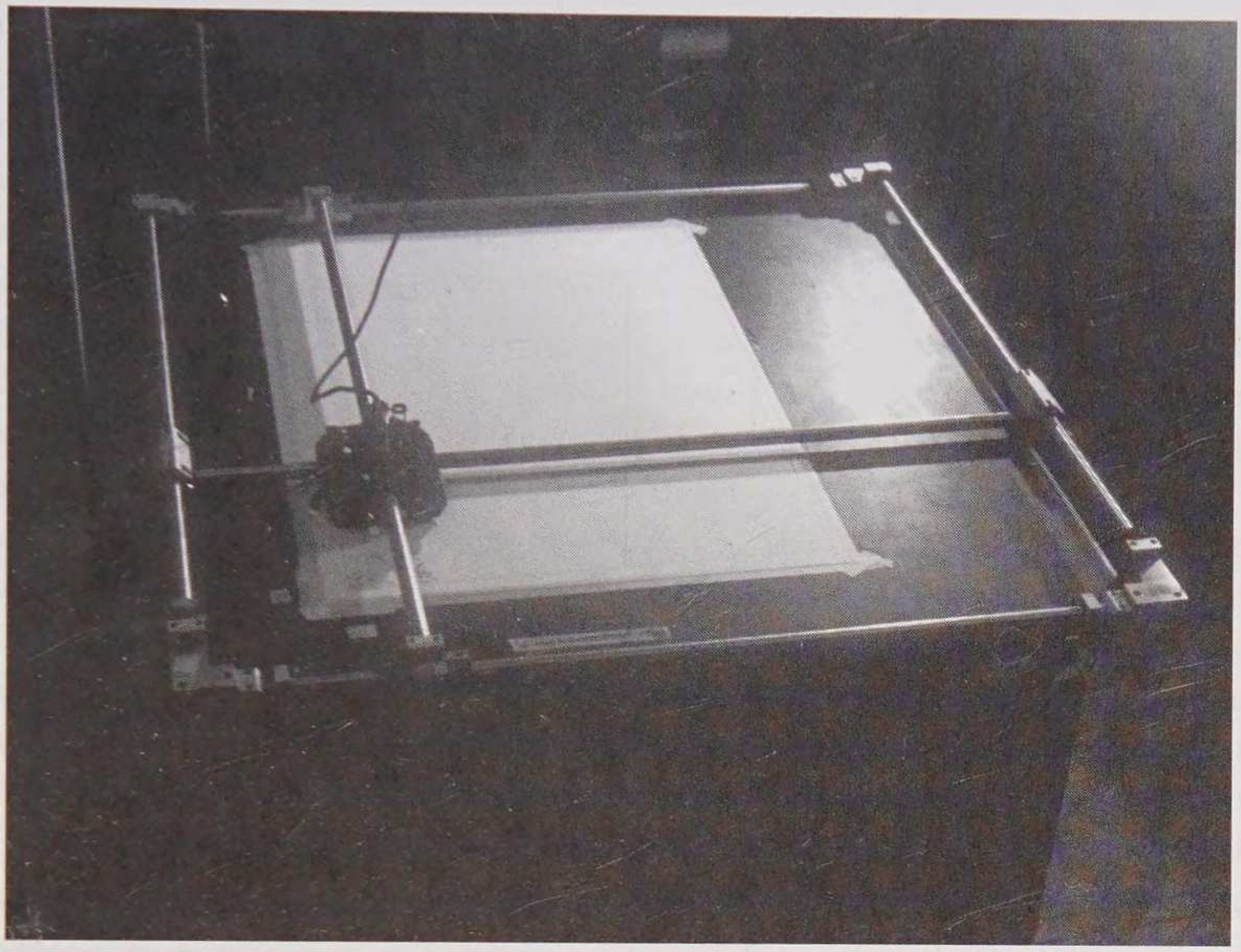


Figure 21.2 View of the flatbed plotter.

faculty. At the Slade these facilities were tightly integrated into the program and profile of the postgraduate school.

EXP became a magnet for artists and theorists throughout the United Kingdom 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,[15] and Ernest Edmonds, who was setting up a pioneering program investigating creativity and cognition first at Leicester Polytechnic, then at Loughborough University, and more recently at the University of Technology, Sydney.[16] At the time PhD research opportunities were not available within mainstream art education, so several of the EXP students (including Stephen Scrivener, Stephen Bell, and Dominic Boreham) went on to pursue PhDs under Edmonds's mentorship and were among the first visual arts students to achieve this award in the United Kingdom. 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 1970s 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.

Among the first students in the department were Stephen Scrivener[17] and Julian Sullivan. Sullivan was a mature student who had 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."[18] However Hornsey was about to merge with Enfield College of Technology to form Middlesex Polytechnic, and Sullivan and Darrell Viner were among the first students to work with the computer graphics pioneer John Vince, who was then beginning to develop his art-oriented graphics package PICASO.[19] Viner was also accepted into the Slade postgraduate program but opted to major in sculpture although 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 × 16 × 1-bit frame store that displayed on a LED (light emitting diode) display he had also built. He later extended this into a 96 × 96 × 1-bit system that displayed on the screen of a standard monochrome video monitor (figure 21.3).

In the later 1970s, with the growing interest in animation, Sullivan 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 wireframe animations and later with the AED 512 to make full-color sequences. After graduating, Sullivan joined the department as a technician and worked alongside Briscoe until the former's untimely death in 1982. At the time Sullivan was working to commercialize 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 (CA), which had been popularized by Martin Gardner's piece about John Horton Conway's "Game of Life" in *Scientific American* in October 1970.[20] His work on boundary detection using CA models was so robust that it was adopted by the image processing researchers at UCL.

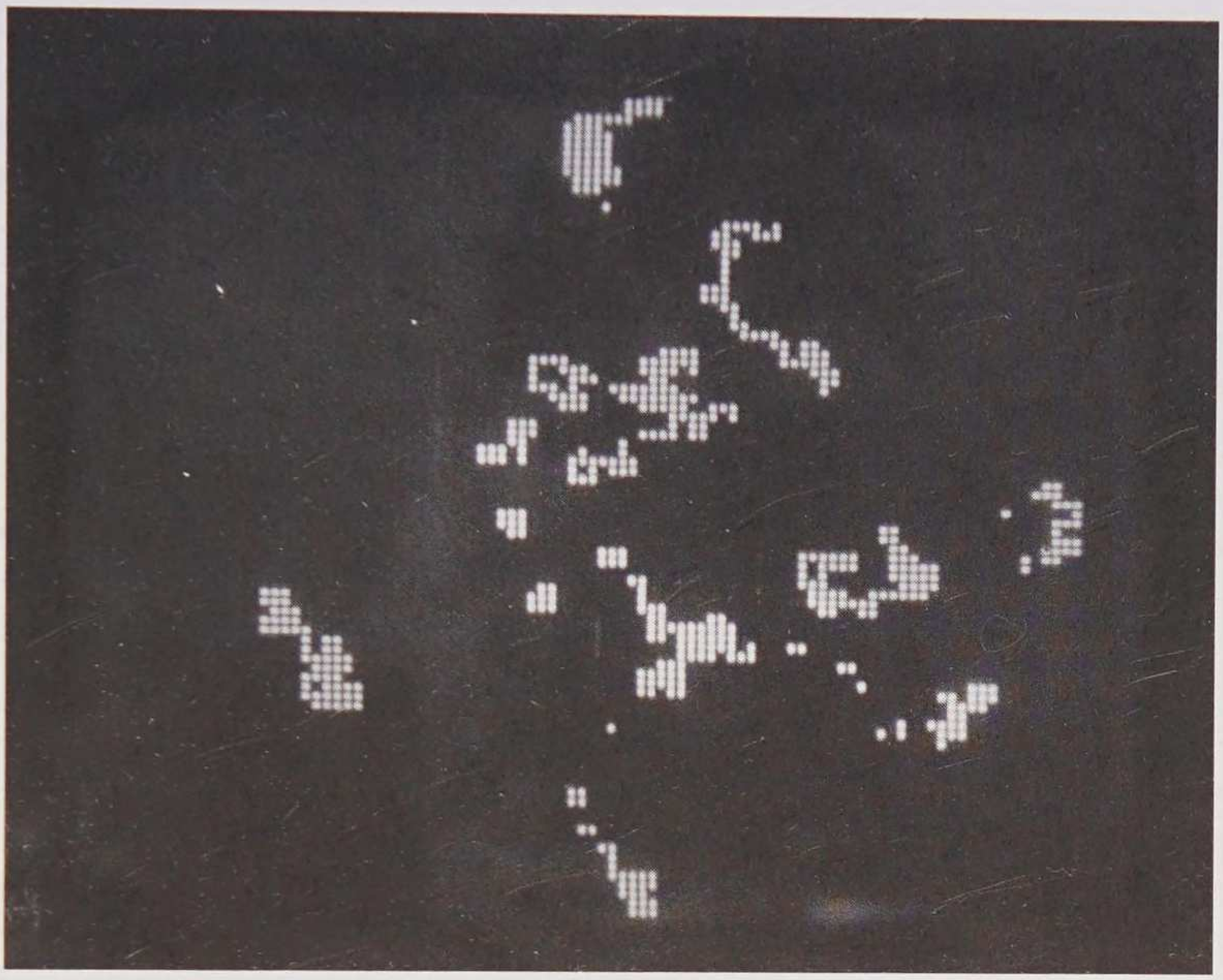


Figure 21.3 Sullivan's 1-bit frame store running Brown's "Builder+Eater."

Darrell Viner made many large-scale kinetic works during his career. The pieces he made for his graduation 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 IBM 360/65 computer with the assistance of Allan Hume and output by UCL's 16mm microfilm plotter. Like many other EXP members Viner made extensive use of the UCL central computing facilities (using 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 access to expensive supercomputers that were intended for bleeding edge scientific research was highly privileged and was mediated by David Clark of London University's Central AV Unit; Clark was another regular visitor at EXP. He was an early proponent of computer graphics in media communications and edited an early and influential book on the subject.[21] After his post-graduate work in sculpture, Viner became a part-time lecturer in the EXP and went on to teach at the Chelsea School of Art and Portsmouth Polytechnic. Unlike most of the other pioneers of the computational arts he achieved recognition in the mainstream art world by 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?" This piece 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 department after graduating. He was also interested in computers and had a close relationship with EXP throughout the 1970s. Like Viner, Crabtree 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, which gave them a strong objective presence. The experimental filmmaker Chris Welsby also taught part time in EXP. 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 its 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 is illustrative of 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*.[22]

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 21.4).

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*,[23] which featured the work of Briscoe, Sullivan, Scrivener, Crabtree, Viner, and Beyls. Spencer was Malcolm Hughes's 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.

Among the students in the department who pursued an interest in the nascent field of generative art was Stephen Bell, who went on to complete a PhD with Ern-

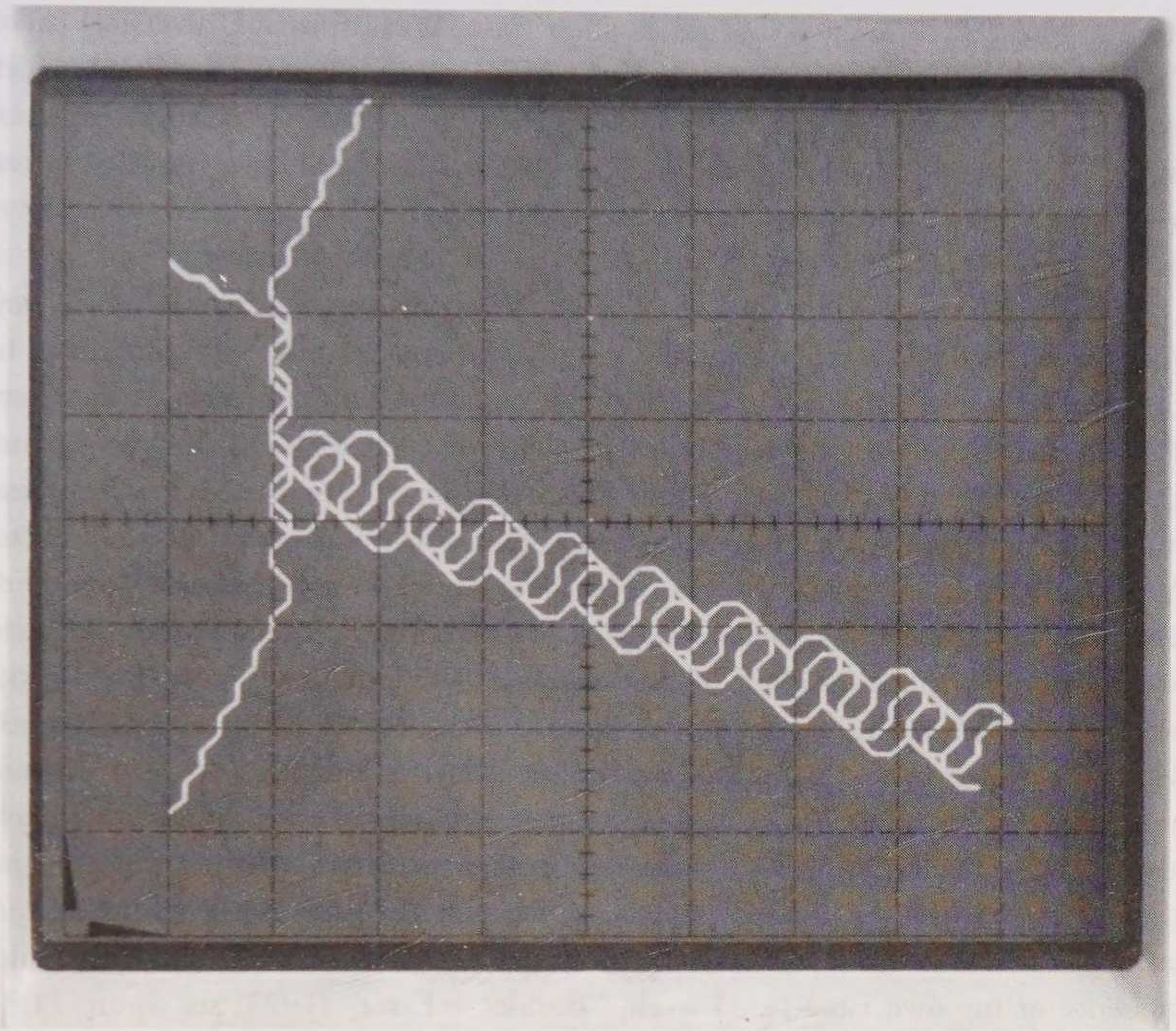


Figure 21.4 The 8 × 10 cm storage oscilloscope with a drawing by Chris Briscoe on the screen.

est Edmonds at Loughborough.[24] 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 1977–1979. My primary interests were cellular automata 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.[25] 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, Robert Gordon University, Aberdeen. Later Nigel Johnston joined the program and created a number of large-scale interactive works that were inspired by Ihnatowicz's robotic works from a decade earlier. In 1979 Hughes organized 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 participated in the show, which included other experimental genres in addition to computer-based work. An illustrated catalogue was produced, and each student was allocated a double-page spread with which they could do whatever they liked. Hughes wrote the introduction to the catalogue.[26]

The Australian artist and theorist Mitchell Whitelaw suggests that Alife is a natural development of artistic practice in the twentieth century.[27] In particular, he cites the work of Paul Klee and Kasimir Malevich as examples. 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 1970s 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" nor would we have associated with the term as Langton defined it over a decade later as a form of "experimental biology."[28] Our focus was more on procedure and process in their most general sense and many artists actively resisted attempts to apply anthropomorphic interpretations to their productions. However, references to life and physical and biological processes were implicit in many of the works. Examples include Conway's "Game of Life," which had a major influence or my own time-based work, "Builder + Eater" (1977; see figure 21.3), where two concurrent processes dynamically compete for possession of a digital image.

It has been interesting (and reassuring considering the continuing lack of recognition by the arts mainstream) to find that we are now being rediscovered by a new generation of Alife 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 relationships 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 was discussing new ideas like chaos theory. Through 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, visualization, simulation, and modelling.[29] Many of the scientists respected our work and our contributions 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 1990s and 2000s, it is worth emphasizing the Slade's pioneering role in first developing the concepts that still define the field. 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 that reflected a change in emphasis at the school. 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 department. It was the United Kingdom'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 at 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 3D cameras, the output of which was the precursor to the 3D freeze-frame sequences popularized in 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.

Acknowledgments

I would like to thank my colleagues Charlie Gere and Nick Lambert on the CACHe project for their input and support, and I must especially thank Catherine Mason who has allowed me to mine an exceptionally well-researched chapter on the Slade from her PhD thesis. Old friends and colleagues from both the Slade and the Computer Arts Society have provided essential information. I completed this essay while artist-in-residence at the Centre for Electronic Arts (CEMA) at Monash University in Melbourne and I would like to thank Troy Innocent and his colleagues there for their support and understanding.

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22

Connections: A Personal History of Computer Art Making from 1971 to 1981

Stephen A. R. Scrivener

For a period of fourteen years between 1967 and 1981 I practiced art, and from 1972 to 1981 my work was computer-based. In this chapter I cover the decade from 1971 to 1981, which, as we shall see, took me from the School of Art, Leicester Polytechnic, to the Slade School of Fine Art, London, and back to Leicester. In the process I acquired a diploma and higher diploma in fine art, a PhD in computing, and another practice—namely, computing research.

During the period covered in this history, Leicester Polytechnic and the Slade played an important part in shaping the development of computer-based art in the United Kingdom. As a creative practitioner, working at and traveling between both centers, I benefited from their development. In this chapter I will attempt to reveal how these and related contexts influenced my computer-based artmaking by telling the story of the work. I take this approach because on reviewing my notes from the period I found a lack of direct reference to my work contexts and their inhabitants. Hence, by unpacking the story of the work, I hope to reveal something of both the thinking process that led one artist toward computer-based work and the influence of Leicester and the Slade on the nascent practitioners who passed through their doors during the period covered by this book.

Leicester Polytechnic

Although I did not use a computer before 1972, I begin my story in 1969, because the work I produced while working toward my diploma in fine art was formative of the later work. I joined Leicester Polytechnic as a representational painter, following a pre-diploma program at Banbury School of Art, with a very sound grounding in the history of art from the Renaissance through to abstract expressionism. I was also aware of contemporary developments, including minimalism, op art, and pop art. Indeed, I had already explored most of these directions, producing work in the style of Riley, Stella, LeWitt, inter alia. However, the fundamentals of my practice were more or less untouched by these experiments. The course at Banbury was grounded in close observation of the natural world. There were regular life classes and we were encouraged to go out and to draw and paint what we saw. The first discovery that I made was that the world does not appear to us as we think it is; for example, shadows aren't black, and seeing in this way is exciting and enjoyable. In other words, painting appeared to offer a way of understanding the world—a way of having a "truthful" response to it. My second discovery was that when painting from observation, the painting seemed most satisfactory when it "looked right," even when the things seen appeared in a highly abstracted or simplified form in the painting. Put another way, I felt that a "truthful" response could be represented "truthfully" by a painting. Viewed from this perspective artmaking is seen as a way of knowing and of communicating that knowing. Consequently, on leaving Banbury, I felt most comfortable as an artist when working from sight, and disliked personal invention: I liked it that the "order" of the work was determined by the "order" of the world. In retrospect, I believe this tacit preference underpinned all of my subsequent artmaking.

In the first year at Leicester we were introduced to a variety of artmaking means, including life drawing and painting, printmaking, construction, and new media. The staff at Leicester comprised painters and printmakers such as Roy Bisley, Gordon Wootton, and Dick Young, and more experimental artists such as Gavin Bryars, Stroud Cornock, Mike Haile, Mike Hoare, Colin Jones, Jack Rodway, Susan Tebby, and Alan Welsford.

However, I found it difficult to continue as a representational painter. From a modernist perspective, traditional representational painting seemed impossibly anachronistic and backward looking. More fundamentally, although I could see that my painting was somehow improving, I found it difficult to accept that I had virtually no cognitive grip on why it was improving. Truth in both response and in representation seemed unknowable and indistinguishable from the mere reproduction of the forms and qualities that I admired in other artists' work. Furthermore, it was not easy being a representational painter at Leicester, where the ethos was to challenge existing ideas and where the critical context was one of constantly being pushed out of the comfort zone.

I appear to have found a way out of this impasse during the early part of my second year of study, during which I participated in an optional experimental course run by Jack Rodway (which perhaps also involved Gavin Bryars). We explored a range of nonconventional media, working, for example, with light and sound. During the course, I constructed a screen by cutting a sheet of cardboard into squares, which were then attached to lengths of thread and suspended in columns. A number of such screens were suspended one behind the other. Slides were then projected onto the front layer of the display and through onto the other layers as the columns of squares in each layer rotated under the influence of ambient air currents.

The course represented a seminal moment in my practice because it suggested both a medium and method for overcoming the hurdles that faced me as a painter. In the first place, I had found a stimulating phenomenon to study, that is, light. Second, I found I could control the properties and behavior of this phenomenon for image-making purposes: Light could be treated as a medium of artistic expression. Third, natural science provided the primary knowledge base for the work: I had to understand natural phenomena in order to exploit their image-making potential. Finally, I discovered that experimentation offered both a means of testing understanding and of seeing and working with visual possibilities.

Somehow I found that if you took the lens out of a projector containing a slide composed of vertical strips of red, green, and blue gels, what appeared on the projector screen was just white light. However, if you placed an obstacle in front of the beam, then colors appeared. I reasoned that the gel strips emitted beams of light that mixed in space. An object placed in the path of the projector beam (comprising these multiple beams) would occlude one or more of them, in effect casting a shadow or shadows on the screen. If this theory was correct, then given a slide comprising a red, a green, and a blue strip, occluding the blue beam should produce a yellow shadow. So I constructed an experiment that confirmed this hypothesis. Of course, my goals here were not scientific. My need was to understand the phenomena I was working with so that I could control it for image-making purposes. The results of such experiments were then judged as images or potential art.

I found that if you rotated objects in front of the beam, the colors changed as the shadows expanded and contracted across the display. So I constructed a cardboard modulator and placed it in front of the projector on a motor driven turntable. This led to another form of experimentation in which the properties of the modulator were systematically manipulated and assessed in terms of the visual quality of the resultant pattern and its transformation over time.

I worked in this way for the remainder of my time at Leicester, exploring and manipulating different natural phenomena. I produced a range of light pieces; I devised kite-like structures that altered in appearance under the influence of the wind; I constructed three-dimensional plastic sheet tanks filled with colored water that presented surface wave patterns when the tank vibrated; I made drawings exploring the idea of patterns created in sand by the wind; and so on.

Influences

The body of my work produced at Leicester was characterized by a number of features: natural phenomena were explored and then exploited as image making media; the pieces had a time-based dimension; in some cases, chance contributed to the experience, as did the viewers' interactions with the work. In addition, the work was process-oriented in a number of ways: understanding was built through systematic experimentation; and control over the medium was achieved through the systematic cyclical process of creation and evaluation.

Where did these concerns come from? In the first place, as noted above, my dissatisfaction with painting manifested itself in two primary anxieties. The first arose from my apparent lack of conscious control over response to and rendering of phenomena, that is, the given and the constructed phenomena. The second arose out of an inability to distinguish what was a true response to the phenomenon under investigation (e.g., light) and the artistic renderings of that response, and what was merely the reapplication of familiar and admired artistic ways of seeing and representing. These anxieties primed responsiveness to new ways of seeing and making.

At the local level, Jack Rodway's experimental course provided me with a process and phenomena to work with. Gavin Bryars introduced us to the work of John Cage, demonstrating in a concrete way the potential of chance as a constructive component in artmaking and art experience. Although I did not work under Colin Jones, the Systems artist (I had seen his work but knew little of how it was constructed and only discovered Systems art toward the end of my time at Leicester), or Susan Tebby, they did contribute to critiques and to the course philosophy.

On March 17–18, 1971, I attended the *Creativity in a Machine Environment* symposium. This formed part of a festival, organized by Stroud Cornock, entitled *The Invention of Problems II*. It was here that I first became aware of Ernest Edmonds, who was already collaborating with Cornock, but it would be two more years before we would begin working together. Speakers at the symposium included, in order of appearance, Stroud Cornock, Edward Ihnatowicz, John Lifton, Stephen Willats, and George Mallen. Of these, Ihnatowicz and Willats had the greatest impact and influence on my development at Leicester. Ihnatowicz's work, for example, the *Senster*, demonstrated the potential power of interactive art. Willats, on the other hand, described work in which the viewers did not merely interact with the work, but participated in its construction.[1]

In terms of the wider context, Dada, de Stijl, constructivism, and the Bauhaus, including artists such as Duchamp, Gabo, Moholy-Nagy, and the kineticists, Tinguely and Calder, inter alia, were standard fare in contemporary art books. Also, notions relating to the rational, industrial, technological, and scientific in art were part of the intellectual currency of the time disseminated in journals such as *Artforum* and *Studio International*.

The Slade

In 1972, I joined the first cohort of the newly created Experimental Department, led by Malcolm Hughes, at the Slade School of Fine Art, London. In notes dated January 4, 1973, I noted, "Since leaving Leicester my work has passed through an unsatisfactory period. I have found it difficult to settle in at the Slade and most of my work has been done at home. Due to the lack of space (at the Slade) I have not developed any of my light and water ideas at all over the last three months."

At Leicester, my studio space was around sixty square meters, which allowed me to explore large-scale work. At the Slade, space was at a premium and in effect my studio there was a bench and a chair. Furthermore, I was living in Wimbledon, a forty-minute drag into and out of Central London on the District line. The same was true for most of the cohort and the relative creative isolation came as something of a shock after the studio culture of Leicester. Nevertheless, the crisis was not just one of resources and creative culture; I also appear to have questioned what I was doing and why, writing, "It makes one wonder what one is really interested in. I am sure that it is not light and water as such. They are just vehicles. But vehicles of what and why I am not sure."

Regardless of how beautiful and captivating the light and water pieces produced at Leicester appeared to me, it did not seem to be enough merely to produce pleasing phenomena. I might have been influenced by Stephen Willats more than I imagined, when he exhorted the artist to measure effectiveness not by reference to the standards of performance set by the art business itself, but by reference to the wider community.[2] It seems that I was unclear about what the work was doing, that is, what kind of responses it was eliciting from the viewer beyond pleasure.

The Ideas Informing the Slade Work

Although the Slade lacked studio space, University College London had a mainframe computer. I learned how to program in the FORTRAN IV computer language and designed programs that modeled homeostatic, self-regulating systems, using ideas set out in two books by W. Ross Ashby.[3] These books became the foundation of the work I produced for the Slade Higher Diploma show.

From my notes it would appear that I saw these books as providing material for me to explore two interests:

- defining and establishing conceptual models (mechanisms) exhibiting similar characteristics to those observed of natural systems;
- procedures and methodologies for constructing such models and for winning information from natural systems.

I was attracted to these ideas because they offered greater control over and understanding of the phenomena under investigation than I had been able to attain using light and water. My notes show that I saw modelling as providing a "disciplined and rigorous approach for research."

The computer programs I produced modeled systems that were stable under displacement, that is, when disturbed they returned to a stable state, like the surface of a pond after a pebble has been thrown into it. The programs output drawings that visualized the behavior of these systems. My purpose was to retrace the ground covered in Ross Ashby's book to ensure that I had a sound understanding of the ideas presented and a firm foundation for later research.

In this respect I was continuing the experimental practice established during my time at Leicester. In undated notes written sometime during the first half of 1972, I explain this process as follows:

> It is noticeable that my notes give an impression of a perception that is totally orientated towards an almost scientific study of phenomena. However, it is not the phenomena that really interest me. My aim is not primarily to understand the phenomena. It is the feelings and thoughts that the phenomena provoke in me that are the motivating factors. Whilst the process of study is almost scientific it is used mainly as a method of control. The interest is in the meaning of the sensations experienced during study . . . Firstly, it is a matter of perception. You see something and it excites you. At this stage there should be no consciousness of ART. Just interest. The phenomena are explored firstly in an attempt to control the medium in order that the factors that stimulate interest can be revealed. At this stage one doesn't know why one is exploring. Whilst there is pleasure in this activity one is happy. As one works it (the art) begins to emerge.

Although I have no contemporaneous notes relating to the production of the computer-based Slade work, I do have undated notes reflecting on it. In these notes I observe that change or movement in the earlier Leicester light pieces was arbitrary and dependent upon the repetitive rotation of a light modulator, therefore lacking kinetic complexity and structural unity. Instead, I wanted change and form to emerge out of the structural and functional logic of the phenomena manipulated in a piece. "The cybernetic type system," I wrote, "seemed to provide a solution to these issues" because

- it offered the possibility of greater complexity of movement;
- movement (or behavior) is the consequence of the internal structure of the system.

The main piece I produced for the Slade show, *The Machine*, was also a response to problems associated with the computer-plotted drawings described above, and a manifestation of new ideas about spectator interaction. In my notes, I recorded three problems with the drawings:

- The activity of the system was presented in static format. Given the discussion above concerning the phenomenological experience, kinetic visualisation seemed essential.

- The system represented moved through many states producing unmanageably large drawings.
- The batch production of the drawings meant that interaction was virtually impossible, and I saw interaction as being essential to learning and discovery (although my notes do not make it clear whether the implied learner was the viewer or I). Since the system could not be observed behaving, decisions based on its behaviour were unlikely to be central to the experience.

Homeostatic systems provided a solution to the light piece problems reported earlier because rather than cycling repetitively, the stable state of the system provided a natural endpoint to the change process. Whereas the kinetic phenomena in the light pieces was determined by a somewhat arbitrary logic, the kinetic structure of *The Machine* was also governed by the logic of the homeostatic system. In this way, neither the end point nor the kinetic composition was determined by personal preference. In addition, I wanted to produce an interactive piece where the participant would have significant control over his or her experience of the piece. The aim was to offer phenomena open to discovery, through manipulation and observation of input and output values. I anticipated that the participant would develop "activity strategies," that is, personal plans for continued interaction designed to learn, to hypothesize about, and to test understanding of the system: in other words, to learn through surprise and discovery. In this way, the participant would control his or her experience of the piece. Although not explicitly stated in the notes, these ideas imply the notion of participant as investigator—as agent of their understanding of the phenomena provided to them.

The Machine

The Machine comprised three components: input, machine, and output. The machine part comprised a four-part system (A, B, C, D), each of which could take values between 0 and 9. The parts were related in a chain of immediate effects: A affected B, B affected C, C affected D, and D affected A, thus completing a chain of effects with feedback. The functional relationship between parts, where X is the affecting variable and Y the affected, was

if X is greater than Y then the value of Y is increased by 1;
if X is equal to Y, then the value of Y is not changed;
if X is less than Y, then the value of Y is decreased by 1.

The order of effects was such that A was compared to B, followed by B to C, and so on, until all of the parts in the system had the same value—the system had reached a stable state of no change. The input component provided a means by which the initial state of each part, and thus the system as a whole, could be reset. The output part visualized each state of the system as it returned to stability.

Figure 22.1 shows the input and output components of *The Machine*.

The black square at the top is the output display. It was a square, black Perspex sheet drilled through to reveal four hundred light-emitting diodes. Each quadrant of the square represented one part of the system, the innermost three-diode line in each quadrant representing State 0, the outermost line of twenty diodes representing State 9 of the corresponding part. The white Perspex square below the display was the input panel. This comprised four sets of four light-emitting diodes, plus four pushbutton switches arranged underneath, and one to the right. Each set controlled a given part of the system. The four pushbutton switches in each set enabled binary-coded decimal values to be set, the value set being indicated by the corresponding row of diodes. For example, if the diodes of Part A in the input panel working from left to right, were lit, unlit, unlit, lit (that is, 1,0,0,1), then the input value entered into Part A would be 9. However, the system would only be activated upon depressing the button to the far right of the Part A diode and button rows (see figure 22.1). Once the system was activated in this way, it could not be interrupted until it had once again returned to a stable state. Both panels were mounted onto a wall, behind which the actual electronic system was concealed.

Reflections on *The Machine*

My notes show that although the piece functioned well, it did not match my expectation in terms of participant interaction, participant experience, and my own personal creative needs. For example, I observed that even though I supplied notes on how to operate the system, visitors did not find the piece intuitive to use. Some did not seem to have the time or motivation to read the notes and those that did generally found it difficult to operate and understand. Some people did not seem to know what was expected of them and appeared inhibited in the presence of *The Machine.* Although kinetic art was well established at the time, the participants seemed confused by a work that required action from them first in order to have something to react to. Those that did manage to operate the device successfully seemed to quickly lose interest in it once they discovered that it always returned to a square; it was as if they had solved the puzzle. Few seemed sufficiently motivated to discover the state change behavior of the system. In short, there was little evidence of the learning, discovery, and activity strategies that I had hoped to stimulate.

Because the system was hardwired it was very difficult to modify the embedded algorithm (unlike a re-programmable computer), thus limiting its potential as a medium for artistic exploration. I further recognized that such exploration requires systems of sufficient complexity that behavior cannot be predicted in advance or readily

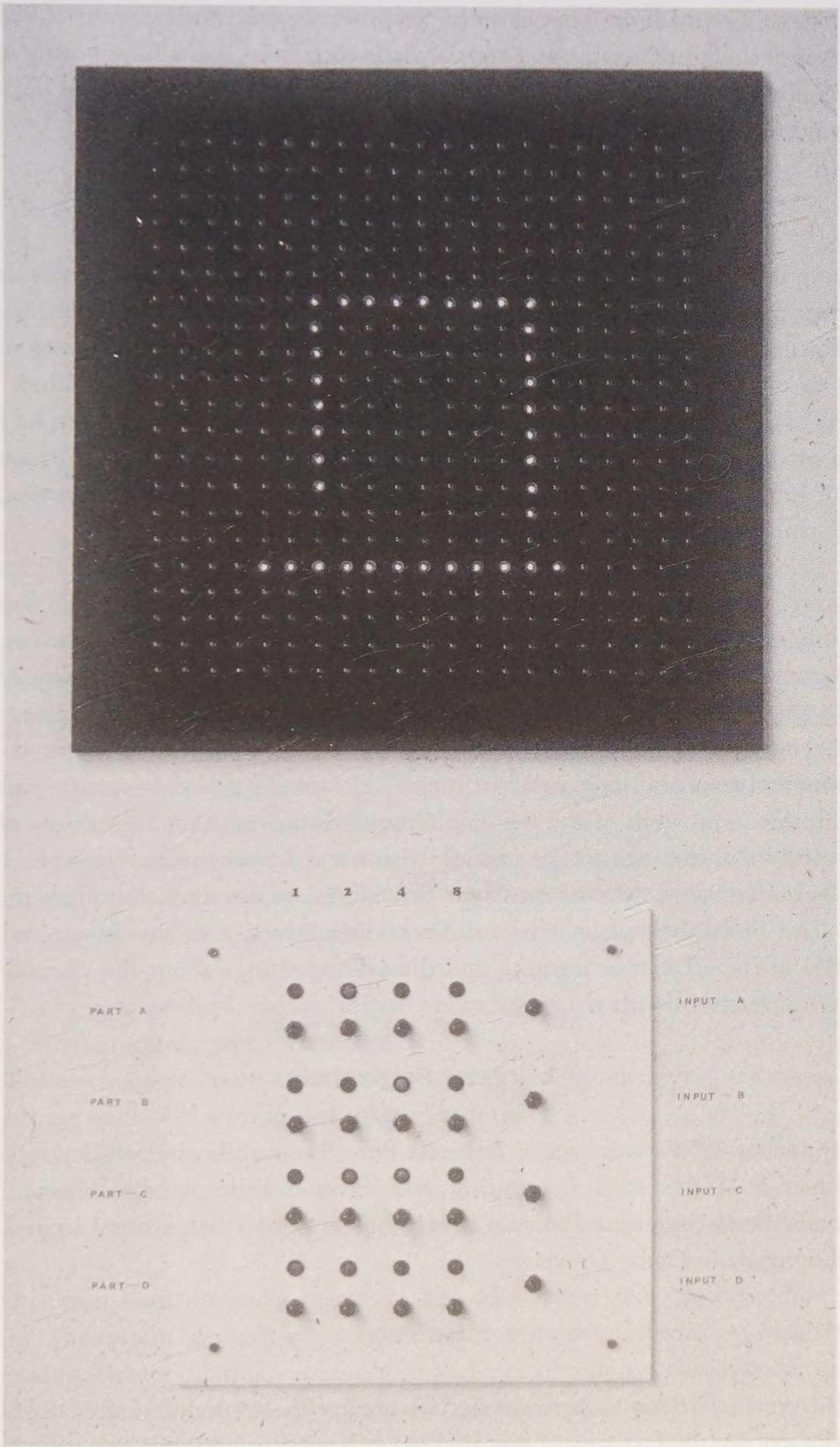

Figure 22.1 Stephen Scrivener, *The Machine*, 1972.

understood: The medium must allow for surprises. For me, the behavior of *The Machine* was entirely predictable and thus of little interest as a medium worthy of further exploration. Nevertheless, as we shall see, these successes and failures helped to shape subsequent work.

Influences

In many respects the Slade work continued threads established at Leicester. In my working process, I continued to avoid personal expression and drew on non-art-based generative systems. Understanding and control of the phenomena was sought prior to exploitation of its artmaking potential, through experimentation. New aspects of the Slade work were: the use of electronic and computer systems; an interest in modelling natural phenomena rather than working directly with it; and the idea of interactive art as a process of learning and discovery, resembling that now firmly embedded within my own creative practice.

At Leicester, I had already been primed to the idea of the computer in art and the absence of studio space pushed me toward more economical, abstract, and internalized modes of working. Malcolm Hughes introduced me to the ideas and work of the Systems Group, many of whom, such as David Saunders and Jeffrey Steele, visited the Slade as tutors. This group of mainly British artists (including Colin Jones) employed various kinds of (frequently mathematical) systems to provide ordering and structural principles for their work, usually realized in static painting or sculpture. The work of the Systems Group showed me that formalisms offered even greater control over image making than natural phenomena. However, much later I observed that, "the systems type procedures are not deducible from the image." This probably explains why I did not align myself with this group and why the idea of the art viewer learning and discovering things about the phenomenon through interaction with it.

Leicester Polytechnic

By September 1974 I was back at Leicester Polytechnic to begin a PhD program in the School of Mathematics, Computing, and Statistics under the direction of Ernest Edmonds. Our orbits would remain closely linked until 1992, when I moved from Loughborough to Derby University.

Sixteen

The piece called *Sixteen* is the most documented of those produced after the Slade.[4] At Leicester, for the first time, I was able to work with an interactive vector graphics

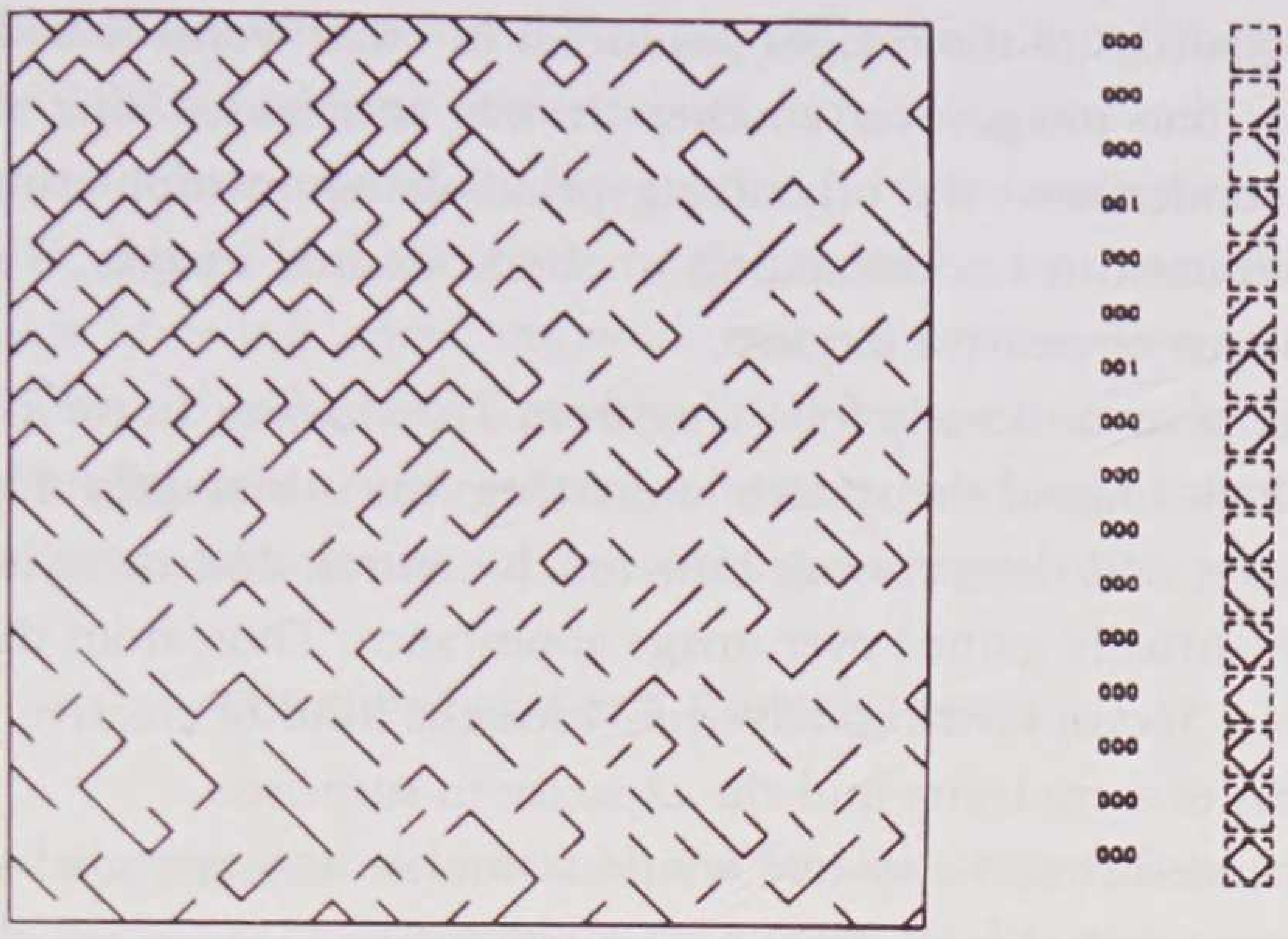

Figure 22.2 Stephen Scrivener, *Sixteen*, 1976.

workstation. The image surface of *Sixteen* was a 20 × 20 cell matrix, the image being created by filling the cells with graphic elements selected from a set of sixteen (see the table of symbols at the far right of figure 22.2, representing the sixteen possible states of a four-bit binary variable). An equilateral diamond was used to represent this variable: The absence of a line represented a bit value of 0 and the presence of a line represented a bit value of 1. The distribution of the elements over the matrix was controlled by a probabilistic function.

The images were produced as a result of an interaction between the participant and the computer system. The interaction was viewed as the primary component of the participant's experience of the work and proceeded as follows:

1. The computer displayed an initial image in which there was a more or less equal distribution of graphic elements.
2. The participant could then modify the image by changing the probability weightings associated with one or more elements.
3. The computer would then display the new image generated according to the participant defined probability weightings.
4. Steps 2 and 3 could be repeated for as long as the participant desired.

Given sixteen elements and a matrix of 400 cells, the system could produce 16^{400} images. The system was seen as a way of exploring the set of drawings: with weighting modification regulating the direction and rate of progress through the space of drawings. Hence, *Sixteen* embodied a global organizing principle that controlled the distribution of elements in the visual field. However, the system was neutral with respect to the qualities of the images produced: In other words it had no hardwired "preference" for one image over another. It was anticipated that the participant would seek to understand the organizing principle by manipulating graphic elements, and then use this understanding to obtain desired images. This process was seen as an analogue of creative inquiry.

Sixteen can be seen as directly following from *The Machine*. In my notes I recorded two ways in which I found the system interesting: the initial difficulty of predicting image appearance; and determining how much control, and therefore understanding, could be eventually gained over image appearance. Thus, from the personal creative perspective, *Sixteen* seems to have provided the kind of creative medium I was seeking in terms of complexity and the capacity to surprise.

It was anticipated that the system would stimulate stronger goal-seeking behavior in participants than *The Machine* had. Furthermore, I expected the sequence of images produced during an interaction to reveal something of the participant's decision-making process. However, although I did exhibit and publish[5] images produced using *Sixteen*, I don't recall or have documentary evidence of the system ever having been used interactively in an exhibition setting. Nevertheless, there seems to have been sufficient ad hoc use of the system to encourage a range of ideas for developing *Sixteen*, only one of which appears to have been implemented (to allow the participant to apply the organizing principle to user defined regions of the picture space).

Influences

Initially, during this period I explored the ideas formulated at the Slade, but with the novel dimension (at least in terms of my practice) of user control over the image-making process. Ernest Edmonds was a significant influence, not so much in terms of his own computer art practice, but his ideas on interactive systems, and the research that we subsequently undertook together on drawing recognition and interactive human-computer systems.

I did not regard myself as a computer artist at the Slade and consequently looked very little at the work of other contemporary computer-based artists, other than those working around me. However, as part of my PhD research, I conducted a review of computer art and as a consequence became familiar with the key texts of the period[6] and the artists represented in them.

I was now engaged in two practices, research and artmaking, and I found it difficult to combine the two. I also became committed to implementing an innovative approach to computer graphic system design, which became the focus of my doctoral research. Unfortunately, this had little or nothing to do with my art practice, thus creating a distance between the two activities. Increasingly, through the late 1970s and early 1980s I became immersed in computing research. This was an era of rich and excited debate around themes such as human-computer interaction, artificial intelligence, image and speech recognition, and adaptive systems. My notes suggest that these ideas influenced my work more as my engagement with the contemporary art debate diminished. The separation between artmaking and research, and the lack of engagement with contemporary art thinking, probably account for the gradual and eventual cessation of my computer art practice.

Connections and Consequences

I had discovered the personal significance of artmaking through a form of painting that engaged with the material world. I saw artmaking as a way of knowing and of communicating that knowing. Yet as my competence in and knowledge of painting increased, satisfaction with my progress and direction decreased: knowing the material world seemed confounded by knowing about painting. This initial dissatisfaction started a process that terminated in *Sixteen*. However, in many respects I ended up pretty much where I had started.

I had replaced one kind of phenomenon—landscape, the figure, etc.—by another: first light and water and then that produced by models. I had replaced one method of knowing—observation through painting—by another—experimentation—which, as I saw it, freed my thinking from the tacit operation of preferences acquired through familiarity with the history of painting. Eventually, I replaced the arbitrary composition of artistic reflections of phenomena by artifacts directly constructed by these phenomena. Ultimately, I abdicated from the responsibility of conveying the known by providing the viewer with an experimental method of knowing. In short, I had found a way of working through the anxieties that seemed to underlie my dissatisfaction with painting.

It can be argued that my understanding of artmaking functioned as a constant throughout. Additionally, the developmental process itself can be seen as a quest for rigor in the application of this understanding. However, the history described above suggests that the attainment of rigor was greatly influenced by the contexts in which it was sought.

It should have been possible to continue as a painter and the fact that I did not is probably a result of the context in which I found myself at Leicester, where many staff members were modernists exploring new media other than painting and sculpture. Artists such as Jack Rodway, Gavin Bryars, Alan Welsford, and Stroud Cornock were between them exploring time, change, chance, system, interaction, mixed and new media, including computing technology. They were all highly persuasive and committed, which were appealing characteristics. Under their direction, I found a way of using these ideas and the artmaking strategies they offered to move beyond dissatisfaction with painting.

It would be wrong to suggest that Leicester professed a single doctrine: rather it constituted a nexus of ideas reflecting those prevalent in the wider art community. Cornock, in collaboration with Edmonds, had already begun to connect the art nexus with the computing nexus, introducing ideas that I would explore more directly at the Slade. This nexus constrained and afforded options in a manner particular to the community of practitioners responsible for it. Similarly, my response was particular to the Leicester context.

At the Slade, Malcolm Hughes and Chris Briscoe were the key influences. Malcolm Hughes's contribution was to reinforce my interest in systems, but it was Chris Briscoe who opened the door to computing for me. Chris was a day-to-day presence with great competence in electronics and computing, and his knowledge and guidance made *The Machine* a feasible project. The Slade expanded my personal nexus of ideas, which then connected with those current at Leicester on my return in 1974, when I began to work closely with Ernest Edmonds in the world of computing.

However, in my case at least, the effect of the immediate (and wider) context on my practice was not one of ideological attachment. Time, chance, interaction, computing, etc., were not ideas that I saw as fundamental to my practice, as having special importance as properties of the world or human experience to be known, or as the subjects for art. Certainly, I found them interesting and exciting, but for me they served primarily as a resource for working through the problems and possibilities of a certain conception of artmaking. Thus while the work was certainly influenced by the intellectual situations within which it was created, it was not determined or caused by them; the work emerged out of a search for conceptual rigor in artmaking, as framed herein to understand and to convey understanding truthfully, negotiated within the boundaries of a number of interconnected contexts. To the extent that the experience I have described is characteristic of creative practice in general, it suggests that in order to understand how ideas affect the practitioner, we need to understand both the context of practice and the fine detail of the practice itself.

Notes

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5. Scrivener, in Spencer, *Working Information 3*, n.p.

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23

My First Brush with Computer Graphics

Stephen Bell

In this essay I describe how my use of the computer at the Slade School of Fine Art in the late 1970s grew out of and was related to my other work. I have tried to avoid hindsight and discussion of ideas that I have formed since 1980 by using notes taken at the time. Many events that surrounded and contributed to what I did have been left out.

I was born in central England in the mid-1950s. By the late 1970s I was into science fiction, punk rock, *Dungeons & Dragons*, *2000 AD*, *The Hitchhiker's Guide to The Galaxy*, real ale, and art by minimalists, conceptualists, Fluxus, performers, arte povera, land art, and experimenting with new media.

Orientation

Through experiment we form beliefs and place ourselves relative to the universe of sensations that we experience; we orient ourselves. As we move through natural spaces or buildings, we sense changes in volume and structure. If we actually manipulate something in the environment, we become aware of its texture and distribution of mass—how it resists, reacts, or responds to our touch. We can investigate how and why the place we are aware of exists in the way that it seems to.

Orienting ourselves is usually a continuing process of disorientation and reorientation. Most of the time, we seem to be in a state of more or less tolerable ambiguity, where things sort of make sense. There are, however, occasional brief moments when everything slots into place and there are no doubts. For me, making art is part of a process of orientation, and if a piece of my work does what I intend, it is capable of creating one of those fleeting, life-affirming moments.

I attended art college in the United Kingdom at a time when the educational structure was supposed to encourage fine art students to "do their own thing." I thought that this meant that I could do anything as long as it worked for me. Being an artist was a career choice; it seemed that in order to do what I wanted with my life, the best role available was to make art. I felt that fine art had a moral advantage over politics, religion, science, the applied arts, and many other practices, as people could choose to take it or leave it. They could ignore my work if they wanted to and it would not impact on their lives. If people chose to take an interest in my work they were voluntarily putting themselves into my hands, giving me a license to do for or with them whatever I thought was appropriate; they were the final arbiters of its value to them as individuals and could choose to pull out at any time.

Through my work I was trying to resolve and articulate a complex mess of ideas and feelings. Learning new techniques was part of a search for the best medium to embody these ideas and feelings, so that I could address and reflect upon them and, where appropriate, share them with other people. At twenty-two I possessed a number of technical skills and was interested in learning more; I thought that artists should use the most appropriate medium to realize a given work. I also believed that developing a new form of art, simultaneously defining a new medium, was the most creative thing an artist could do.

I had heard of artists using computers in TV reports about *Cybernetic Serendipity* and Edward Ihnatowicz's *Senster*, but did not expect to use a computer myself. Then a couple of guys from the Slade School visited us at Bristol Polytechnic. I remember seeing a picture of an interior and thinking how amazing it would be to have a perspective drawing of a sculpture constructed for me, rather than having to do it myself. I think we were shown some of Chris Crabtree's work too. My attention was caught briefly.

I don't know whether I would have sought out computer technology if I had not been offered a place in the Department of Experimental and Electronic Art at the Slade. The departmental philosophy encouraged students to explore new ideas with a broad range of technologies and they provided access to several that I had not used before and therefore wanted to try, including computer programming. Using the computer was part of an intensive couple of years of experiment in various media and grew out of previous work and ideas.

Background

Audience Participation

While constructing a sculpture with old house timbers, at Bristol Polytechnic, I realized that my understanding of the piece was informed by my physical experience of lifting and maneuvering the timbers into place. How could the audience feel the same way about the work unless they had hefted timbers about? I had been interested in encouraging audience participation for some time. On the art foundation course at Yeovil, I had become aware of some of Richard Long's work and had thought, why paint landscapes? Why not simply design walks for people to follow so they could have an unmediated experience?

When fellow students at Bristol started walking over another construction that I had made with the house timbers, interacting physically with it and becoming part of the piece, it convinced me that audience participation was the best way to bring people closer to my own position so that they might understand more clearly what I was doing.

I briefly experimented with some works using posters that began "There is nothing you can do about it, but you are now part of an artwork . . ." Some people did not seem at all comfortable with this form of participation.

I made two portable folding sculpture kits of modules to construct artworks with. My intention was that others would also use the kits to make work. I made small, chess-piece-sized modules too. When I exhibited the pieces people did not play with them. They did, however, play with an old one-armed bandit that I had used to make design decisions when making paintings and sculptures and had exhibited alongside the other work. I realized that if I wanted people to participate, they would have to be comfortable with it, or even unaware that they were doing it.

Randomness

I had found the one-armed bandit on a city waste tip. I replaced the faded symbols on its wheel with color swatches and used the machine in making paintings that consisted of grids of color swatches, where each color was determined using the machine. I was looking for a pattern to emerge; perhaps I could beat the system.

I also used randomness to compose the sculpture modules. I would plan out a grid and then use dice to determine what type of module should be placed in each location on the grid. Once I had an arrangement of modules I would systematically rotate each one in turn to see how it affected the overall composition. I was interested in alignment and how separate parts, unconnected physically, could be associated by being aligned, a gestalt phenomenon that I had first seen in Henry Moore sculptures and encountered again in Alfred Watkins's ley lines.[1] I took a simple delight in the way rotating the modules could transform how the composition was read.

Using the Computer at the Slade

Software

When I started at the Slade I had never used a computer, but found that programming related well to my previous art practice. Writing programs did not seem strange; artists had delegated making work to other people for centuries so why not to a computer? I had already been using rules to compose work, and I thought people might be encouraged to interact with work on a computer.

Perspective projection, rotation, and so on was handled by the Gino graphics library so I did not need to learn the geometry, mathematics, and programming techniques for projection and transformation. The system also had programs set up to control the plotter. I just had to learn how to write FORTRAN programs that would make the computer produce the kind of drawings I wanted.

I liked programming. I enjoyed trying to keep in mind all the things that had to happen for the program to work. Before writing a program I would work out the logic of it in notes and in diagrams. I would try to get a picture in my mind of what would be going on when the program was running: this will happen, then this; if this has happened then this will follow, otherwise this will; and so on. This complex changing form had to be represented by a series of instructions. It was like working out the rules for a game; like visualizing a complex moving architecture or a multidimensional sculpture freed from physical laws. Some people have said that programming is like making an art object. There are similarities but I found it closer to composing a piece from existing modules than directly manipulating a raw physical medium.

Hardware

"Nurr Nurr Nurr . . ." A mapping pen, secured in a special cradle, is moved across a sheet of paper laid flat on a horizontal metal table by an arrangement of metal tubes, pulleys and taut steel wire. "Click Click . . ." The nib is placed on the paper and moved in a straight line. "Nuuuuur . . ." It is then lifted ". . . Click . . ." or left in contact with the paper and moved again. "Nurr Nurr Nurr . . ." Sounds of electric motors changing speed and the thrumming of an electric pump sucking air through small holes in the surface to pull the paper as smooth as possible syncopate with the clicking of the device holding the pen. They all follow a rhythm dictated by the order and size of the marks being made on the paper. Painstakingly, step by step, a drawing is built up out of thousands of plotted lines.

Creating computer drawings was a sensuous experience: the controlled power and the tension of the mechanism of the plotter; the touch of the pen or brush on paper and its unpredictable movements; the slow revelation of the final composition over several hours. Images were previewed on a green vector refresh screen with no shaded lines, which meant that the part played by color was only revealed as the drawing was plotted.

The plotter was pretty accurate so different colors could be drawn over each other and an extended palette could be created using transparent cyan, magenta, and yellow inks. I did not mind if the registration wasn't completely accurate because it meant that the colors could be seen in two ways—at a distance to see them mixed, or close up to see them separately.

I fitted brush-pens in the plotter instead of mapping pens for some drawings, a technique that produced curves that varied in breadth as the brush trailed across the paper. It was possible to imagine how it might feel to make such marks: softer, less harsh, less mechanical than using mapping pens. The brush-pens were potentially messy, the ink dried slowly so if the paper did not absorb it quickly, the metal plate that the brush protruded through would cause smudges. To stop the smudging I used newsprint instead of cartridge paper. Using the plotter this way appealed to me as it challenged the commonly held view that the main value of computers was their accuracy.

You could start a plot, then go to the pub for a drink, returning later to see what had been drawn. It had its risks, however, as ink would sometimes clog the mapping pen nib and you could return to find that the machine had gone through some of its moves without drawing anything.

For overnight stints it was possible to get into a routine: set a plot running, grab some sleep on a camp-bed, wake and check the drawing when the plotter stopped, change the pen or the paper, set the next plot going, grab some more sleep. You could get used to the sound of the machine and wake when it stopped. These solitary overnight vigils with the machine and the time it took to produce a drawing were an important part of the experience.

I knew that the computer was a Data General Nova Minicomputer. I had no idea how it worked. Once, I heard a visitor exclaim, "Ah, so *this* is the naked mini!" I thought, "Ah, so I'm using a 'naked mini.'" I tried to understand how computers worked but the paucity of my understanding can be gauged by the fact that I thought that the computer used magnetic cores to store data and even spelled computer "computor" in my notes. There did not seem to be any books in the libraries or shops written for people who did not already know about programming and how computers worked. I would ask Chris Briscoe, Julian Sullivan, and fellow students for advice, but the concepts were so new it could often take several attempts before I understood what they were saying. Sometimes I could not make any sense of their explanations at all. My favorite book on computers was Laurence Lerner's *A.R.T.H.U.R.: The Life and Times of a Digital Computer.*[2]

As I didn't know how computers worked I didn't really understand what a "crash" was. So I always had a sense of apprehension when running a program. I would imagine sparks, smoke, and flames pouring out of the machine. This added a certain frisson to working alone with the computer through the night. I was assured that my programs shouldn't be able to damage anyone else's work, but I always wondered, what if? When the system did crash it was less spectacular than expected. It just stopped working. I would then follow instructions to "bootstrap" the computer, pressing a button each time I had entered the appropriate pattern on a panel of switches. Eventually the computer would start working again.

The Programs

Ranstak

The program's name is an abbreviation of "random" and "stack." The algorithms for *Ranstak* were based on the rules used to compose sculptures at Bristol. The program generated compositions of shapes located on a regular grid of points in three-dimensional space.

The code was very simple: "do" loops generated the translations for each shape to locate it in the grid. The decision to locate a shape at a given point in the composition and what shape it would be was worked out using a pseudo-random number generator. The color and orientation (i.e., how it was rotated about the point) were also determined using pseudo-random values. I could control compositions by getting programs to prompt me to enter values for parameters and editing the programs explicitly. The perspective projection could be altered to promote particular aspects of the composition and to make it harder or easier to read as 3D.

When I started using the computer I got it to draw pictures of shapes that looked like the sculpture modules I had made previously. It did not work. They were like proposals for sculptures. I quickly realized that it would make more sense to use shapes derived from traditional drawing techniques to make works that had intrinsic value. This led to the development of the "hatch" shape to generate cross-hatching, the "helix" shape to produce intersecting curves (figure 23.1), and "zig" to produce textural squiggles (figure 23.2).

The hatch shape consisted of seven parallel lines, defining a square plane, slightly offset along the plane normal from its local origin. Seven lines were used because my reading of gestalt psychology suggested that it would be enough to indicate a plane, at the same time being recognizable as separate lines.

The helix shape used random values to determine length, amplitude, and frequency. High frequency and length would generate a recognizable helix. Low frequency and amplitude would generate a very gentle, almost straight curve.

The zig shape was made from eight randomly determined points in a cubic space joined as a continuous line. The shape was not closed.

In previous work I had used dice or the one-armed bandit to make randomized decisions. In programs I could use a pseudo-random number generator (RNG). When invoked several times, an RNG produces a sequence of numbers following a relatively unpredictable sequence—sufficiently unpredictable to be considered random. Some produce less predictable distributions of values than others. RNGs usually accept a "seed" number that is passed to the function before it is invoked for the

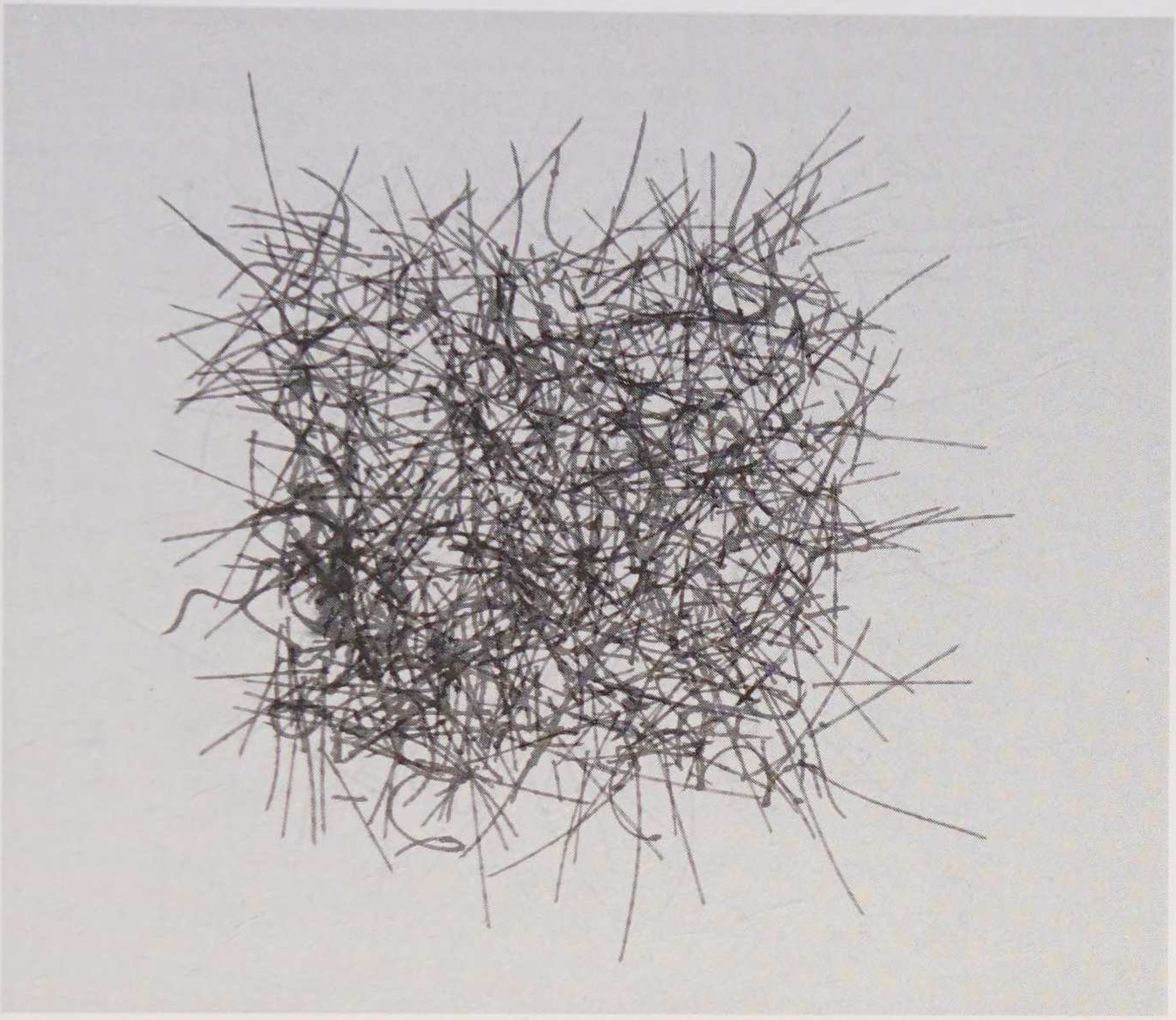


Figure 23.1 Stephen Bell. Untitled drawing. Data generated using *Ranstak* program and "helix" shapes, plotted on newsprint with cyan, magenta, and yellow edding 1380 brush-pens. 9″ × 9″. 1978.

first time. Different seed numbers will result in different sequences of numbers. A peculiarity of these functions is that if the same number is entered as a seed each time the program is executed, exactly the same sequence of numbers will be generated. This is extremely useful. If you use an RNG to make decisions in a computer program and want different results you enter different seed numbers, but if you want the program to produce the same results over again you just have to keep a note of the number and re-enter it into the RNG. In some works I used the same seed number for two or more drawings, changing the viewpoint so I could look at the same "random" composition from different directions. I enjoyed the notion of governing degrees of disorder.

A major part of my fascination with the *Ranstak* drawings was that although the general appearance of a drawing was fairly predictable, the details were unplanned.

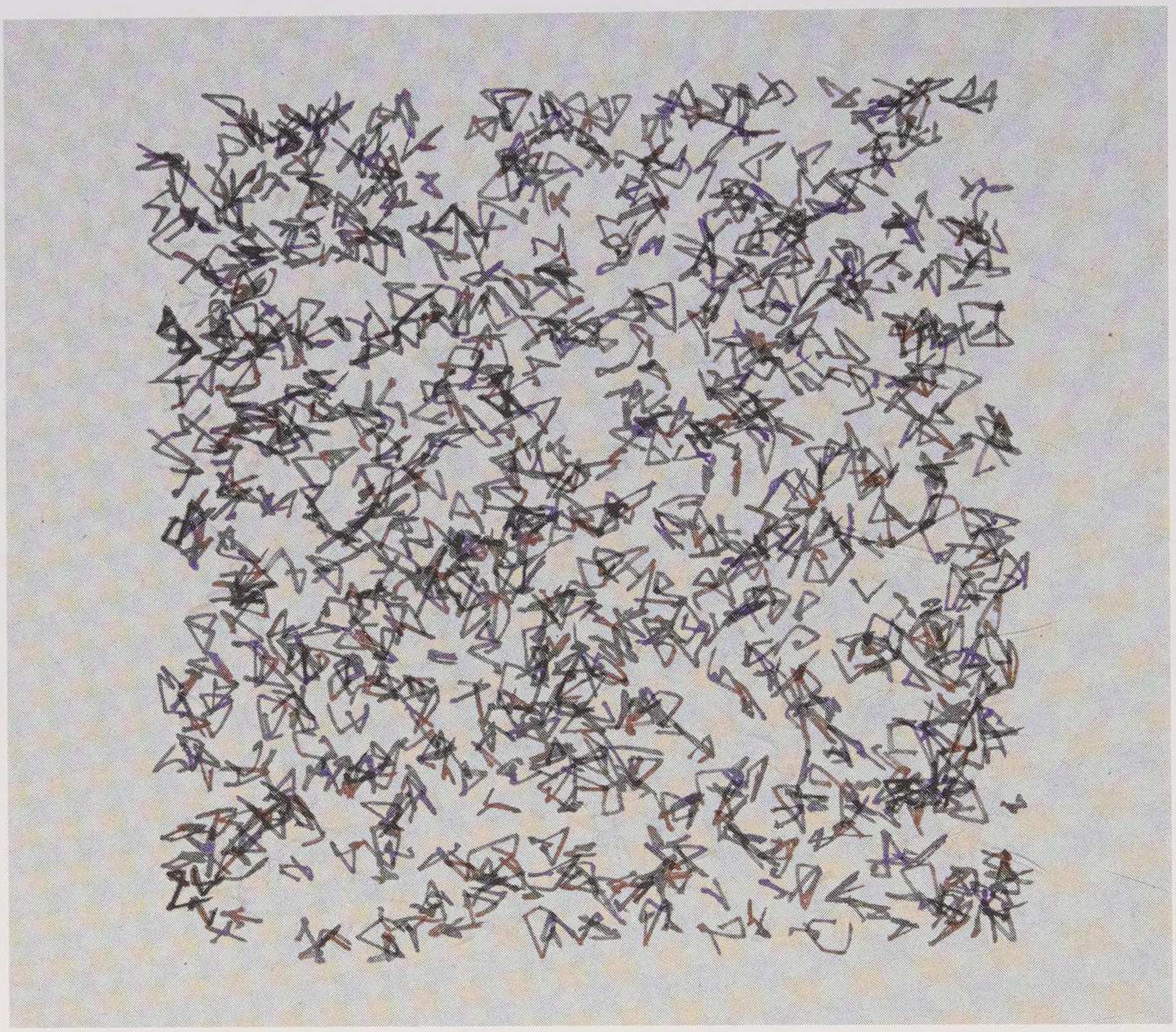


Figure 23.2 Stephen Bell. Untitled drawing. Data generated using *Ranstak* program and "zig" shapes, plotted on newsprint with cyan, magenta, and yellow edding 1380 brush-pens. 9″ × 9″. 1978.

The role of serendipity in determining events in the overall composition and the feeling experienced when discovering these events intrigued me. I enjoyed being surprised by the way chance determined that a particular line was of a given color, or crossed another at a given angle, or that a shape contributed a particular effect. I was also interested in the figure-ground effects formed by the space left when no shapes were drawn, where blank paper or an underlying drawing showed through.

Another important aspect of the *Ranstak* drawings was the ambiguity caused by perspective projection. We sense architecture and landscape as three-dimensional spaces, so when we see projections of them, we see 3D spaces. In the *Ranstak* drawings, where random 3D shapes were projected onto a 2D surface, it created an ambiguity similar to what we see when we look at constellations. Our sense of the distribution of stars when we look at the night sky is as if projected onto the inside surface of a sphere. We are not able to sense the distances of the stars from us and, without instruments, cannot build a picture of how they occupy a three-dimensional space. So when we see constellations, we don't see 3D space. If you know that the *Ranstak* drawings are perspective projections, you can try to work out what the 3D form of a shape is. But if the drawing is of an unfamiliar shape like a zig, it is not easy. It is easier when the same zigs are shown from different points of view. Looking at projections of recognizable objects like regular helices is easier too, but your cognitive system has less to work on with more subtle part-helices. I experimented with red-green anaglyphic computer drawings, which removed the ambiguity.

I was interested in Scandinavian and Anglo-Saxon zoomorphic patterns and Middle Eastern and Oriental calligraphy, as well as Tolkien's invented language. This led me to make some drawings appear like pictograms or handwriting to encourage viewers to view the shapes like text. I toyed with the idea that the machine might be controlled by my subconscious, as automatic writing was supposed to be. Could the computer be controlled remotely by aliens trying to communicate with Earth, or mysteriously influenced like the yarrow stalks used when consulting the I-Ching? When we base decisions on astrology and the tarot, are we projecting meaning onto arbitrary patterns, like Leonardo seeing scenes in stains on the wall, or Ernst's frottage? Is it like seeing castles in clouds or faces in wallpaper flowers and ghostly figures in the dim shadows of twilight? The way meaning could be projected onto the arbitrary squiggles of the computer drawings was disturbing—simultaneously amusing and alarming.

Space Exploration Game

The *Space Exploration Game* drawings (figure 23.3) were generated by a program that I intended to eventually be an interactive game that would engage the audience as players. The project wasn't completed, but it took a lot of attention and became the foundation for work that I produced later; I was to re-use several algorithms from it in a later work called *Smallworld.*

For several years before arriving at the Slade I had been considering games as a way of leading people into rituals and other formal and informal experiences. That play and games might be used to structure art first came to my attention in a review of Öyvind Fahlström's work, then an article by Ellen Dissanayake.[3] A game seemed an excellent way to structure participation so that the audience could be led into new aesthetic experiences.

I hadn't been particularly impressed by video games and did not play them often, but this notebook entry, dated 7/1/78 indicates how I was thinking about video games as a potential art form: "Try and find out about T.V. games systems, i.e. could one market them or are they too complex?—you buy a kind of

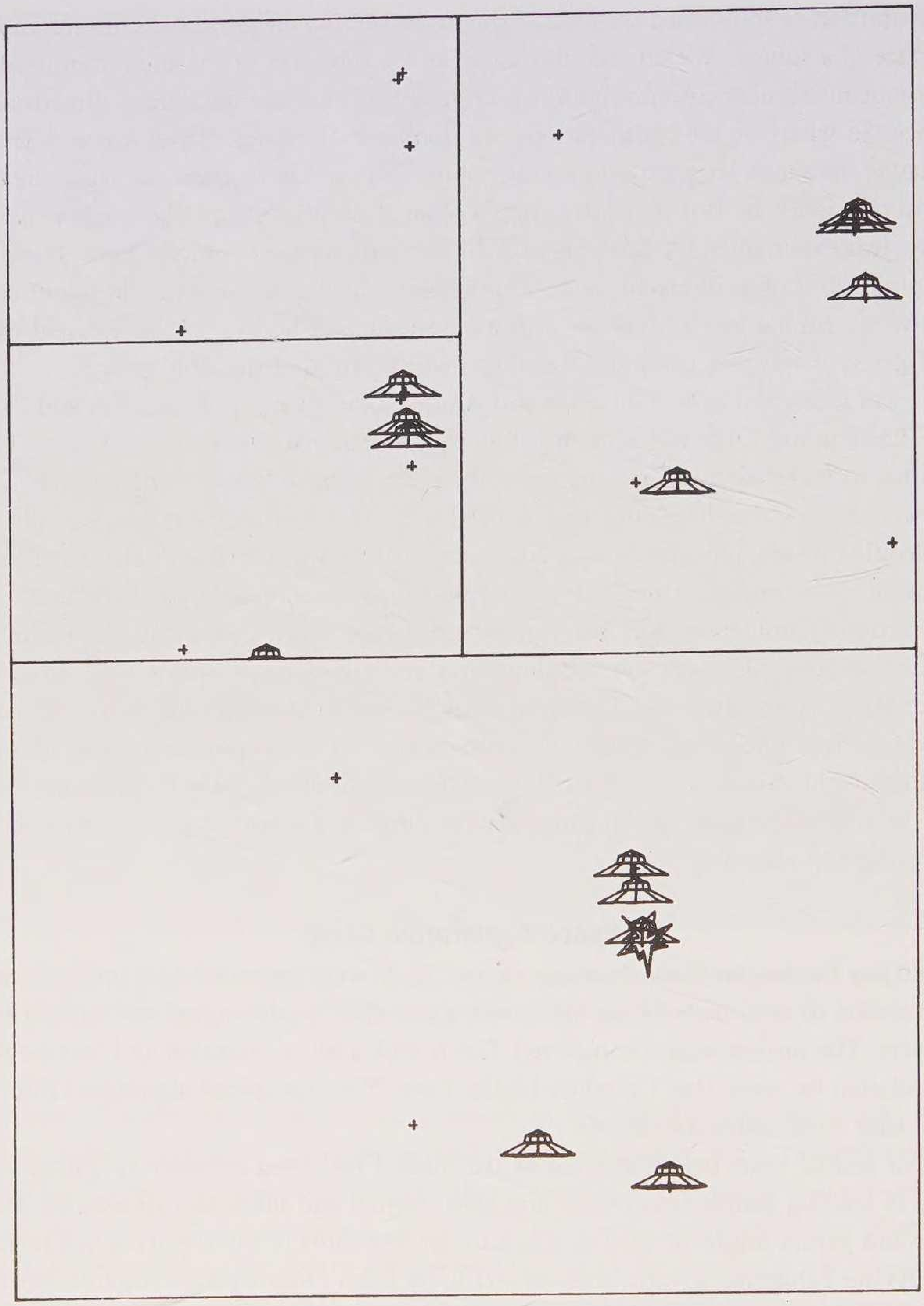


Figure 23.3 Stephen Bell. Untitled drawing. Data generated using *Space Exploration Game* program, plotted using black ink on cartridge paper. 9″ × 12″. 1979.

game for T.V. like buying a sculpture or painting, which you can have as 'moving wallpaper'."

As secretary of the UCL Science Fiction & Fantasy Society I started playing *Dungeons & Dragons*. I was immediately convinced that roleplay gaming was a new art form, as culturally significant as drama, film, and literature, and wondered whether roleplay games could work on computers.

In the proposed *Space Exploration Game* a participant would play an adventure game, then be presented with a comic strip documenting the major events in their adventure. The work could only exist if the audience took an active part in realizing it. I anticipated that, if I could give stars local to our own sun a strategic importance in the game, players would build a strong picture in their imagination of the stars' relative 3D locations, to create a mind-sculpture.

I wrote a program that produced diagrams based on the positions of the nearest twenty stars relative to our sun. Moving the viewpoint around showed how stars would appear from different directions. Next, I introduced a component to calculate the movements of spacecraft—enter a destination and the craft's software simply plotted a direct course to it, updating the position of the craft over time. I included a routine that enabled spacecraft to check how far they were from their destination and each other; if they were in weapon range they could engage in combat. The program kept track of significant events (e.g., attacks) to show in the comic strip. I developed a system that would plan the page layout so that more significant events were automatically drawn in larger frames.

A book, A. C. Day's *FORTRAN Techniques*,[4] was recommended to me. I found it very useful; it helped me sort out event-driven spacecraft behavior, as it had a chapter showing how symbol-state tables can be used to represent complex choices in tabular form.

I tried to make the game interactive by producing real-time animations on the Tektronix screen. Chris patiently explained how double-buffering works, but I could not quite get it. I could get the monitor to display frames, and refresh the screen between frames, but the screen would clear before a drawing had been completed; it just became a stroboscope! As I had to prepare for my final show and time was pressing I had to put the work aside.

First Steps

I thought that learning to program would give me an insight into human logic. My reasoning was that computers were logical machines designed by humans and they should consequently embody human logic. I expected that once I understood this logic I would be more able to make sense of why humans think some things are art and others aren't. I also hoped that using a new medium would enable me to break away from limiting myself to using straight lines in my work.

It worked, as the *Ranstak* algorithm generated curves. Practical experiment, imitation, and good advice led to a certain degree of success. The drawings I produced are evidence that despite my inexperience I was able to write programs that worked. Instead of playing a game, visitors to my final show had to be content with watching *Ranstak* drawings being drawn on the Tectronix display, but I had taken the first steps toward using computers in participatory work.

My Other Work

The computer drawings were only a part of the work I did at the Slade. I did not see them as a separate pursuit. The following summaries give a broader idea of what I was doing.

Installations

I produced two installations using video and closed-circuit television (CCTV) to explore my interest in human behavior, ritual, and body language.

In *Clews*, participants entered a room where there was a video monitor opposite a sofa. A notice with simple instructions explained that they could give instructions through a microphone in the camera above the monitor to an operator in another room who would follow their instructions ("up," "down," "left," "right," "stop") until they had navigated their way out of "the maze." I was on the other side of a dividing wall, focusing a video camera on a small part of a maze taped on the wall. The participants saw only this part of the maze on the monitor and had to build up a picture of the whole maze in their minds as they navigated to an exit. Initially participants were unaware that they were being recorded on video, which wasn't in common use at the time. When one group realized it, they asked to see the recording as a prize for completing the maze. From then on I incorporated this reward into the piece. I later collected the sketch-maps participants had made and studied the tapes to look for interesting gestures and behaviors. I saw my role in this installation as that of the computer program in an electronic game.

Monitored Doors was one of the pieces in my final show. Julian Sullivan helped me install all four of the department's CCTV cameras so that each one focused on a different door on the route through the postgraduate exhibition to my part of the show, where four monitors mounted on a wall showed the view from each camera. On arriving at the exhibit visitors could watch others as they passed through the doors on the monitors. At some point viewers would realize that they might have been subject to other people's gazes as they made their way to the exhibit.

Stereo and Immersion

I was interested in stereoscopy and the possibility of holographic TV, so I experimented by setting up two CCTV cameras and monitors in parallel. It was surprisingly easy to get stereoscopic views. When Chris Briscoe said that he could view stereo pairs without a viewing device I went home and gave myself a splitting headache learning how to do it by staring at pictures in N. A. Valyus's book.[5] I made sketches in my notebooks of a project that involved using back-projection on all six planes of a cube of films taken on walks through interesting environments. The idea was to give viewers inside the cube a sense of being in the filmed space. The expense of obtaining the kit, however, put realizing this project out of the question.

Documentation

Like many others at the time I was interested in creating and documenting ephemeral work. I also wanted to provide an insight into my thinking and working methods in my final show. My solution was to produce a bound, typed copy of the notes I had taken over the two years of the course. The notebook included copies of computer drawings, sketches of projects, and extracts from books and articles. I was excited by the aesthetics of the newly available color photocopying process and used it for some photographs.

The notebook included documentary photos of a semi-performance process that I called "arting," which I had started as a student at Bristol. I took a folding modular sculpture to various locations to build temporary installations. I refined this process at the Slade, basing the documentation on NASA reports of moon exploration. The documentation process became an integral part of the arting—the relationship between the documentation and phenomenon was part of the artwork. I copied the way the NASA documentation process was itself documented; one saw photographs of astronauts taking photographs. So I included photographs of me taking photographs.

In my notes I drew parallels between arting and the activities of people using tools for tasks like repairing the road, acquiring samples on the moon, making tea, performing religious acts—any activity repeated so regularly that it becomes a ritual. Any such ritual, I felt, could be approached as one approaches a work of art, focusing attention on the formal and aesthetic aspects of the experience instead of its original purpose. I saw game design as a way to create new aesthetic rituals.

Other People's Work at the Slade

Chris Crabtree's work had a major impact on my realization of what might be done with computers. The storyboard presentation of the *Space Exploration Game* pictures was based on his work, and his programmed automata influenced what I was to do later in the 1980s, as did Chris Briscoe's drawing and sound pieces based on the interactions and movements of particles.[6] I can also remember seeing a film of machines with multiple legs driven by electric motors switched on and off by computer; what made it appealing to me was that the machines were enclosed in a playpen. I was introduced to John Conway's *Game of Life*, but at the time I was trying to find a way of escaping the grid as an ordering form so I didn't want to use cellular automata. Peter Beyls was also at the Slade: In the late 1980s Ihnatowicz put me back in touch with him and I became anxious when Beyls sent me some pictures of his work, because it appeared remarkably similar to mine. I wondered whether I had inadvertently reworked ideas he had been using in the 1970s. But when Peter and I met up again it turned out we had reached similar positions through separate routes.

I didn't make any notes about how artists were using computers outside the Slade, so I'm not sure what I was aware of at the time. I recall that Paul Brown arranged a screening of some computer animations. I went to one or two meetings of the Computer Arts Society, but the discussions seemed to be more about computers than art, using jargon that I did not understand, so I did not continue to go.

Filmmakers like Chris Welsby, Bob Fearns, Renny Croft, and others opened my eyes to how film could be used. I remember seeing a really interesting piece where the computer plotted a drawing of itself while a camera attached to the plotter filmed the computer.

A couple of my contemporaries were doing work with pencil drawings and projection. John Cass did a piece in which he produced projected drawings by hand, based on contour maps of sites in Scotland, according to the characteristics of camera lenses; he then used those lenses to photograph the actual locations from the same points of view. Colin Gale was drawing projections of four-dimensional objects by hand. What made the department so special and enabled me to contextualize my practice was that the computer was treated as just one technology among many others.

After the Slade

My time in the rich environment of the Slade ended in 1979, and I started to work at Florian Beigel's architectural research unit at the Polytechnic of North London. It was a three-year contract, so I decided to stop producing my own work during that time and create a critical distance from which I could reconsider my position.

When I began to work as an artist again I found that I could not explore the ideas I was interested in without using a computer. I applied for art college teaching jobs, an established way at the time to start supporting your art practice, but they were more interested in life drawing! They were certainly not interested in computer graphics. I did not want to "sell out" and go commercial, using computers for design; I wanted to use computers for fine art.

I was about to give up when in 1984 I got a residency at the Computing Laboratory of the University of Kent at Canterbury, sponsored by the Arts Council and South East Arts. This enabled me to pick things up where I had left off four and a half years earlier. I decided to use the residency to start a ten-year project to determine whether interactive computer art had any real potential as an art form. The outcome was a suite of interactive programs called *Smallworld*. As part of the project I also completed a PhD at Loughborough University.[7]

My interest in unpredictability continued. Originally I had adopted the use of randomness as an attempt to reduce authorial responsibility for decision making. Later I realised that these methods, where I did not know exactly what was going to appear in the image, were more like garden design methods, where you know what the overall effect will be but cannot predict the exact shape and color of individual plants. At Canterbury I stopped using RNGs, preferring to let human participants contribute the unpredictable element.[8]

Using computer technology did enable me to think more logically, but more important, I learned the value of being human: you are vulnerable to a tendency to oversimplify and see things that may not actually exist, yet able to follow hunches and intuition to deal with complex situations.

Notes

1. Alfred Watkins, *The Old Straight Track* (1925; repr., Abacus, 1994).

2. Laurence Lerner, *A.R.T.H.U.R.: The Life and Times of a Digital Computer* (Brighton, UK: Harvester Press, 1974).

3. Ellen Dissanayake, "A Hypothesis of the Evolution of Art from Play," *Leonardo* (1974): 211–217.

4. A. Colin Day, *FORTRAN Techniques, with Special Reference to Non-Numerical Applications* (Cambridge: Cambridge University Press, 1972).

5. N. A. Valyus, *Stereoscopy* (London: Focal Press, 1966).

6. Donald Michie and Rory Johnston, *The Creative Computer: Machine Intelligence and Human Knowledge* (New York: Viking, 1984).

7. Stephen C. D. Bell, "Participatory Art and Computers: Identifying, Analysing and Composing the Characteristics of Participatory Art that use Computer Technology (PhD thesis, Loughborough University, 1992).

8. To find out more about what happened after 1979, see http://ncca.bournemouth.ac.uk/sbell.

24

Conceptual Art, Language, Diagrams, and Indexes

Graham Howard

Diagrams and indexes have, for a long time, been important ways in which we communicate with one another about the world. Diagrams allow key features of an idea to be depicted, and indexes allow ideas to be related to their worlds.

Using language and showing and pointing are fundamental strategies for communication. The quality of the communication is determined in part by the nature of the language used and the architecture of the diagrams and indexes. In oral cultures these underlie the rhetorics that develop, and when they are recorded, either as images on surfaces or as texts in books, they become artifacts of the culture, which can help structure the culture and others' understanding of that culture. When diagrams are images on surfaces, they may continue to exist as artifacts, but without an index to a known world and an associated narrative, they may become culturally and communicationally lost (Yates 1969). Later, when diagrams and indexes become embedded in print culture, new architectures for communication and distribution become available.

With the advent of computer technology, those who were thoughtful about language, diagrams, and indexes and struggling with data-intensive tasks started to develop tools and methods to enhance communication or the architecture of communication. Such experiments occurred in the later 1960s and early 1970s in the work of a number of people working in and around Coventry in the United Kingdom.

Conceptual Art

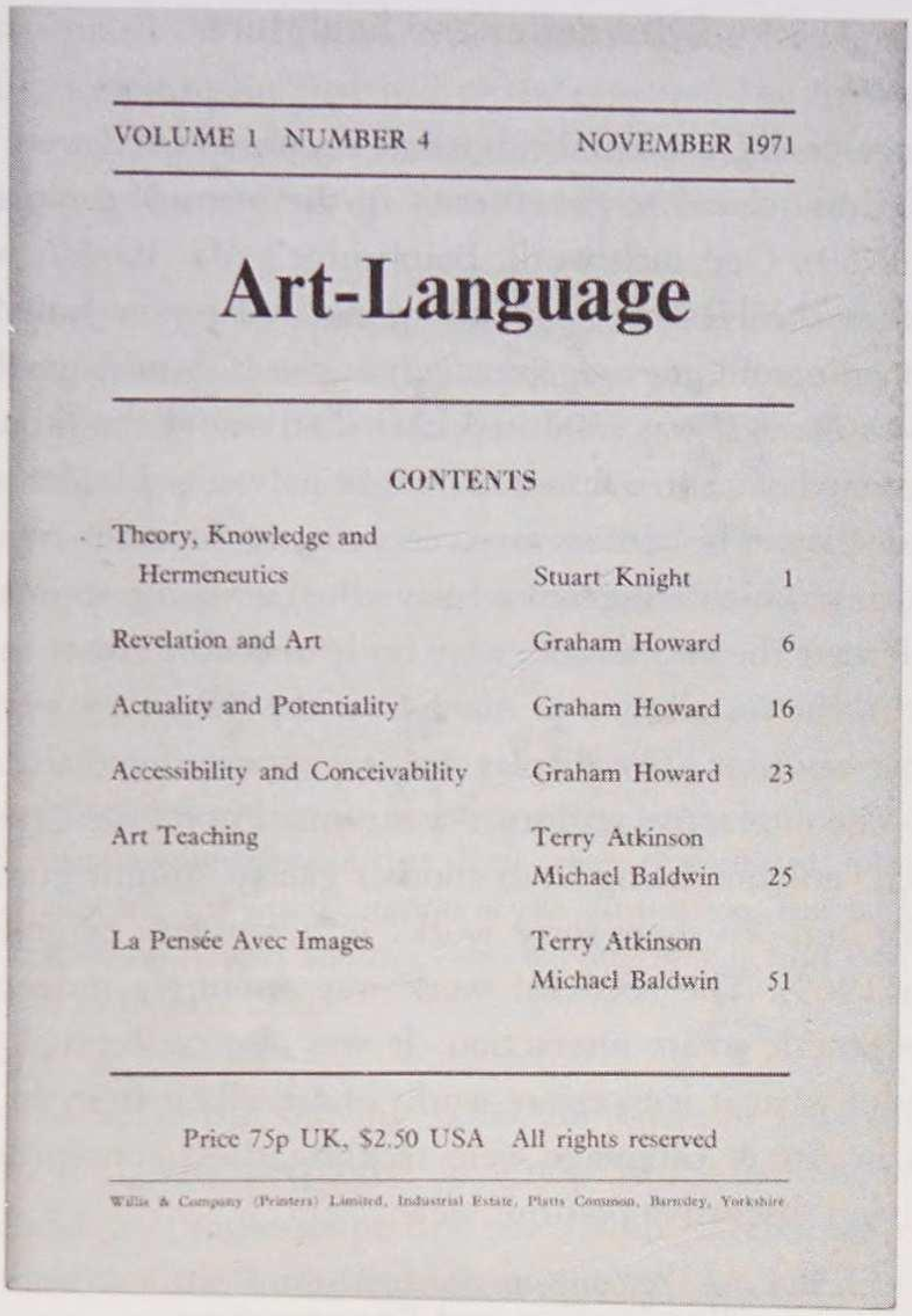
In the late 1960s the first flush of American post-war art had gone; skepticism and doubt were in the air. Pop art had poked fun at the Western establishment, its culture and its consumerism, while adopting its substance. Minimalism had countered by attempting to reduce art to formalism, evacuating it of meaning. The Vietnam war was raging. Art seemed to have reached the point of "anything goes."

Art had become removed from its original significance. No longer in the service of relatively clear ideologies, whether of religion, state or politics, art had lost its persuasive function to design in the age of the consumer. Art was left to faintly mirror the world of the market economy and, as it had always done, experiment with new materials.

Clement Greenberg had provided the theoretical underpinning for the production of Jackson Pollock and the abstract expressionists (Harrison and Wood 1992), as the world of high modernism slipped into history, there was a need for a new theoretical understanding to be developed. The historical instigator of much of the debate around "anything goes" was Marcel Duchamp with his creation of his readymades in the early part of the century. He had suggested that because he was an artist, and he had a record as a painter and more, then if he chose an object and said that it was art, then it was art. If this is a definition of art, then the issue of who is an artist comes to the fore. The search for new theoretical structures became a focal point for some of the artists involved in the decline of minimalism and in the emergence of conceptual art, which was predicated for the most part on the declarative Duchampian model.

Alongside this theoretical development, there was a burgeoning interest in new emergent technologies. While computers, both analogue and digital, had gradually been developing since the wartime work of Alan Turing and others at Bletchley Park, a new interest in the significance for the world of the creation of "thinking machines" started to surface. This was further informed by the work of John von Neumann (von Neumann and Morgenstern 1944), the initiator of game theory; Norbert Wiener (Wiener 1948, 1950, 1964), the coiner of the term *cybernetics* and instigator of the Wiener circle near MIT; and others who had worked upon notions of cybernetics and its ramifications. At the same time Marshall McLuhan (McLuhan 1962, 1964) had started to popularize and elaborate the theories of orality and literacy of Walter Ong (Ong 1982).

By 1968 this confluence of theoretical and cybernetic/technological approaches had led to new groupings. One emerged in Coventry, which was to become known as Art & Language. The group was a loose assemblage of people, initiated by Terry Atkinson, Dave Bainbridge, Michael Baldwin, and Harold Hurrell, and soon to include Joseph Kosuth, Mel Ramsden, Ian Burn, Graham Howard, Philip Pilkington, Dave Rushton, and Charles Harrison (Harrison 1991). Its intent was to understand and elucidate the theoretical and pragmatic structures that fundamentally articulate the production of art. It was to do this not as academic research but while being deeply involved in the process of producing art: an attempt to be both Plato and create the shadows on the wall of the cave. *Art-Language*, originally subtitled *The*



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Art-Language

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Figure 24.1 *Art-Language* journal table of contents, November 1971.

Journal of Conceptual Art, was first published by the group in May 1969 (Art & Language 2000) (figure 24.1).

Art & Language researched voraciously and widely with each of the members bringing their own approaches. Certain areas of focus emerged rapidly. This was in part due to the ways in which the group sustained itself through the interchange of documents and initially because most, though not all, of the members were either teachers or students at what was then Lanchester Polytechnic in Coventry (now Coventry University).

At first there were two clear strands of activity, which may be crudely characterized as follows:

- a sculptural approach, heavily influenced by cybernetics.
- a conceptual theoretical approach, strongly influenced by the philosophy of language and logics. (Atkinson 1969)

Cybernetics and Sculpture

In Art & Language both Dave Bainbridge and Harold Hurrell were involved in the development of ideas related to cybernetics in the form of sculpture (Bainbridge 1969; Baldwin 1969). One such work, Bainbridge's *M1 Mark I*, was exhibited at the *Vat 68* show at the Herbert Art Gallery in Coventry in June and July 1968, just before the opening of *Cybernetic Serendipity* at the ICA in August 1968 (Herbert Art Gallery 1968). *Mark II* was exhibited later that year at the Ikon Gallery in Birmingham. It consisted of a three-hundred-weight galvanized boiler with two sensors attached and a display. The sensors were capacitance switches set into galvanized metal sensing plates, which triggered a relay when a visitor approached them. For *Mark 1* at the Herbert the two sensors were built to enable either or both to trigger the display, but in the installation of *Mark II* at the Ikon they were set up so that both had to sense a visitor. The display was a galvanized metal disk that rotated when triggered. The interactive sculpture was posited upon the device of imagining the criteria which "an alien being from another galaxy" might guess were required to be fulfilled for him "to show some work" in a museum or gallery (Bainbridge 1969; Atkinson 1969). The resultant work was resolutely industrial in its form while clearly cybernetic in its interaction. It was also conceptually engaged with the problematics of what it is to create works of art, albeit from an empirical point of view. Others in Art & Language were tackling these conceptual issues from a more theoretical and discursive point of view.

Nomination and Conversation

If art objects can be simply chosen as such by an artist, then what is the limit to the types of object that could be considered for such singling out? And what might be their status? If the objects become more evanescent, how do you identify them? Once the notion of nomination has been transferred from the every day objects of the ready-mades to the less tangible "a column of air over Oxfordshire," then all of the classic philosophical questions of identity are raised.

Terry Atkinson and Michael Baldwin made a series of pieces of work that exemplified and triggered these questions: *The Air Conditioning Show* (1966), *The French Army* (1967), *Map not to indicate . . .* (1967). These were typically declarative pieces referring to "theoretical" objects and were self-contained, exhibitable letterpress prints or books. However, Baldwin's *Sunnybank* (1968) (Baldwin 1970), which used the notion of an as yet unbuilt wall as a motif for the discussion of identity, essentialism, and ontology (Quine 1953, 1960; Geach 1962, 1969), was more discursive and essayistic and more clearly part of a conversation.

In the late 1960s there was a considerable amount of activity in the world of the philosophy of language, derived especially from the work of Gottlob Frege (Frege

1959), Bertrand Russell (Whitehead 1910), and Ludwig Wittgenstein (Wittgenstein 1961, 1967, 1969) in the first half of the century. The mathematical foundations of Russell's work had also spawned significant developments in logic. This was not unconnected with the notions of control in cybernetics and emergent information theory.

While Wittgenstein's early work in the *Tractatus Logico-Philosophicus* (Wittgenstein 1961) had helped make possible logical positivism, it was his later work, especially *Philosophical Investigations* (Wittgenstein 1967), which was to have the greater influence on Art & Language. Wittgenstein put significant emphasis upon conversation or language in actual use. At one point in *Philosophical Investigations* he considers how a simple diagram might be used to mean different things by being talked about in different ways.

> You can imagine the illustration  appearing in a book, a text-book for instance. In the relevant text something different is in question every time: here a glass cube, there an inverted open box, there a wire frame of that shape, there three boards forming a solid angle. Each time the text supplies the interpretation of the illustration. But we can also *see* the illustration now as one thing now as another.—So we interpret it, and *see* it as we *interpret* it. (Wittgenstein 1967, 193e, part 2, xi)

This motif was taken as the starting point for Graham Howard's *Diagrammata* (1970) (Howard 1970), which explored the way in which the diagram could become part of the text and its simple shape did not dictate the references that could be made. As you construct the interpretation or theory, you can begin to see  as many different things and how such an image can start to become part of a linguistic statement. That is, the element gradually slips from being an extralinguistic element to becoming an intralinguistic element. This starts to indicate the robust ways in which image and text can be intertwined and the ways in which this is affected, by context, by the conversation.

If visual objects do not in themselves make statements about the world, let alone act like logical propositions and have truth values, it is to language and especially semantics that we have to turn to fully understand the context or embeddedness of an image (Howard 1971). How a conversation holds certain ideas and how those involved in the conversation can be seen as a group, which is at least partly defined by those ideas, was becoming a key focus for Art & Language.

Diagrams and Gazebos

While this enquiry into the relationships between language and art was occurring, others at Coventry were involved in the rethinking of technical drawing and especially the use of diagrams in light of advances in computer technologies. Unlike the questioning and antiauthoritarian attitudes of conceptual art, technical drawing was then, as it always had been, searching for the best way to represent a proposed design to an engineer, manufacturer, or user. The advent of computing and its ability to output line drawings from vector descriptions opened up new opportunities for the technical draughtsman. At the same time that Art & Language was active at Coventry, Clive Richards, whose background was in engineering and publishing, met with Ron Johnson, a computer scientist, and considered the way in which an ALGOL architectural drawing system might afford new possibilities for technical drawing and especially for the animation of such drawings.

Technical illustration had always been a labor-intensive job, and once a particular view of an object was chosen, only when the drawing was finished could it be seen whether it was the most appropriate view; by then it was too late to change it. Vector-based computer drawings had the potential to change that. The first experiments began at Coventry in 1969, and by 1970 Richards had produced the *Spinning Gazebo* animation and a spinning logo title sequence for a Lanchester Polytechnic promotional film (Richards and Johnson 1980).

At this time the look of computer-derived design was starting to become fashionable in the business and promotional world, with people producing hand-drawn typefaces that looked as if they had been created on a computer, and animations that looked as if 3D models had been built on a computer and then animated but that were actually derived from hand-retouched photographs of Airfix model airplane kits (Richards 2005).

To produce accurate models for animated sequences, the programming became very complex. In order to simplify this work Richards drew conceptual charts and diagrams of the routines before assembling the punch cards. These flowcharts were used to test out and debug sequences before they were actually entered into the machine, dummy data being processed through the flowchart to see if it would work. As time went on Richards became more interested in how these diagrams were representing and impacting upon the programming (Richards and Johnson 1980). This led him into his PhD work at the Royal College of Art in the Design Research Department, in which he considered the theoretical frameworks for diagramming. It became clear that how a diagram was to be used, what it was to be used for, and in what contexts, were the key questions for understanding the nature of the diagram.

Groups, Language, and Logics

When considering conversations in Art & Language and how they might identify the members of Art & Language, the parallels with the history of science and its methodologies were instructive. How do you decide what is science? What is a scientific theory? This debate was also current in the late 1960s. Karl Popper's *Logic of*

Scientific Discovery (Popper 1959) had laid out the case for all scientific theories being essentially falsifiable and, in 1968, Thomas Kuhn (Kuhn 1970) explored, through the concept of the paradigm, the interweaving of the social and the instrumental with the theoretical (Masterman 1970) in *The Structure of Scientific Revolutions*. A little later Paul Feyerabend (Feyerabend 1975) suggested an overtly anarchic methodology in *Against Method*. It started to become clear just how dependent upon the conversations of the scientific community science was for its validation. One's work is only understood as science if it is validated by the scientific community through, for example, publication in respected journals.

Kuhn pointed out that what was seen as science changed occasionally in a dramatic fashion when a paradigm shift occurred, when a theoretical change with its associated technologies supplanted a previously accepted theory with its associated technologies. So it appeared that with theoretical and technological change, science could change its ontologies. If this was the case, is it not possible that something similar was true with art? If so, paying attention to the conversation of artists who were considering such a change was the critical task at hand. How did such a group of people proceed or "go on"? As a group of practicing artists, Art & Language was well placed to consider this.

As a matter of practice, Art & Language regularly collected large bodies of written material created by the various members of the group and then at group meetings tape recordings were made of the discussion. This provided raw material for an analysis of our conversations—but results were naturally going to be qualitative rather than quantitative.

Much of the discussion was about how to make an analysis effective and was based upon the current work of logicians and philosophers considering language and its relationship with belief structures, knowledge structures, and structures of being—deontologies, epistemologies, and ontologies. From a logical point of view, those that were particularly useful in this context were many, but the work of W. V. Quine (Quine 1953, 1960, 1969), Peter Geach (Geach 1962, 1969), Arthur Prior (Prior 1962), Jaako Hintikka (Hintikka 1962, 1969), Saul Kripke (Kripke 1972), Yehoshua Bar-Hillel (Bar-Hillel 1971), and Richard Montague (Montague 1972) featured particularly strongly, providing a basis for the development of new approaches to our task. From the linguistic point of view, J. L. Austin (Austin 1962, 1970), Noam Chomsky (Chomsky 1957, 1965, 1966), Jerry Fodor (Fodor and Katz 1964), and Jerrold Katz (Katz and Postal 1964; Katz 1972) particularly influenced the way in which we thought about syntactic, semantic, and pragmatic structures, and the notions of competence and performance. At the time there was a significant debate raging between logicians looking at language and the philosophers of language, all of them edging toward notions of radical translation, machine translation, and computational linguistics.

Gradually what emerged was the possibility of developing a second order or meta-level of discussion about our conversation. Then it was a question of how to draw this material together and how to make it apparent and visible to others. The *Indexes* shown at *Documenta 5* and at the Hayward Gallery in 1972 were the first full manifestation of these endeavors. They have since become recognized as seminal works of conceptual art.

Art & Language *Indexes*

There were six *Indexes* produced by Art & Language in the early 1970s. *Index 01* was shown at *Documenta 5*, Kassel, *Museum of 100 Days*, in 1972, curated by Harold Szeeman. Joseph Kosuth had been invited to exhibit at Documenta but had been perplexed as to what to show. Michael Baldwin suggested an index and offered to design a logic for it. Joseph Kosuth agreed. The endeavor was to collect together some of the writings of Art & Language, mostly those published in *Art-Language* (Art & Language 2000) and some manuscripts, and to produce an index of them and also to map the interrelationships between them. The *Index* could have been put together as a book; indeed there had been thoughts in the group to do it this way. But it was decided that a more appropriate form was required for exhibition. In discussion Joseph Kosuth and Michael Baldwin agreed on the form for the *Index.* The collected papers were put in standard office filing cabinets and the room that contained them had the printouts of the cross references displayed around the walls (figure 24.2).

For the viewer this imposed a kind of discipline of looking at the references on the wall and then looking up the paper referred to, following its interrelationships back to the wall and then on the references onward in an iterative fashion. This created a kind of trajectory for the reader, taking you through the interrelationships in a specific direction. It allowed you to follow a thread, a kind of narrative. However, the relationships were not simple; they were characterized by "compatibility," "incompatibility," and "transformation." That is to say, some elements were seen as compatible, while others were incompatible; but others required a transformation of their conceptual space for there to be a relationship. The decisions about these relationships were complex, each one requiring the consideration of how two sections of text related to one another, and some of these texts were themselves considering these sorts of issues. Each decision had to be made and recorded to build the whole index and in many ways this typified the discursive nature of the internal work of Art & Language at the time, the continuous reconsideration of what was being said. The form of the *Documenta Index* was an endeavor to encapsulate this process in a way that would encourage the viewer to engage in a similar process. But the form had a further quality and has been referred to as "conceptual art's own of-

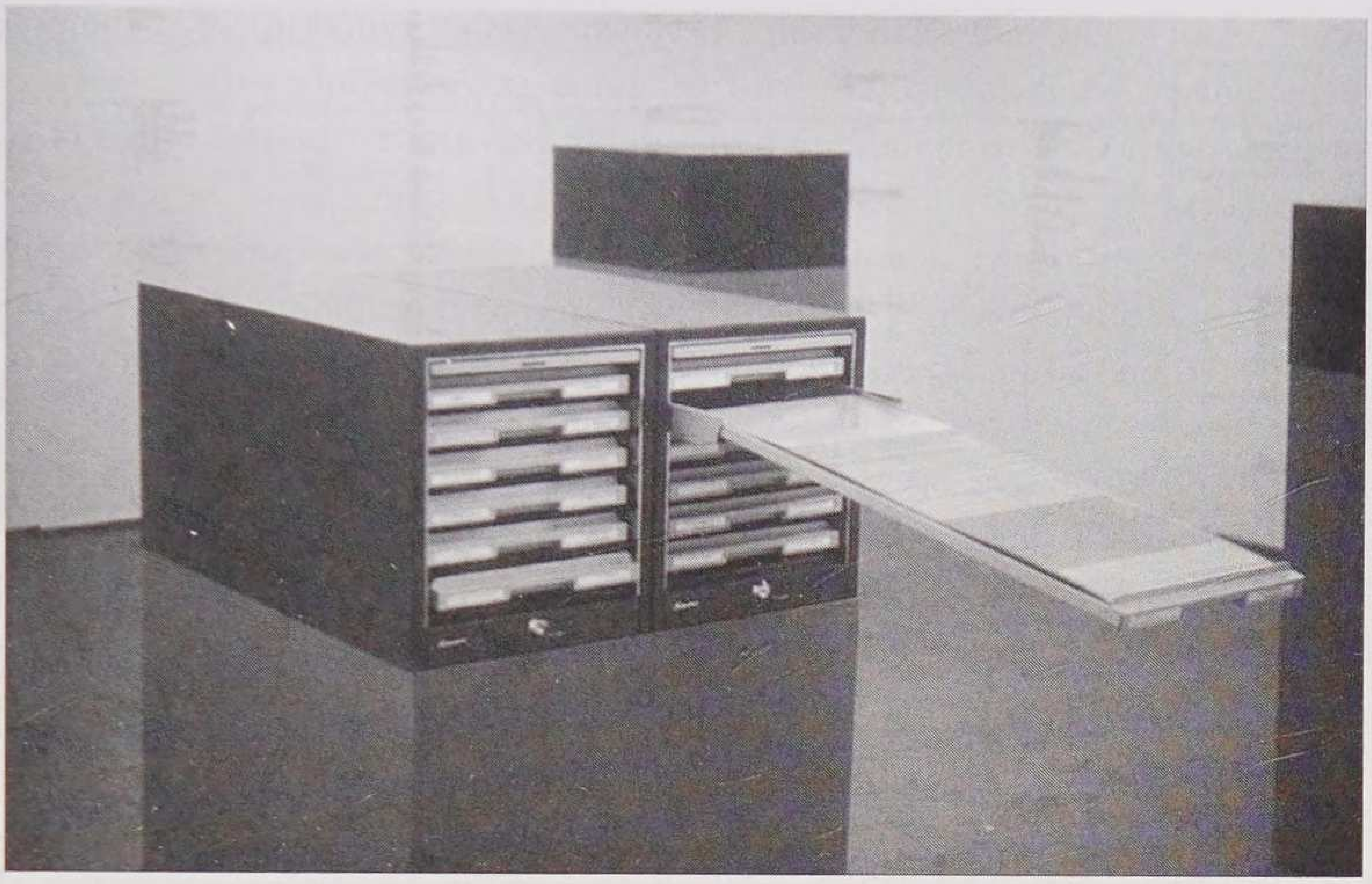


Figure 24.2 Art & Language *Index* installation, 1972.

fice" (Art & Language 2005b). It created a space that was separate from the normal administrative gallery space, and encouraged a different kind of activity. There was also a Map created out of one of the citations of the *Index*. It was printed on newsprint and given away at the exhibition. This map was a visualization of the interrelationships of one element of the index, so that the patterns of interrelationships could be viewed.

The *Index* was not rigorous but an attempt to understand the territory. It was also a way of trying to grasp the areas that implied transformation and so understand the way in which the group could "go on." The notion of "going on" was specific to the practice of Art & Language at the time and referred to the was in which we might proceed to do work but was related to the parallel questions of how, from the point of scientific methodology, scientists might proceed to do work in science. It was the first repository of Art & Language work and was represented as an index of itself.

Of course from today's perspective, the *Index* looks a lot like hypertext and its form a lot like a model of the Web. However, this structural similarity belies the richness and complexity of the links between sections of texts in the *Index*. These links were always qualified and evaluative, unlike the simple links of the current Web.

Index 02 was shown at the *New Art* show at the Hayward Gallery, London, from August 17 to September 24, 1972 (Atkinson and Baldwin 1972; Howard 1972). This was assembled at the time when *Documenta* was still running. This *Index* looked in more detail at the interrelationships between texts and superimposed the notion of transitivity. If A is compatible with B, and B is compatible with C, then A is compatible with C. This simplicity while doing damage to the real range of relationships between texts allowed for a formal logical structure to be established. This indexing process actually demonstrated the snapshot of a conversation quality of the index. The relationships deemed to be correct at the time show a specific view at a specific time and in a specific context, generated by the indexmakers.

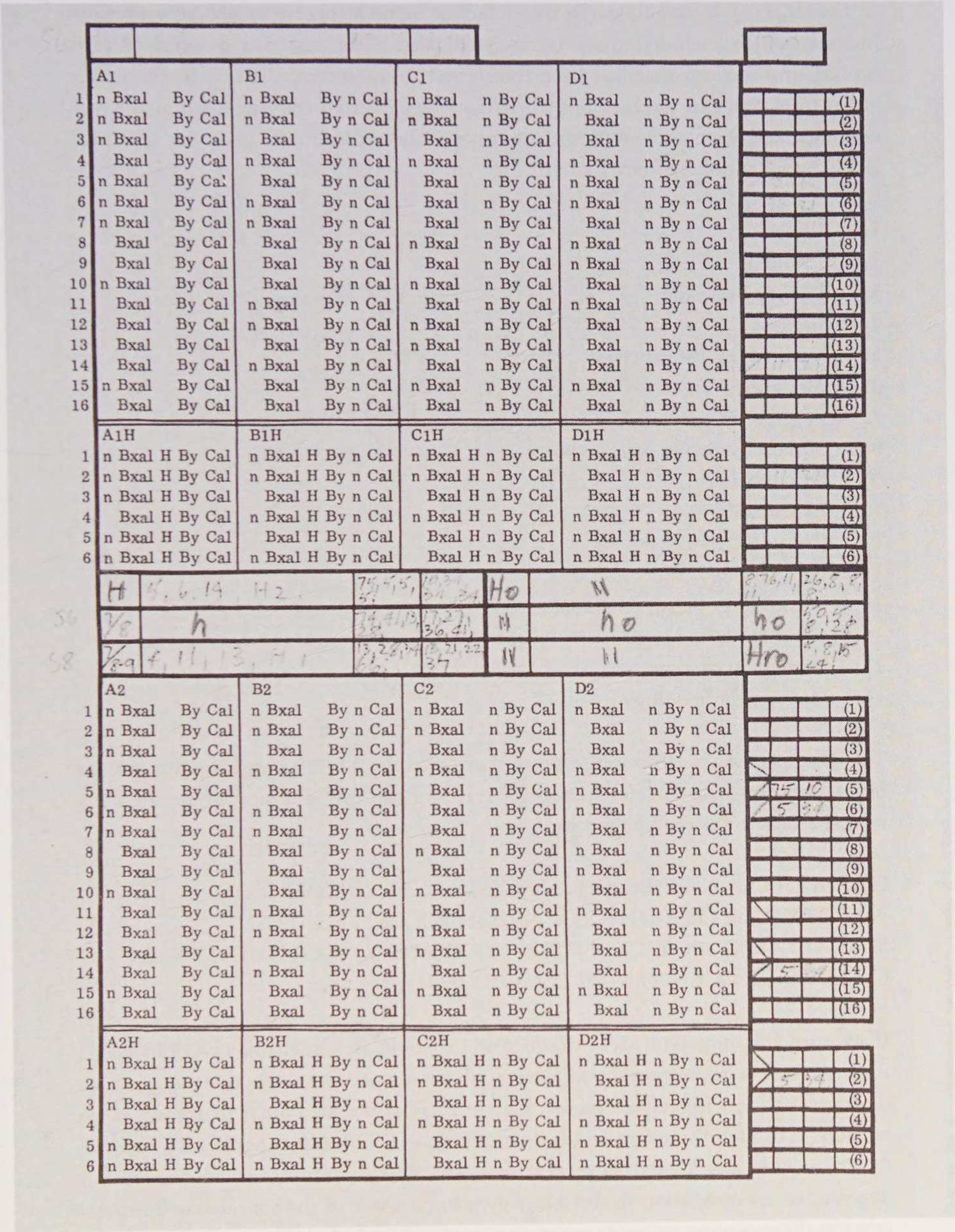
Index 03 was shown at the Lisson Gallery, London, as *Li Proceedings* in September and October 1973 (Harrison 1991, 99). It had three basic components: a body of microfilmed texts divided into sections each of which was ascribed a letter in an alphabetical sequence; a list of topics from 1 to 16; and a computer printout listing the kinds of relations that could hold between items under certain topics and assuming the operation of some form of interest. *Index 04*, shown at *Contemporanea* at the Parcheggio di Villa Borghese in Rome in October 1973 was similar in structure to *Index 03* (Harrison 1991, 79). This was also true of *Index 05*, which was shown at *Projekt '74, Kunst über Kunst*, Kunstverein, in Cologne in 1974. The work for *Projekt '74* was an *Index* that involved color. It was a handmade object that dismantled a short polemical text.

The most complex index, *Index 002 Bxal*, was shown at the John Weber Gallery in New York in December 1973 (figure 24.3).

Of these *Indexes* (*01* to *002 Bxal*), most are no longer able to be seen. *Index 01* has been exhibited many times since 1972 and has become a partial representative of the whole project, while many of the others have rarely been seen since their original appearance, and some have lost parts and would be hard to exhibit without reconstruction (Art & Language 2005b). However, some fragments, most notably the *Bxal* forms, which resulted in the *Index 002 Bxal*, have come to have a metonymic relationship with the most baroque of the *Indexes*. Examples of these forms have often been exhibited as representative of this work. However, this is particularly hard on the viewer without the help of one of us who was involved in the project. Even those close to the work find it difficult to understand what is going on.

Indexes and Computers

It had become clear to some that Art & Language was composed essentially of its conversation. If it was to proceed then conversation would set them terms in which it would understand itself. There was a need to understand what our methodology might be or how we were "going on" and to do this the *Indexes* had to be capable of evidencing the underlying nature of the activity. They had to become more sensitive, evaluative, and qualitative, and in consequence they grew more complex and in the end baroque (Art & Language 2005b).



	A1	B1	C1	D1				
1	n Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal				(1)
2	n Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal				(2)
3	n Bxal By Cal	Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal				(3)
4	Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal				(4)
5	n Bxal By Cal	Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal				(5)
6	n Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal				(6)
7	n Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal				(7)
8	Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal				(8)
9	Bxal By Cal	Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal				(9)
10	n Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal				(10)
11	Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal				(11)
12	Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal				(12)
13	Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal				(13)
14	Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal				(14)
15	n Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal				(15)
16	Bxal By Cal	Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal				(16)

	A1H	B1H	C1H	D1H				
1	n Bxal H By Cal	n Bxal H By n Cal	n Bxal H n By Cal	n Bxal H n By n Cal				(1)
2	n Bxal H By Cal	n Bxal H By n Cal	n Bxal H n By Cal	Bxal H n By n Cal				(2)
3	n Bxal H By Cal	Bxal H By n Cal	Bxal H n By Cal	Bxal H n By n Cal				(3)
4	Bxal H By Cal	n Bxal H By n Cal	n Bxal H n By Cal	n Bxal H n By n Cal				(4)
5	n Bxal H By Cal	Bxal H By n Cal	Bxal H n By Cal	n Bxal H n By n Cal				(5)
6	n Bxal H By Cal	n Bxal H By n Cal	Bxal H n By Cal	n Bxal H n By n Cal				(6)

	H	5, 6, 14, H 2,	75, 5, 5, 5!	10, 34, 34, 34	Ho	M	8, 76, 11, 11,	26, 5, 8, 8,
56	7/8	h	74, 41, 13, 38,	17, 27, 36, 41,	M	ho	ho	50, 6, 8, 28
58	7/8-9	4, 11, 13, H 1	13, 28, 34, 61, 66,	13, 21, 22, 34	N	H	Hro	4, 8, 15, 24!

	A2	B2	C2	D2				
1	n Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal				(1)
2	n Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal				(2)
3	n Bxal By Cal	Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal				(3)
4	Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal	\			(4)
5	n Bxal By Cal	Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal	/	75	10	(5)
6	n Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal	/	5	34	(6)
7	n Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal				(7)
8	Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal				(8)
9	Bxal By Cal	Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal				(9)
10	n Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal				(10)
11	Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	n Bxal n By n Cal	\			(11)
12	Bxal By Cal	n Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal				(12)
13	Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	Bxal n By n Cal	\			(13)
14	Bxal By Cal	n Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal	/	5	34	(14)
15	n Bxal By Cal	Bxal By n Cal	n Bxal n By Cal	n Bxal n By n Cal				(15)
16	Bxal By Cal	Bxal By n Cal	Bxal n By Cal	Bxal n By n Cal				(16)

	A2H	B2H	C2H	D2H				
1	n Bxal H By Cal	n Bxal H By n Cal	n Bxal H n By Cal	n Bxal H n By n Cal	\			(1)
2	n Bxal H By Cal	n Bxal H By n Cal	n Bxal H n By Cal	Bxal H n By n Cal	/	5	34	(2)
3	n Bxal H By Cal	Bxal H By n Cal	Bxal H n By Cal	Bxal H n By n Cal				(3)
4	Bxal H By Cal	n Bxal H By n Cal	n Bxal H n By Cal	n Bxal H n By n Cal				(4)
5	n Bxal H By Cal	Bxal H By n Cal	Bxal H n By Cal	n Bxal H n By n Cal				(5)
6	n Bxal H By Cal	n Bxal H By n Cal	Bxal H n By Cal	n Bxal H n By n Cal				(6)

Figure 24.3 *Bxal* form, *Index 002 Bxal*, 1973.

Indexes 03, *04*, and *05* were based on the same structure as the two previous indexes, which included three interrelated parts. The first was a series of texts broken into sections that had been transferred to microfilm; the text sections were either from previous publications in *Art-Language* or from the Art & Language proceedings, and were annotated with numbers. The second part was a list of topics, labeled with numbers from 1 to 16.

1. Idiolect
2. Ideology
3. Ideology revision
4. Interest
5. Technology/Bureaucracy
6. Modalities
7. Pragmatics
8. Situations . . . Guessing who . . .
9. Socialization
10. Indexicality
11. Going on grammar
12. AL Teleology
13. Community presuppositions
14. Good faith, bad faith
15. Darwinian descent
16. History/Methodology

The third part was a computer printout that listed the 64,000 possible permutations of relationships between the sections of text and the list of topics (figure 24.4). A typical relation was represented thus:

C(EX)AB1(X) & N(EX)BC2(X) & N(EX)CD3(X) & N(EX)EF5(X) & N(EX)FG6(X) & C(EX)GH7(X) & N(EX)HI8(X) & N(EX)IJ9(X) &N(EX)JK10(X) & C(EX)KL11(X) & N(EX)LM12(X) & C(EX)MN13(X) & C(EX)NO14(X) & C(EX)OP15(X) & C(EX)PQ16(X).

If we turn this into English it would read "there is an x such that you can go on from A to B with respect to Idiolect & there is not an x such that you can go on from B to C with respect to Ideology & there is not an x such that you can go on from C to D with respect to Ideology revision . . ." (Art & Language 1974).

The viewer was invited to pick a topic and thus its number and find where it appeared as an annotation in the texts; then to pick one of the concatenated expressions in the computer printout to use as a guide to track their interest in a section of

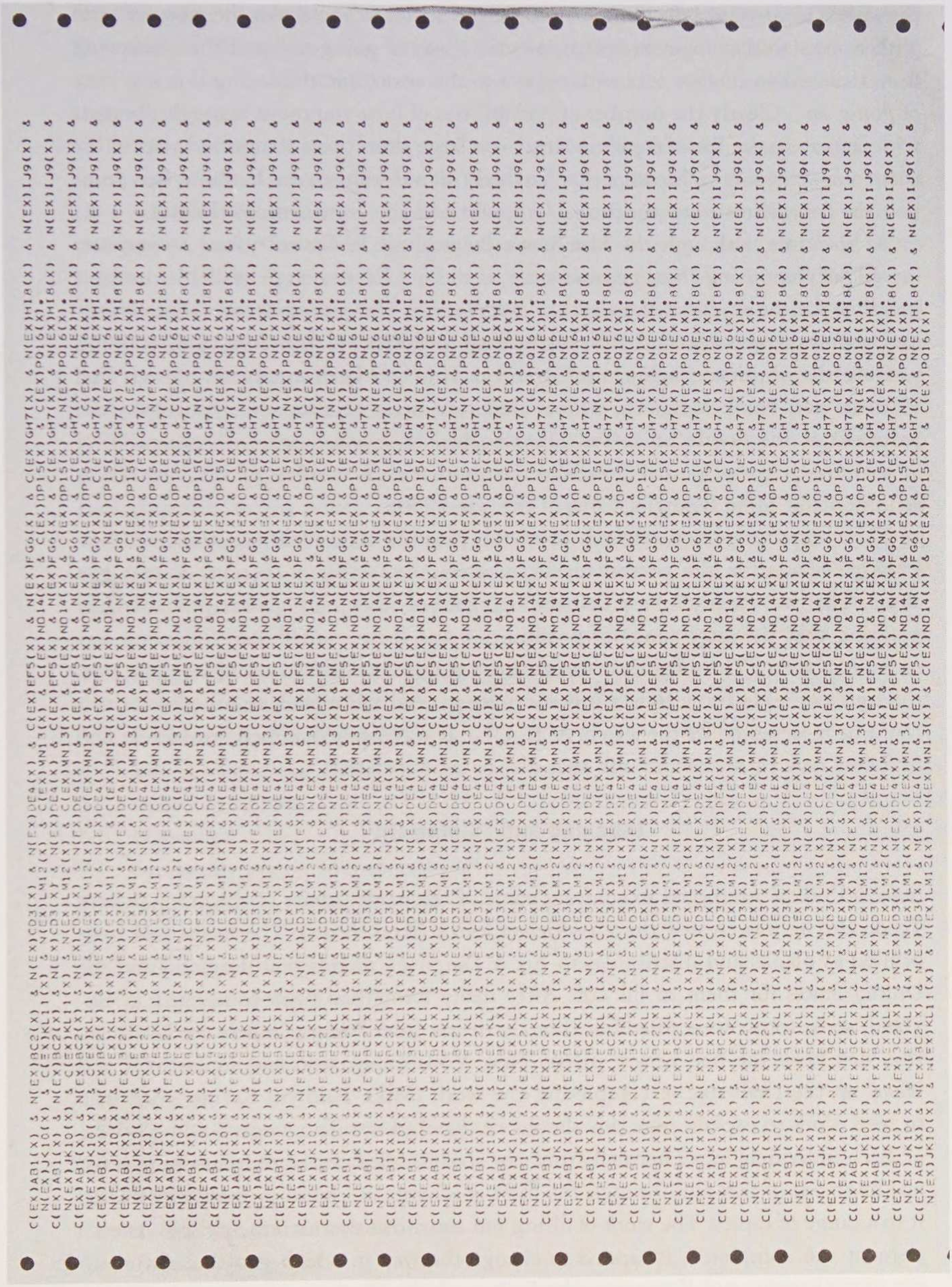


Figure 24.4 Computer printout, *Index 03*, 1973.

the text. This involved deciding on a topic and then reading across the range of texts with respect to that topic to find a potential "way of going on" and then following from that text to another text with respect to the next topic and seeing if it is a "way of going on." Clearly the number of possibilities of how you move through the texts with respect to the list of topics is large—so large that it was recognized that to list them out was going to be more than anybody would want to do. It was at this point that the parameters were put into a computer and the permutations derived.

At the time, although the Lanchester Polytechnic at Coventry had a computer capable of computing these permutations, it did not have enough available computing time for the software to be run to completion. The procedure was actually carried out over five weekends, running twenty-four hours a day, on a computer at a produce distribution company in Coventry. This had been arranged through Ted Harrison and Frank McGrath, who at that time were running the typography department at the Polytechnic. Ted Harrison had been associated with the printing of the *Art-Language* journal from the start and with a number of the joint Terry Atkinson and Mike Baldwin works of the late 1960s.

The computer printout listed all of the possible concatenations that could be envisaged based on the sixteen topics, whatever sequences of sections of text you chose. This was clearly a very demanding piece of work, any viewer probably just grasping that the large range of possibilities was there, rather than following any number of them. The software elaborated the range of possible trajectories of interest through a series of texts. In fact it was a quite generalized model, as any piece of text could be represented by the letters A, B, C . . . It was a way to closely read a text and to follow new pathways through that text or series of texts.

Indexing and "Going On"

Index 002 Bxal attempted to confront some of the inadequacies of the other *Indexes*. To do this it was created from a series of forms (Bxal forms). The forms had been printed as blanks and distributed to Art & Language members in England and the United States for them to fill out. After many forms had been completed in England, some forms were filled out directly in the John Weber Gallery by Ian Burn, who had been the one person in the New York group who had understood and taken up the challenge of completing the work (Mike Baldwin having gone over to New York to explain how this should be done) (Art & Language 2005b).

Each individual form, normally (but not always) filled out by one person, indexed one fragment of text and through the filter of a range of logical propositions related it to a range of topics. The work of filling out the forms was extremely hard. As each element was completed, it tended to change the way in which you thought about the next element, and if you went back through the elements after completing the form you were highly likely to now disagree with some of the choices you had made. Returning in this way was not advisable; it either prompted you to think you should start again with a new blank, or to continuously reconsider, which produced a sort of mental collapse.

Reading other people's forms was also hard work, although you could skim a form and guess at its overall view. If time was spent thinking through the choices they had made in detail, the complexities could easily overwhelm. But it is exactly this sort of work that made the process worthwhile. In some ways the *Bxal* forms became a tool for understanding what we were doing, how we were talking to one another. In other ways the *Bxal* forms turned on themselves and forced an indexing of themselves and their associates. You could not help considering the others you had completed when filling out a series of the forms. The process seemed to have built into it the potential to spiral out of control.

The process was not seen as an attempt to do a scientific, philosophical, or logical experiment, and it was not rigorous in any sort of way. It was, however, a device for exploring the way in which the members of Art & Language were "going on." It was idiosyncratic, and particular and clearly so. For example, the range of topics against which fragments were indexed was wide and varied, and it typified an aspect of our conversation. The list for Index *002 Bxal* was the following:

1 Languages are ever so interesting
2 Dead language
3 I wish we had a dictionary
4 I wish they had a dictionary
5 It is only syntax ...
6 Semantics ...
7 Synonymy is ever so important
8 'Significance' ... oh my word:
9 Paralysis
10 A history of language
11 Language of the 'group'
12 History of the 'group'
13 Epistemological conservation
14 Paradox
15 Contradiction ... for whom?
16 'Contextual logics' sounds funny
17 Assertion
18 Locale ... formalities of culture
19 Explicate-structure
20 Mesomerism ... hybridify

21 Learn . . .
22 Education . . . finger wagging
23 Condition(me/us)
24 . . . Associates . . . . . . association
25 Objects, figure and ground
26 Have an idea . . . a range of . . .
27 Prospect of ideology
28 Hope
29 Morality
30 Teleologically(incidentally(?))
31 Teleologically
32 Good faith . . . inculcate
33 Bad faith . . . execrate
34 Hermaneutic . . . consider
35 Christology
36 Depression
37 This belongs to something as portentous as the Geisteswissenschaft
38 History of B-ing xal
39 Guilt
40 Group . . . transmit penance
41 Possessive individualism
42 America vs England
43 England vs America
44 Selfishness in the group
45 Relations to the group historically
46 Ethical subjectivity
47 Map internally
48 Map for a specific context . . . externally
49 . . . The good . . . imperatives
50 Ideology as 'formal' culture
51 Culture relativity
52 History . . . consciousness
53 Concatenate . . . input from history
54 America! America!
55 God save the Queen
56 Guess if it seems to be English
57 Learn . . . (no drill)
58 Condition(them)
59 Against ideology . . . Inspector Descartes
60 Outside ideology . . . Inspector Descartes

61 Against thought . . . Inspector Descartes
62 Outside thought . . . Inspector Descartes
63 Dead parrot
64 Principle of existential indulgence (qualify?)
65 Fear
66 Xenophobia(ours)
67 Guess(in the limit)
68 Drill . . . learning as scandal
69 Skeptical . . .
70 Ironical . . .
71 Cynical . . .
72 Funny
73 Reinforce . . . anaphor
74 Subjective
75 Striving(me/us)
76 Negative . . .
77 Positive . . .
78 Absurd . . .
79 Decide . . .
80 God(talk)
81 Self(talk)
82 Resignation(sigh!)
83 Corruption
84 Homo religiosus
85 Chile
86 Modern history
87 Christian . . .
88 Comic . . .
89 Individualism is ever so impressive
90 Conscience requires . . .
91 Idiolect
92 Ideology sloganised

These were set against a further set of topics:

1 Grammar
2 Concatenation
3 Everyone's aspirations
4 Discourse
5 Ideology

6 Principle of existential tolerance
7 Historical input to group
8 Historical relativity
9 Linguistic relativity
10 Ethical relativity
11 Education
12 Indulgence
13 Immanence
14 Hypocrisy
15 Subjectivism
16 Disassembly

It can be seen that while the project was serious and immensely productive, it was also at times exhausting and funny. For those participating in the project the experience of the work on the early *Indexes* was formative and has continued to affect their ways of working. For the viewer, getting at the core of the work is very difficult, especially as the full Indexes are rarely shown and an immense amount of work is needed to get to the point of recognizing the semantic spaces that the *Indexes* adumbrate. There was an abortive attempt to create a lexicon or thesaurus to help map out territory that Art & Language inhabited, and the nature of the topic list above gives a clue as to why this project failed; there was far too much to adequately systematize.

The complexity of *Index 002 Bxal* and the fact that its baroque nature scared off most of the people who came across it, resulted in there being no attempt to transfer it and its potentialities onto a computer.

The logical statements used in the *Index* were of the form:

nBxal ByCal nBxal BynCalnBxal nByCalnBxal nBynCal

"Bxal" can be understood as "blurting x in Art & Language" and similarly "ByCal" as "blurting y goes on (concatenates) in Art & Language," "nBxal" is similarly "not blurting x in Art & Language" and "BynCal" is "blurting y does not go on(concatenate) in Art & Language."

These codes had been derived from modal logic and axiomatic set theory juxtaposed against ideas in syntactic and semantic theory, and were used as a way to envisage the nature of the relationship of the text fragment with the topic. It was an attempt to enable the figure to be seen against the ground.

One issue that arose throughout the early Art & Language *Indexes* was the level of granularity that was appropriate in the choosing of the textual elements to be analyzed. In *Index 001* and *002* the elements were typically large, either whole texts or sections, mostly in the form of paragraphs, of text. In *Index 002 Bxal* the elements were phrases, pairs of words, or single words. In other words, the level of detail being considered increased dramatically over the span of the *Indexes* and contributed significantly to the complexity of their creation and consumption.

In some ways the indexing project had come out of the shift from people in Art & Language contributing articles to the journal *Art-Language* to a situation where members of the group contributed to ongoing proceedings. These proceedings became the focus of the whole group in the United Kingdom at the monthly meetings that were then regularly taking place. The proceedings were voluminous, and each month each member brought photocopies of the texts that they had produced since the last meeting for all the other members. Just keeping up with what was going on in the group became difficult because of the volume and density of the texts produced; it became obvious that we were evaluating the texts with respect to how or how much they contributed to Art & Language "going on."

"Going on" in Art & Language was seen as a transformational and a learning experience. The *Indexes* helped to map such transformations against a broader set of ideologies or idiolects, providing a figure/ground description of learning or conceptual transformation. They characterized the way in which "going on" could occur in different possible worlds.

Unfinished Project

Looking back, two types of conceptual art may be distinguished, one based upon a theater of display, often as installation, and the other a discursive, critical, and essayistic endeavor. Art & Language's activities were firmly part of the latter approach and the *Indexes* remain the most lucid and complex examples of such work; they have resonance with and significance for much that is around us today.

The *Indexes* have been described as "hand driven software" (Art & Language 2005b), and this, to an extent, is true. Procedural and logical structures were used to enable both the creators and the viewer/reader to confront more of the complexities bound up with the understanding of natural language and how the development of that language both underpinned and defined a group who were concerned with how this process occurred. The last of the early *Indexes* (*002 Bxal*) demonstrated the complexities in the extreme and was both hard to work on and hard for the viewer/reader to understand. This still merits more unpacking and reflection. It brought to an end this style of index within Art & Language.

Conclusion

Since this work in diagramming and indexing happened in the late 1960s and early 1970s, diagrams and indexes have become more integrated into the development and use of information technology (Howard 1986, 1988, 1991).

Dynamic visualizations have started to enable us to see and browse complex networked datasets and indexes have become, amongst other things, fundamental to our ability to search the web and other remote datasets (Howard and Beecham 2004). Conversational analysis continues to be problematic but the pursuance of ideolects is now leading to work in social tagging, which integrated with our deepening understanding of well structured thesauri and their cross mapping, is reaching toward a more intricate and accessible understanding of how we talk about things and categorize our knowledge. As this happens some of those early experiments continue to resonate and suggest underlying issues and complexities. in the end we are only talking, showing and pointing, but the context has moved from a particular place and a particular time to multiple locations and across time, from one to many to many to many. This changed context both enriches and complicates our communications.

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25

Constructive Computation

Ernest Edmonds

For me, art and computing first developed on twin paths. During the 1960s, I was primarily concerned with abstraction. I painted reliefs that drew upon images from landscape, the nude, and flowers. The works were basically figurative but actually consisted of minimal, often very simple, abstract shapes. Toward the end of the decade my interest in the constructivist[1] tradition crystallized into purely abstract concerns, but I decided to complete my previous phase with a multipart work that brought together most of the successful forms that I had been using. The work was to have twenty component parts, each one-foot square and each dealing with one of the forms in question. It was in making this piece, later named *Nineteen*,[2] that I discovered my first use for a computer in art. My discovery of the computer itself happened on an unconnected path.

Although, even at school, my main interest was in making art, I chose mathematics at university. It seemed an easy subject to me and left time for my art. According to friends, already in the art system, art school did not offer much.[3] My degree experience was valuable in various ways within and beyond mathematics. I was a student at Leicester University, and I took philosophy as a subsidiary subject. I was taught by Bob McGowan, a lively lecturer who was very much part of the student and local life. For example, he introduced me to Tom Hudson[4] and his prediploma students at the local art college.[5] Hudson's approach to artmaking did not, at that time, involve computers any more than I was using them, but it set a direction that was very compatible with their use in art. Indeed his *Times* obituary said of his later thinking, "He began to emphasise not only the importance of the developing process, but also the creative connections between art, science and technology. This too was an attitude with its roots in the Bauhaus, but Hudson now set it in the context of the microprocessor and the development of new ways of shaping and using natural and manmade materials."[6] In retrospect, this connection may have influenced me more than I thought at the time.

In 1967, I took a job as a research assistant in mathematics at the Leicester College of Technology[7] and, at the same time, started a PhD in mathematical logic[8] with Alan Rose at Nottingham University. Neither had much at all to do with computers or art but the work was not demanding of time and I was left with enough time to paint. The college had recently acquired a Honeywell H-200 computer and it seemed quite intriguing to me. I spent some time teaching myself programming and trying it out, mostly for fun. My interest in logic extended to the philosophical foundations of mathematics and the nature of computation. This new opportunity to explore computation performed by a machine was therefore quite interesting. I wondered, for example, how defining a procedure and following it compared to defining one for a computer to follow. Should we trust the result that a computer obtained more or less than one that we produced manually? One thing that soon became clear was that we discovered slips in the definition of a procedure when we gave one to a computer. It was definitely a zero tolerance machine, but that was quite appealing in its way.

A number of things happened during 1968 that really brought computers more centrally into my life. First of all, I was at home that summer when the head of my department knocked on the door quite unexpectedly. He put a simple proposition to me. My research job was both temporary and annually up for review but, on the other hand, a permanent lectureship was available and I would have a high chance of getting it should I apply.[9] The lectureship, by the way, was in computing. Was I interested? I gave the required answer and soon became a lecturer in this new subject in which I was no more qualified than most of my colleagues. So much for career planning. Anyway, I started this new academic life and began to explore computing more seriously.

Also in 1968, I was working on some problems in logic that involved finding sets of numbers that displayed, or revealed, certain conditions. The problem was to show that various axioms were independent by demonstrating that values existed that showed no one of them could be derived from the others. The details of what this means do not matter here, but suffice to say that I realized I could write a computer program that would search for such numbers, and I did so. This resulted in the publication of my first research paper, which was in the *Journal of Symbolic Logic*.[10] An interesting thing to notice is that the paper makes no mention of computers or computer programs. The program enabled me to find the required set of numbers. All I had to do in the proof was to produce them. While the computer was used to help me solve a problem in a noncomputing domain, the computer itself was not part of the solution. This is exactly how it was to turn out in my first use of the computer in art.

I had in mind that the twenty pieces that made up *Nineteen* should be arranged in a 4 × 5 matrix, but I had not planned exactly how they would be placed in that matrix. As I started to try out different options, I kept rejecting them on the grounds that certain related pieces turned up close together or in a line or in some other pattern that dominated the work. I was after a more homogeneous result. It was quite a problem. Or it was a problem until I realized that it was very similar to the logic problem described above that I solved by writing a computer program. So I wrote a program to search for a layout that satisfied a set of conditions that I was able to specify, such as that two given pieces should not be placed on the same row. I had found the programming language FORTRAN and it was quite easy to write a "brute force"[11] search once I had formulated the problem clearly. The problem was obtaining permission to run such a demanding program on the one computer, the H-200, available to the whole institution. In the end I managed to negotiate dedicated access to the machine for a three-hour slot. I had no idea whether this was long enough, so I had the program print out its attempts, even when rejected, provided that they came somewhere near a solution. It was just as well that I did that because no answer turned up during the three hours. However, what I did notice is that by simply swapping three items I could turn a near solution into just what I needed. A computer program, plus a little extra thought, sorted it out and I was able to arrange the twenty pieces to my satisfaction. As with the logic, of course, the computer could be dispensed with once the problem was solved and the work itself neither used nor referred to a computer program at all. However, I could not have made *Nineteen* without the use of the computer (figure 25.1).

The construction of rules to govern special relationships that I began with this work have, as it turned out, played a part in most of my art practice to this date.[12] I was forced to make explicit my intentions for *Nineteen* in order to write the program that helped me determine its arrangement. This enabled me to understand just how important such rules were in my work. It drew my attention to the Systems artists,[13] for example, and to the many uses of rule systems in music. I started a long period of painting and drawing where, although I mostly did not use computers, I used formal geometric systems as the basis of each work. The rule systems that I developed can be found in my current artworks and were particularly important in the generative computer-based works that I began to make in the early 1980s.

Nineteen was significant in another way in relation to my interest in computers. As I fabricated the pieces I decided that in order get the finish I needed it would be best to spray them rather than paint them with a brush. Unfortunately I knew nothing about how to do this, so I wandered over to the Art College to see if I could get help. I found that the Fine Art Department had a spray booth and I tracked down the lecturer in charge of it: His name was Stroud Cornock. As well as helping me with spray painting it turned out that Cornock, a sculptor, had recently developed

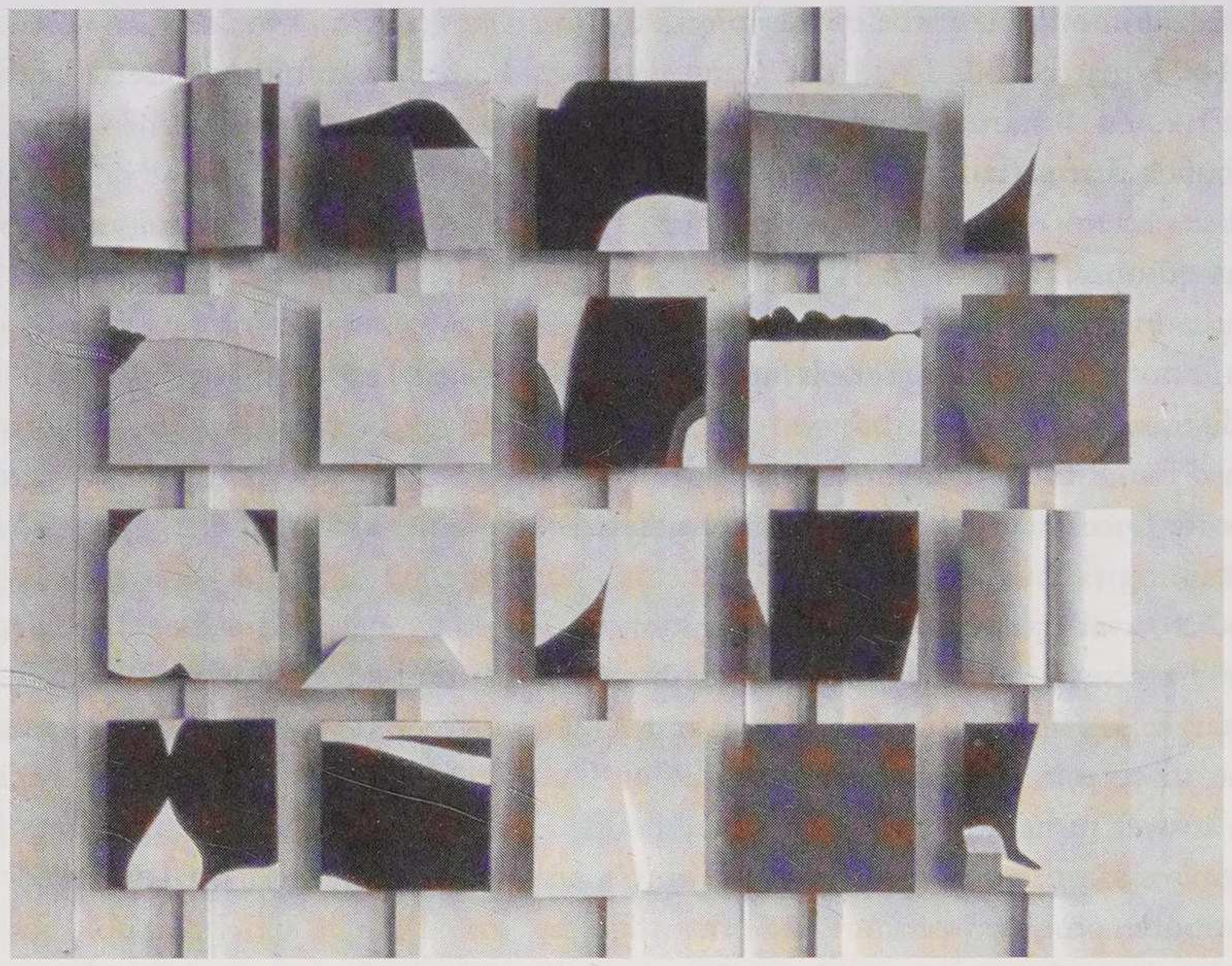

Figure 25.1 Ernest Edmonds, *Nineteen*, 1970.

an interest in systems theory and was deeply concerned with participation and interaction in art. He had been influenced by Roy Ascott, whom I came to know later. Stroud and I struck up a strong relationship and started to work together on interactive art projects that made use of computer technology.

The other event of 1968 was one that had an impact on everyone who was interested in art and technology. It was, of course, the summer show at the ICA in London, *Cybernetic Serendipity*. The many positive factors of this important show have been discussed widely. For me, what was important was the excitement, exploration, and innovation that the multidisciplinary event demonstrated. It showed living art being generated by close interchange with science and technology. It showed a healthy lack of concern for what exactly should be seen to be art, science, or technology. It demonstrated how cross-disciplinary stimulation could encourage exciting innovation. It also demonstrated that it was easy for computers to be used for purely decorative purposes. However, the range of work in the exhibition, as can be seen in the closely related issue of *Studio International*,[14] was amazing, from creative science that had great art potential (Chris Evans's work, for example) to art that was not owned as such by the authors (Frieder Nake's work, for example).

For me, 1969 was a very busy year in relating technology to art. It was the year in which my interest in process and participation was formed. This began as part of my lecturing duties. I supervised some final-year computer science degree projects in which I tried to have the students make software that would be valuable to staff teaching creative graphic design. In those days, computing wisdom dictated that before any code was written the requirements for the program should be set, so that the code could be constructed against a fixed and reliable specification. This proved quite impossible because whenever the designers saw a partly constructed system they changed their minds about the requirements. Were these designers uncooperative users or was there another problem? My conclusion, which seems obvious today, was that the method was at fault and that an iterative design method, in which requirements evolved, was needed. I later gave a talk to the recently formed Computer Arts Society[15] (CAS) in which I argued not only that an adaptive design method was required but also that the process itself could be the basis of a new art form. To be honest, I did not know quite what this implied, but I said that the processes of interaction and evolution of computer-based systems could be viewed as an art form to be contrasted with the products of such processes. Later I tried to publish part of this talk in the journal *Computer Aided Design*. It was rejected on the grounds that "if you do not know what you are going to do before you start you should not start." Fortunately, I eventually found a more sympathetic audience in the area of general systems theory.[16]

The Computer Arts Society was a crucial meeting ground for all of us interested in this new emerging field. In particular, I came to know George Mallen and John Lansdown with both of whom I had many fruitful discussions over the years. In many of the discussions with Lansdown, I think we both noticed a tension between our different perspectives. Strangely, although I held a job in computer science and Lansdown held one in design, I always felt that he was more interested in the potential of technology and less in the fine art context than I was. Neither perspective is better than the other, of course, and both enabled the growth of young artists in the area.

In 1969, planning and preparation began for the exhibition and conference *Computer Graphics '70*, to be held at Brunel University in the United Kingdom. The Computer Arts Society had secured a presence in both aspects of this event (more than a decade in advance of the similar initiative of the Association for Computing Machinery's Special Interest Group on Graphics, or ACM SIGGRAPH), so it was quite important. Cornock and I worked together both on a paper and an exhibit. Independently I prepared a proposal for the key CAS exhibit.

The paper that Cornock and I produced, and later presented at the conference, began by asserting that computers were particularly important in their potential impact on creativity, and went on to propose that *interaction* was a key attribute of what they enabled, that would bring with it significant opportunities for participation and for re-designating the role of the artist. The artist could potentially enable or frame creative behavior rather than only produce objects to be consumed.

The paper was later published in the journal *Leonardo*.[17] Although I would express some of what the paper says in different language today, it nevertheless still reads as a reasonable manifesto for much of what I have done since. Cornock took some of the ideas further soon afterward but then moved to more social concerns, these being, in my view, quite compatible with the 1970 paper.

My paper with Cornock included a discussion of **DATAPACK*, an interactive artwork that we developed in 1969–1970 and showed at *Computer Graphics '70*.[18] My department at Leicester Polytechnic had just obtained a Honeywell 516 computer. It had a teletype and a drum plotter, among other peripherals, and, most innovative of all, could be used directly without having to submit punched cards to data processing personnel who had privileged and exclusive computer access. I set to work using FORTRAN and a set of graphical subroutines to build a system that Stroud and I designed together. The teletype was used to enable the user (members of our active audience) to have a pseudo-English conversation with the machine. As a result of the conversation various decisions were made internally and a virtual volume of space around the Millbank Tower, on the Thames, was identified and "allocated" to this participant. I programmed the machine to print two elevations of the Tower with the virtual space identified in red. This drawing, together with other documentation and records of the session, was included in a pack that was given to the participant. Primitive as it might now seem technically, **DATAPACK* was one of the early examples of an interactive computer-based artwork (figure 25.2).

At the same time as working with Cornock in 1969, I was developing another concept for interactive art and I made a proposal to the Computer Arts Society for its central art exhibit at the *Computer Graphics '70* exhibition. My proposal was not successful,[19] but I continued to develop it over the next few years. My idea was to create a network between distributed participants and to have their interactions with one another, through the system, form the artwork. Of course, this was before Internet art, the World Wide Web, and even before the Internet itself. (In fact the first node of ARPANET was brought into service in 1969.[20]) My proposal and the works that were later realized have been described in a number of papers.[21]

In 1970, Cornock initiated the first *Invention of Problems* event at Leicester Polytechnic. I participated in this in various ways, including showing *Nineteen* for the first time and showing a nontechnical interactive work. I wanted to explore ways in which my current interests in interaction could be realized with maximum simplicity. I hit upon the idea of a re-arrangeable jigsaw. There were to be many different solutions rather than the one that is normal in a jigsaw. The participant could make very many quite varied arrangements in each of which all of the pieces fitted

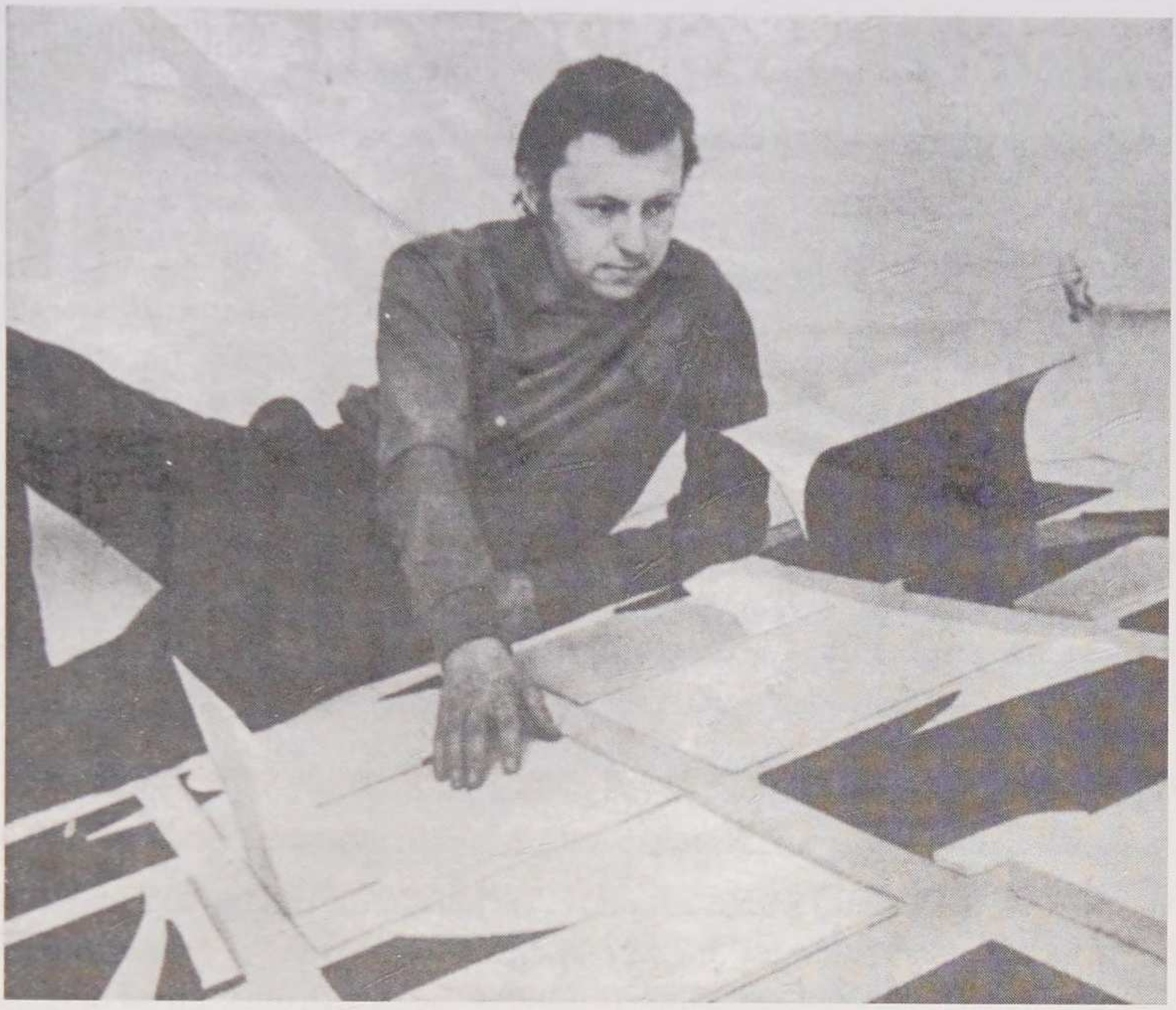

Figure 25.2 Ernest Edmonds operating **DATAPACK*, an interactive artwork by Stroud Cornock and Edmonds, 1970.

together. It was designed in such a way that, while very many combinations of pieces could be chosen, their physical shapes restricted the choices to ones in which certain arrangement criteria were met. It was a simple piece, just sixteen colored pieces of wood, but it proved complex enough for most people. So I became convinced that complexity was an issue of concern in interactive systems. If the system is too complex it becomes unmanageable and apparently random to the participant. In my view, randomness and specifically the pseudo-randomness used in computing is inherently uninteresting. My goal was to make work that is complex enough to be engaging but not so complex as to seem random. Complexity can occur in very many ways, of course, and may not occur on the surface at all. So when, in the 1971 event *Invention of Problems II*, I showed a version of my *Computer Graphics '70* proposal, I simplified it. I called the piece *Communications Game* (figure 25.3).

Communications Game had six stations and there were three networks of three units. Screens kept participants from seeing the units in other stations. Each participant had before them one or two units. The illumination of a light on one of the units was controlled by the other participants by opening or closing their switches

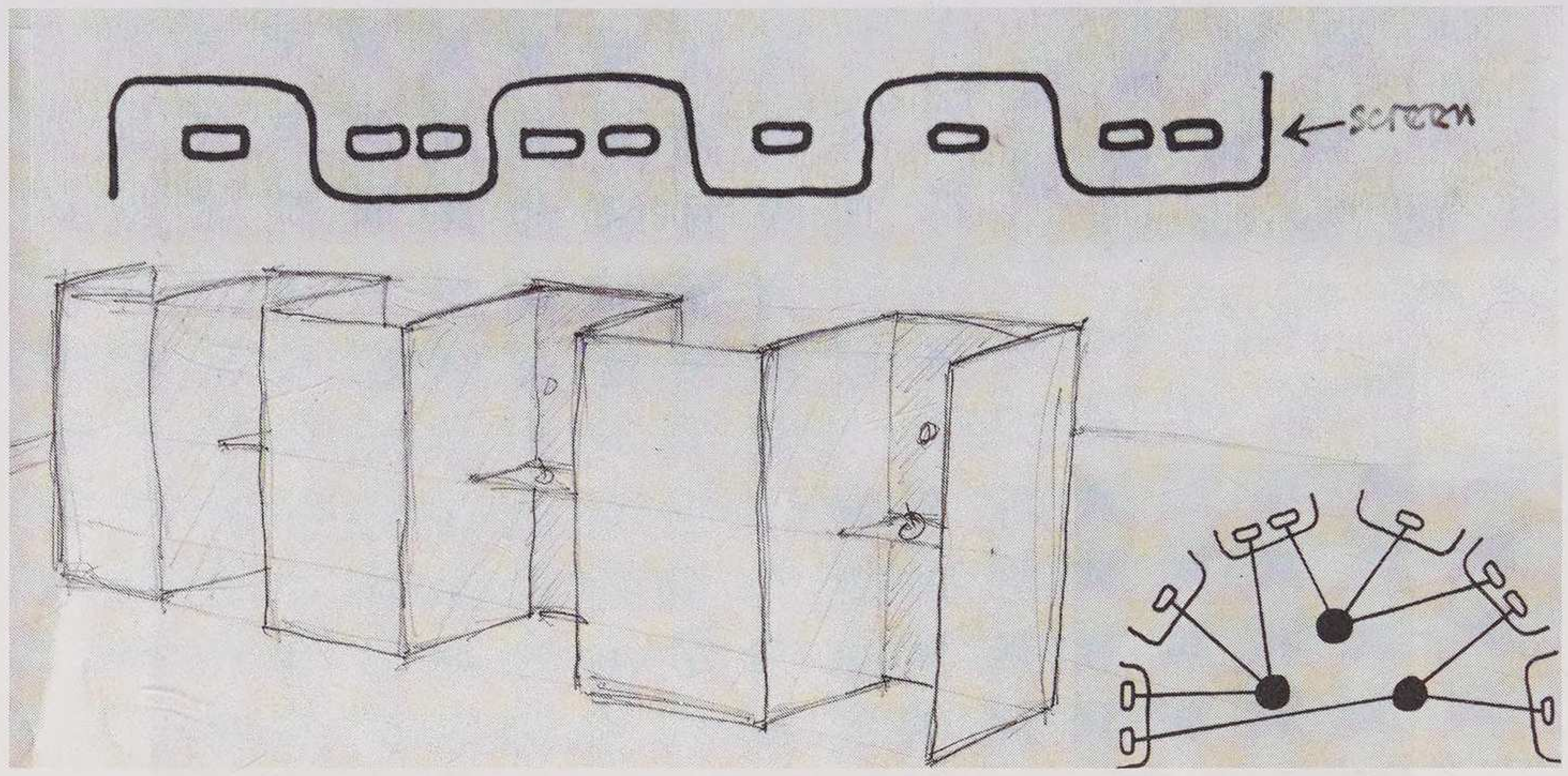

Figure 25.3 Sketches of *Communications Game*, including a plan view, by Ernest Edmonds, 1971.

in the network. Experience with *Communications Game* in the exhibition showed that, when there are more than three or four participants and several networks, the multiplicity of signals is beyond the comprehension of the participants. I then developed a further simplification of the game with only one network and three participants, called *Communications Game 2*. Stephen Willats was another participant in *Invention of Problems II* and, although he did not use computers then or for many years to come, his work was deeply concerned with participation and he was actively building interactive art machines: I found my times with him quite influential conceptually. In 1972, Willats created the *Cognition and Control* exhibition at the Midland Group Gallery in Nottingham. I showed *Communications Game 2* in this exhibition and wrote about it in Willats's magazine *Control*.[22]

At this point my art and my computing research (which was what my computer involvement had started to become) began to move onto twin paths again. My art was firmly in the constructivist tradition and drew from the work of Systems artists, but I was not satisfied with much that I could make at the time using computers. I was as interested as ever but I saw more potential than practical opportunity. At the same time I decided to concentrate my computing work on human-computer interaction issues relating to creative users such as artists and designers. I started publishing papers about, for example, supporting creative designers.[23] Actually, I wanted to research the implications of computers for art and the implications of art practice[24] for computer research. A significant background interest was general systems theory, which influenced, for example, my attitude toward interactive systems and robotics, and in how interactive art systems might be built.[25]

In 1974, I was allocated a PhD studentship (from the Science Research Council, as it was then called) to help support my computing research. I decided to see if I could use it to accelerate the developments in computing and art. This was pretty tricky in view of the perceived subject boundaries at that time, but a couple of phone conversations with helpful officials at the SRC enabled me to find a way forward. With SRC support, Leicester Polytechnic would not object. The next thing was to search for an artist who could, and would, take on this studentship and follow a PhD program that advanced computing and art in some way. It was Cornock who told me of an excellent ex-fine art student of his department who was currently studying in Malcolm Hughes's postgraduate course at the Slade School of Art. I invited Stephen Scrivener up to Leicester to talk about this possibility and, with his characteristic careful but determined approach, he agreed and took the studentship.

Scrivener's PhD[26] was a practice-based study of computing and art. It is interesting to note that Andrew Stonyer (also of Leicester Polytechnic) was the first to obtain such a PhD in the United Kingdom,[27] but Scrivener was the first to start.[28] So Scrivener and I, in our roles of student and supervisor, took some chances initiating this innovative process of studying a practice-based PhD in the intersection of art and computing. Hughes agreed to act as Scrivener's second supervisor and, as a result, I began to be a frequent visitor to that important group at the Slade. Chris Briscoe, in particular, helped many students work with computers and the slow but high quality graph plotter that they had. The Slade was not able to give PhDs so the relationship between Hughes's group and our work in Leicester was quite productive from both points of view. Hughes himself was, of course, an extremely valuable thinker and teacher in the area even though his own art practice made very little use of computers. So he was quite influential, although I suspected that not all of the Slade students saw the extent of that influence. As a teacher he could have a light touch, leaving it to Briscoe and others to really make sure that things happened.

I was in frequent discussion with Hughes, his students, and many of the other people who related to the Slade. As I will mention later, a number of my students, after Scrivener, came from that course. I also first met Paul Brown there and, through that group, I had meetings with Edward Ihnatowicz,[29] with whom I developed a strong relationship. He and I were both very interested in artificial intelligence and, in particular, robotics. The thing that we had most in common, in that area, was a belief that action and perception, as well as cognition, had to play an integral role in any realistic simulation of intelligent behavior. For Ihnatowicz this point was central to his art.

I was quite active in the Society for the Study of Artificial Intelligence and the Simulation of Behavior (AISB)[30] and, in April 1976, I organized an AISB meeting called Human and Robot Behaviour at Leicester Polytechnic. Among the invited talks I included one by Ihnatowicz in which he put forward his argument about the integral significance of the body in intelligent behavior. It was quite far reaching in intent: "We are interested not so much in machines that can learn but in machines that can teach, or at least in machines that can teach, having learnt." In this presentation and in many conversations, Ihnatowicz was sowing the seeds of many future developments in the interactive arts. This presentation in Leicester, including a written paper in the conference preprints,[31] was his most public statement at that time.

I had organized the AISB meeting because I was intrigued by the potential of artificial intelligence and cognitive science for art practice, and decided to bring a collection of experts from these different fields together for a couple of days of intense discussion. Participants included, for example, Edward Ihnatowicz, Brian Reffin Smith, John Lifton, Stroud Cornock, and Stephen Scrivener. From the AI and robotics side, we had, for example, Pat Ambler, Margaret Boden, Max Bramer, Bernard Meltzer, Robin Popplestone, and John F. Young. Bob Hopgood from the Atlas Laboratory was also there, and Stuart Sutherland chaired the final discussion, which brought all of the areas of interest, from art to AI, together.[32] It was an intense two days with many opportunities for cross-disciplinary exchanges.

Scrivener's PhD work was being done at a time when computer graphics was about to move from vectors to pixels, and he was very sharp in grasping the implications of this. The key point was that we no longer had to work with abstract descriptions of the image on the screen (lists of vectors, for example) but could work with the image itself.[33] In some respects this was an advance in relation to creative process rather than art product.[34] It meant that we had the possibility of manipulating images with the kind of flexibility that we used when we thought about them.[35] While it might seem obvious to an artist that as we draw, for example, we look at the resulting marks, see new things in them, and creatively develop an idea through a cycle of action, perception, and thinking, computer graphic systems had been more or less entirely developed for the generation of images. Image analysis was seen as another discipline altogether. Raster graphics offered a way to overcome this problem, but the initial raster graphics systems that were on offer in the marketplace did not allow programs to readily interrogate the image store. We could write pixels but not read them for image analysis. In my group, we built a system that had "read and write" functions available. Lyndon Thomas was the openminded engineer who designed and built it. Funding the work was another issue. Innovation of this kind is always problematic in that respect. However, at the AISB meeting I had an interesting discussion with Alan Bond who explained that Science Research Council studentships had associated with them modest payments to the institution to help support the research. He was using such money to develop innovative robot technologies. Naturally, Leicester Polytechnic had not told me about this money, but once I knew about it I was able to argue that I should control its expenditure when it related to my students. In that way, the Leicester raster graphics hardware came to be built. It was an important facility in Scrivener's PhD research.

By the time Scrivener's studentship came to an end in 1977, I was head of computer studies at Leicester Polytechnic and had enough influence to persuade the authorities that we should create a new post for him. That was the start of his distinguished career as an academic. I am sure that I did not explicitly propose that computer studies employ an artist, but at that time graphical display was of growing importance and, like many others, we were able to follow our art bent under the guise of researching computer graphics.

The constructivist artist Susan Tebby was at this time a lecturer in sculpture at Leicester Polytechnic, and in 1976 I agreed to supervise her practice-based PhD.[36] Again, Hughes took the role of second supervisor. Although throughout her PhD Tebby made no use of computers, her art was entirely concerned with systems and many of the issues were close to those being considered in the computing and art field. Her work applied and developed various mathematical concepts in relation to her art. Computationally, the work was very close to a computer-based PhD.

Tebby introduced me to Kenneth Martin and, at Hughes's suggestion, we chose Michael Kidner as external examiner. Both these artists might well have used a computer but did not—largely, I think, because it came too late for them. Both, however, were able to be influential. Kidner, in particular, took quite an interest[37] in computation, and I have found a number of my conversations with him about this topic influential in the development of my computer-based artwork. In general, there was a significant crossover that I experienced between the Systems artists (also including, for example, Jeffrey Steele and Colin Jones) and those working with computers. I found that my moving on twin paths had developed into bridging gaps. I was active, as I have mentioned, between art and artificial intelligence and now I found myself active between art in the constructivist tradition (not using computers) and the digital arts. This kind of domain bridging became a normal part of my working life.[38] It seems to me that this bringing together of different domains or concerns has been at the core of most of the work involving computers in the arts.

The core scope of this article concludes at 1980, but it is worth mentioning one or two things that happened slightly later. As the 1970s became the 1980s, Dominic Boreham joined us from the Royal College of Art, having recently completed the Slade course, and then finished his RCA PhD[39] with me as external supervisor. He took over the CAS magazine *PAGE* at this time. Boreham was working on various visual perception issues that related psychology, computers, and art practice. My supervising partner at the RCA was George Mallen, and Bruce Archer looked over our shoulders. We had regular meetings with him and it was clear that his rigorous approach to practice-based PhDs, and his insistence that they were equal to conventional scientific ones, was an important contribution to their development in the United Kingdom.

Stephen Bell, also having been at Hughes's Slade course, worked with me on his PhD[40] in the 1980s. He developed his *Smallworld* interactive art system further, and exhibited it, pursuing PhD research into the use of computers in participatory art.

The research and development work in art and technology that we did in the late 1970s started to really bear fruit at the turn of the decade as the personal computer emerged. It was not so much that computers became smaller and "personal." The real change was the acceleration of developments in computer graphics and, in particular, raster, or pixel-based, graphics. In about 1981, I bought a couple of Atari 400 computers. Some of my computer science colleagues thought that I had given up real computing but, in fact, I was buying graphics capability that was pretty powerful for its day. Not much later the Apple Lisa appeared and then the Mac. In my group we found these computers to be a very significant step forward. These Apple machines did not support color but then, even with the Atari, color was not a great deal of use because of the unreliability of its realization on the screens of the day. Not much later, I added an external frame buffer to the Mac, a Pluto Board, for handling color.

In my work, a crucial step was actually made conceptually in 1980, before I had a personal computer. I realized that my long-standing interest in time[41] could lead to a new kind of art with the use of computers. I started working on what I came to call "video constructs." These were time-based, generative, abstract works.[42] The generative rules at the core of these works were, and are, based on the rules that I started to formulate when making *Nineteen* and used in my painting through the 1970s and on. In the video constructs, I started using black and white and only felt comfortable with the technology of color much later. I did not show such work publicly until 1985,[43] but in many ways that showing was the culmination of much of the work of the 1970s. It represented the cusp where the twin paths of computing research and art practice came together to become, as they are today, an integrated direction for my work.

Other concepts and plans that started around 1970 have also become possible to realize in more recent times. In particular, the vision of interactive art systems, discussed in the paper I wrote with Stroud Cornock, became much more realistic after 1980. Developments in image processing and sensor systems in general, together with much richer and more flexible interactive computing environments, have enabled the implementation of the dynamic interactive art systems that we are familiar with today. Actually making these artworks has, of course, moved the conception of them forward as well. The audiovisual discourse that informed much of my early thinking has become very real and is at the core of much recent work.[44] The rules, first formulated for *Nineteen* and then used in generative video constructs, are now used in interactive video constructs, some of which include sound, such as in my collaborations with Mark Fell.[45] Looking back, it seems that the work in the 1960s and 1970s was laying a conceptual base that awaited the technological developments that followed.[46] It is only now that we are able to really advance art practice in the directions that we struggled with and dreamed of then.

Notes

1. George Rickey, *Constructivism: Origins and Evolution* (New York: George Brazillier, 1967).

2. *Nineteen*, 142cm × 180cm × 30cm, mixed media relief, 1968–1969.

3. Obviously, this may have been an entirely incorrect perception. My friends and I were young and inexperienced.

4. Tom Hudson was an important figure, as part of the group that developed basic studies in art education in the United Kingdom.

5. Later to become part of Leicester Polytechnic at which I by then worked.

6. See http://24.80.143.27/tom/tom_timesobit.html.

7. Leicester College of Technology merged with Leicester College of Art and became Leicester Polytechnic in 1969. In 1992, the Polytechnic became De Montfort University, which it is today.

8. Ernest Edmonds, *The Formalisation of Infinite Lattice Logics* (PhD thesis, Nottingham University, 1973).

9. I think that he (Mr. Bridger) had forgotten that only one year earlier he had pressed me to take the research post rather than a lectureship in mathematics on the grounds of workload and freedom to follow my own interests.

10. Ernest A. Edmonds, "Independence of Rose's Axioms for M-Valued Implication," *Journal of Symbolic Logic* 34 (1969): 283–284.

11. A method where each possibility is (laboriously) looked at in turn as against more sophisticated approaches that direct the search toward more likely solutions and hence save time. Where we do not have any clever heuristics, brute force can be the only method and, as computers have become more powerful, objections to it have reduced somewhat.

12. See, for example, Ernest A. Edmonds, "Logics for Constructing Generative Art Systems," *Digital Creativity* 14, no. 1 (2003): 23–38.

13. See, for example, *Systems* (catalogue) (London: Arts Council of Great Britain, 1972). Several of the artists mentioned elsewhere in this article were, of course, associated with that group.

14. Jasia Reichardt, ed., *Cybernetic Serendipity*, special issue of *Studio International* (1968).

15. Talk given to the Computer Arts Society, London, in December 1970.

16. See Ernest A. Edmonds, "A Process for the Development of Software for Non-Technical Users as an Adaptive System," *General Systems* 19 (1974): 215–218.

17. Stroud Cornock and Ernest A. Edmonds, "The Creative Process Where the Artist is Amplified or Superseded by the Computer," *Leonardo* 16 (1973): 11–16.

18. Conference held at Brunel University, United Kingdom.

19. A piece by George Mallen was chosen in which a set of slide projectors was controlled by computer.

20. See, for example, http://www.isoc.org/internet/history/brief.shtml#Origins.

21. Ernest A. Edmonds, "Communications Game," *Control Magazine* 6, (1972); Ernest A. Edmonds, "Interfaces for Human Interaction," CAS Conference, *Computers in the Arts*, Edinburgh, 1973; Ernest A. Edmonds, "Art Systems for Interactions Between Members of a Small Group of People," *Leonardo* 8 (1975): 225–227.

22. Cornock and Edmonds, "The Creative Process," 11–16.

23. For example, Ernest A. Edmonds and John Lee, "An Appraisal of Some Problems of Achieving Fluid Man-Machine Interaction," in *Proceedings of EUROCOMP '74*, Online Computing Systems (1974): 635–645.

24. That is, digital or electronic art practice.

25. See Edwards, "A Process for the Development," 215–218, and the discussion of Edward Ihnatowicz in this article.

26. Stephen A. R. Scrivener, "An Interactive Raster Graphics System and Language for Artists and Designers," Council for National Academic Awards (Leicester: Leicester Polytechnic, 1981).

27. See, for example, in the (useful) paper, Carole Gray, "Inquiry Through Practice: Developing Appropriate Research Strategies," in *No Guru, No Method? Discussions on Art and Design Research* (Helsinki, Finland: University of Art & Design, UIAH, 1998), 82–95.

28. Stephen Scrivener started in 1974 and completed in 1982 while Andrew Stonyer started in 1975 and finished in 1978.

29. I first met Edward through the Computer Arts Society and spent some time with him in Edinburgh at the Society's conference in 1973.

30. See http://www.aisb.org.United Kingdom/.

31. Edward Ihnatowicz, "On the Relevance of Mechanical Manipulation to the Process of Perception," in Ernest A. Edmonds, ed., *Preprints of Human and Robot Behaviour* (Leicester: Leicester Polytechnic, 1976).

32. A list of participants is included in the preprints referred to in note 31.

33. Or at least a one-to-one representation of it: one memory item per pixel.

34. In fact we later published a paper about the impact of the computer on art process: Stephen A. R. Scrivener and Ernest A. Edmonds, "The Computer as an Aid to the Investigation of Art Exploration," ed. Paul Samet, *Proceedings of Euro. IFIP* (Amsterdam: North-Holland Publishing Company, 1979), 483–490.

35. See, for example, Stephen A. R. Scrivener, Ernest A. Edmonds, and L. A. Thomas, "Improving Image Generation and Structuring Using Raster Graphics," in *Proc. CAD. '78* (IPC Science & Technology Press, 1978), 223–229.

36. Susan Tebby, "Patterns of Organisation in Constructed Art," Council for National Academic Awards (Leicester: Leicester Polytechnic, 1983).

37. In fact, Michael Kidner did some experimental computer work with Chris Briscoe at the Slade and during a visit to my group when it was at Loughborough University. No artworks resulted from these experiments, however.

38. For example, founding and running the Creativity and Cognition Conferences with Linda Candy.

39. Dominic Boreham, "Man-Computer Perception of Pictorial Characteristics in Unstructured Grey-Scale Raster Images" (PhD thesis, Royal College of Art, 1983).

40. Stephen Bell, "Participatory Art and Computers" (PhD thesis, Loughborough University, 1992).

41. Music, particularly serial music, had been very influential on my visual work and I was fascinated by film. During the 1970s I made some abstract films the hard way, by filming static abstract images and splicing the film together from many such still clips.

42. See, for example, Ernest A. Edmonds, "Logic and Time-Based Art Practice," *Leonardo*, Electronic Art Supplemental Issue, Vol. 1 (1988): 19–20.

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

44. See, for example, Ernest A. Edmonds and Sondra Pauletto, "Audiovisual Discourse in Digital Art," *SIGGRAPH Electronic Art and Animation Catalogue* (New York: ACM Press, 2004).

45. See, for example, Ernest A. Edmonds and Mark Fell, "Broadway One," *SIGGRAPH Electronic Art and Animation Catalogue* (New York: ACM Press, 2004).

46. See Ernest A. Edmonds, *On New Constructs in Art* (Forest Row, East Sussex, UK: Artists Bookworks, 2005).

26

PICASO at Middlesex Polytechnic

John Vince

It is always difficult to identify a single moment in time when a new idea appears; for whatever the discipline, history confirms that there is a spontaneous eruption of creative events that, over a short period of time, collectively emerge to create a new technology, branch of physics, art movement, or cosmological theory. So it should be no surprise that the emergence of computer graphics followed this same pattern, for as soon as computers started to be used on university campuses, academics and researchers around the world started exploring the potential of a new digital medium, which continues to this day.

Middlesex Polytechnic in north London was part of this creative process, as it provided the necessary equipment and infrastructure to nurture the new hot topic of computer animation. The institute did not have any master plan, nor did the people who worked there, but those involved in computer animation at the time knew that something exciting was happening at Middlesex Polytechnic, and I found myself caught up in this excitement.

The adventure lasted twenty years, during which time I discovered computer graphics and its application to animation. At the start I was aware that computers were being used in CAD but not in art and design, and the software system I developed—PICASO—was one of the first computer animation systems in Europe. By today's standards it was very crude, as graphic displays were still in their infancy, the mouse had not been invented, and the idea of a personal computer was not even a dream. However, one thing led to another and my work in computer animation became well known in Europe.

In retrospect, my early work was a lonely job, as very few people, least of all artists and designers, could see the potential of computers to their own work. I am not sure that I had a strong vision of the future, but something drove me onward to keep solving problems and inventing software that had a creative application. Eventually, the hard work paid off, for by the late 1970s my team at Middlesex had become a center of excellence in computer animation.

The Plot Starts Here

It had all started in the mid-1960s when I was studying electrical engineering at Enfield College of Technology, which, eventually, became part of Middlesex Polytechnic. During my studies I had mastered the newly emerging technology of digital computers. I could program in machine language, assembly language, BASIC, and FORTRAN. Such skills were rare and I found myself being swept along a career path I had not foreseen, for in 1966 I was appointed a lecturer in data processing.

My main lecturing duties were to communicate my knowledge of BASIC, FORTRAN, COBOL, and computer technology to students studying a wide variety of courses. It was very enjoyable. Then one day I discovered that a twelve-inch CalComp 565 graph plotter had been attached to our Honeywell computer, upon which a mathematics lecturer was drawing stereoscopic perspective views of a cube. One image was in green and the other in red, which when viewed through red and green filter glasses produced a solid view of a cube. It was magic!

I asked the lecturer how he achieved this effect, but he was not forthcoming with the answer. Eventually, I persuaded him to share his secret with me. He explained, "If you divide every x and y-coordinate of an object by their corresponding z-coordinate, you obtain a perspective view." I tried it myself and confirmed that he was right. Now I could become a magician!

I taught myself how to control the CalComp plotter. It was not difficult; there were three basic commands: one to initialize the plotter; another to establish a new origin; and a third to move the pen from its current position to a new location with the pen up or down. Very soon I could draw circles, ellipses, graphs, and even elephants. Circles and ellipses required trigonometric functions, but elephants only required coordinates traced from a child's book. I still recall a group of people visiting the Honeywell and looking over my shoulder to see the CalComp plotter drawing the silhouette of an elephant, when someone whispered, "He has found the equation of an elephant." Who was I to destroy this illusion by saying that it was only a list of Cartesian coordinates!

Ignorance Is Bliss

Although I had had no formal training in programming methodology, it soon became obvious that one could save amazing amounts of time by creating a library of often used programs. But before this strategy could be implemented I needed to design a flexible data structure capable of storing two- and three-dimensional coordinates.

I had no idea how this should be done. There were no books for reference and I knew no one working in this area. After a little thought I came up with a simple data structure that required a minimum of internal logical support and yet provided the flexibility to search the data at an object, facet, or vertex level.

Once this data structure had been defined I set about organizing a library of programs. To begin with, I started with a collection of 2D shapes and 3D objects. The shape library contained regular polygons, a circle, ellipse, parabola, line, and familiar shapes that included an elephant, horse, sea horse, fly, a human face, a rhinoceros, and a shark. The object library contained a box, sphere, cylinder, and the Platonic objects: tetrahedron, cube, octahedron, dodecahedron, and the icosahedron.

One of FORTRAN's rules dictated that variable and program names had a maximum of 6 letters, which meant that the word "elephant" had to be abbreviated to "LEFANT" and "tetrahedron" became "THDRON." Although this was unfortunate it was bearable.

Next came the display commands, which drew the 2D shapes and 3D objects. The shapes were displayed using the command DRAWIT or DRAW while the objects were displayed using DRAWIT or DRAW3D. For example, to draw an elephant one declared three statements:

```
REAL FRED (1000)
CALL LEFANT (FRED, 5.0)
CALL DRAWIT (FRED)
```

The first statement reserved an array called FRED capable of storing one thousand real numbers. The second statement loaded the coordinates of a five-inch-high elephant in FRED. The third statement drew the contents of FRED on the plotter. What could be easier?

I soon discovered that it was easy to make all sorts of mistakes, which could drive the plotter's pen a hundred feet along its roll of paper, or even attempt to drive the pen outside the drawing area. To prevent this I introduced a clipping feature which clipped every displayed line segment against a rectangular window. Such a window was defined using

```
CALL FRAME (xmin, xmax, ymin, ymax)
```

which, apart from setting the minimum *x*-coordinates and *y*-coordinates, defined the position of the origin within the displayed frame.

The plotter required initializing and terminating, which ensured that every command had been executed; thus every program began with a CALL START statement and terminated with a CALL FINISH statement.

To implement Stanley Hayward's perspective drawing feature I decided to define an arbitrary observer whose position was declared using:

```
CALL EYE (xeye, yeye, zeye, zpos, ypos, zpos)
```

This statement located an observer at (xeye, yeye, zeye), who was looking at the point (xpos, ypos, zpos). Thus a program to draw a perspective view of a cube looked like:

```
REAL FRED (1000)
CALL START
CALL FRAME (−3.0, 3.0, −2.0, 2.0)
CALL CUBE (FRED, 5.0)
CALL EYE (10.0, 5.0, 10.0, 0.0, 0.0, 0.0)
CALL DRAWIT (FRED)
CALL FINISH
STOP
END
```

Such a program could be designed in a couple of minutes with very little thought. However, it had to be prepared on punched cards, which were then submitted to the Honeywell 200 computer. Normally it took twenty-four hours to execute and return a program, during which time I had written further programs and extended the library.

Further Education

It was now 1970 and I decided to continue my education by undertaking a master's degree. Brunel University has always had an excellent reputation for computer science and I enrolled in a two-year part-time degree program for a Master of Technology in Computer Science. This was an excellent course as it introduced me to advanced aspects of computer science and topics such as compiler design and higher mathematics. Professor Michael Pitteway was responsible for the course and was very interested in computer graphics. For the next two years I drove once a week to Uxbridge to discover a new world of algorithms and their design.

During this period The Beatles rose to fame and I was very impressed by the songwriting skills of Paul McCartney, so I decided to see if I could devise an automatic method to write similar songs using a computer. I designed a program that created melodies according to parameters contained in various tables. Such parameters controlled the key, whether it was in a major or minor scale, the time signature, the dynamics of the melodic line, and a random touch, which I hoped would add that extra touch of inspiration!

The program was very inventive and could produce several hundred melodies in an hour. Unfortunately, the output was printed on paper using an alphanumeric notation, which made it virtually impossible to translate while playing a piano. To resolve this I wrote a drawing program that annotated the music, using the traditional notation of treble and bass staffs with the full range of notes, accents, bars, etc. This was very successful, even though the music was very forgettable! Nevertheless, this exercise became my master's project at Brunel.

PICASO

It was now 1972 and Professor Pitteway persuaded me to enroll in a PhD program, which I did. My research was to design a programming environment for artists and designers. My own library of plotting programs was taking shape and even had a name: PICASO. The letters stood for Picture Computer Algorithms Subroutine Oriented. I always regretted dropping the second "S" but was influenced by FORTRAN's ridiculous six-letter rule for names.

I now had a focus for my research and the ensuing three years were very productive. I set about expanding PICASO and formalizing its structure. I identified seventeen categories of commands, which are listed in table 26.1.

By 1975 most of the 260 commands were designed and documented; my PhD examination took place at Brunel University in the same year. Professor Pitteway was the internal examiner and Patrick Purcell was the external examiner. The title of my PhD was "PICASO: A Computer Language for Art and Design."

The Marriage of Art and Science

In 1973 Middlesex Polytechnic was formed from Enfield College of Technology, Hendon College of Technology, and Hornsey College of Art, and I became a member of a much larger academic community. Apart from teaching engineering and business students, I was invited to teach art and design students located on the Cat Hill campus and at the Hornsey College of Art. Again, I found my career taking a subtle new direction.

Having studied art at school I was very pleased to be working with art and design students, and very keen to show them the drawing abilities of computers. Little did I appreciate that not everyone shared my enthusiasm for digital technology!

Table 26.1 PICASO's Commands

Command type	Function	Example
System commands	Global effect over a program	START
2D shape library	Collection of mathematical curves and animal silhouettes	HORSE
3D object library	Collection of geometric objects	CUBE
2D shape drawing	Displaying single and multiple 2D shapes	DRAWIT
3D object drawing	Displaying single and multiple 3D objects	DRAW3D
Shape and object analysis	Exploring geometric features of shapes and objects	CENTRE
Shape and object manipulation	Manipulating geometric features of shapes and objects	ROTATE
Surfaces	Displaying real and pseudo 3D surfaces	SILUET
Input-output	The input and output of user-defined shapes	IN3D
Array manipulation	Provides array searching and manipulation	IFIND2
Vectors	Stores a vector as a PICASO structure	UNIVEC
Vector analysis	Analyzing vectors	ABSVEC
Vector manipulation	Manipulating vectors	ADDVEC
Special effects	Various graphical effects	SNOW
Special functions	Random numbers	TAKE
Contour generation	Coordinate extraction from shapes and objects	XSIN
Interactive	User interaction	EDIT

To understand this skepticism one must remember that computers were far from friendly. The mouse had not been invented; color was not possible (apart from using colored pens in plotters); and the medium for communication with the machines was paper tape or punched cards. Yet here I was attempting to persuade the next generation of graphic designers to embrace computer graphics!

During my visits to Hornsey College of Art I would lecture to art students about PICASO and describe how easy it was to produce computer-generated images. I would start by writing a PICASO program on a blackboard with chalk and indicate to students how they could control the size and position of their images, and the nature of the shading effect. They, in turn, would copy down the program, which included their own modifications, onto coding sheets. Some unenthusiastic students would even transcribe the positions of exposed wood screws on the blackboard to their coding sheets to convey their lack of interest. Nevertheless, I made sure that their marks were faithfully encoded into the nearest IBM punched card symbol I could find, which meant that when I returned in a week's time with their computer output, they received messages such as, "Illegal symbol in column 24"! Fortunately, not many students displayed this little interest.

I soon discovered that perspective was a good application of computer graphics for graphic design students. In order to produce a perspective view of an interior or exterior of a building, students constructed a perspective grid showing vanishing points and perspective scales, which, when placed beneath a sheet of tracing paper, enabled them to draw realistic illustrations with correct perspective, accurate depth information, defined cones of vision, and horizon lines. However, it took considerable skill to produce this perspective grid and I proposed to design a computer-generated perspective grid. My endeavors were successful, and PICASO's perspective grid command became an instant success.

The Plot Speeds Up

By the mid-1970s Middlesex Polytechnic had abandoned its CalComp 565 plotter and invested in a new A0 CalComp belt plotter, which could draw at an amazing speed of 1 meter/second. Instead of using a continuous roll of twelve-inch-wide paper, A0 sheets were cut from a roll of paper and taped to a plastic belt. This meant that much larger designs could be contemplated and this opened the door to computer animation. The computer had also been replaced by a Prime 550, which was much faster, and had a megabyte of memory.

Another display device that played an important part in the development of computer graphics was a Tektronix 4020 display, which had a very high resolution, green screen. Middlesex Polytechnic bought one of these devices and I interfaced it to PICASO. The display was similar to a plotter in that lines were displayed and stored on its screen. Eventually, the screen would become overwhelmed with lines and would then have to be cleared by pressing a button. In spite of this restriction it did permit a certain level of interaction and provided a new medium for inputting coordinate data. The Tektronix 4020 storage tube also had a facility for transferring the contents of the screen to paper.

Ivory Towers

Because I was working in total isolation in a small polytechnic in the early 1970s, I was completely unaware that researchers in the United States were working on a wide range of computer graphics topics. In 1974 Ed Catmull published his paper, "A Subdivision Algorithm for Computer Display of Curved Surfaces"; in 1973 Bui Tuong Phong published his PhD dissertation, "Illumination for Computer-Generated Images"; and in 1971 Henri Gouraud published his PhD dissertation "Continuous Shading of Curved Surfaces." I had not even heard of Ed Catmull, Bui Tuong Phong, or Henri Gouraud. This demonstrates the importance of attending conferences, reading journals, and being part of a research culture. But ignorance was bliss!

Hide-and-Seek

Scenes drawn on a plotter appeared as a collection of lines and showed individual objects as transparent wireframe structures. When one object was placed in front of another, one could see the distant object through the front object. Eventually, algorithms were developed to remove lines on objects that were completely or partially obscured by another object. This was known as the "hidden-line problem," and when raster images appeared, the corresponding "hidden-surface problem" was resolved.

In 1973 I was attempting to make individual objects appear solid and thought of an idea to remove back facets. It required declaring a facet's vertices in a counterclockwise sequence, such that when the facet was seen from its front, its vertices would be counterclockwise; but when viewed from its back it would appear clockwise. Thus, if only counterclockwise facets are displayed, the final image is much clearer and easier to recognize. All that I needed now was a way of detecting whether a facet's vertices were clockwise or counterclockwise!

Today, one can open any technical book on computer graphics and discover how to test the order of a polygon's vertices, but in 1970 there was not one book that I was aware of! Eventually, after much thought, I did discover a technique, only to learn months later that it had been discovered a hundred years earlier! I discovered this in a book on vector analysis.

It was extremely easy to implement this algorithm into PICASO's 3D drawing commands, which ensured that convex objects could be drawn as either opaque or transparent. However, the problem of removing hidden lines in a general scene had to wait until Paul Hughes joined me on the task. Paul turned out to be a brilliant programmer and made some significant contributions to PICASO and its rendering system PRISM, which appeared in the early 1980s.

A Transformation

I cannot remember what caused me to write a program to transform one set of coordinates into another set by a specified percentage, but I suspect it was Jasia Reichardt's book, *The Computer in Art*, published in 1971. This book reviewed the work of many early artists who were exploring computer graphics. Charles Csuri was experimenting with the effect of geometric transforms on shapes, while in Tokyo, the Computer Technique Group, which was established in 1967, explored the idea of transforming one shape into another.

I decided to implement a general transforming program called TRANSH, which could transform one 2D shape into another or a 3D object into another by a specified percentage. It was designed such that the two shapes or objects did not require the same number of facets, and it utilized a clever strategy to ensure that every vertex on the start shape had a corresponding vertex on the target shape. Although I did not know it at the time, this command was to become an important animation inbetweening command. Figure 26.1 shows an example of this program.

Keeping to the Script

FORTRAN's command to repeat a task was the DO statement. This took the following form:

```
      DO 20 I = 1, 100
      . . .
. . .
20    CONTINUE
```

which repeated the block of commands between the DO statement and the statement labeled 20 one hundred times. The integer variable *I* incremented each time the loop was repeated and could be used as a dynamic parameter by any of PICASO's commands.

A PICASO program was basically a FORTRAN program, but one in which the user was working at a very high level. Today, the very same technique is the basis of the scripting features found in MAYA and Softimage XSI.

Work Surfaces

In 1974 I attended a computer graphics conference and exhibition at Brunel University and saw examples of computer-generated surfaces. At last, someone was making line drawings appear solid, and the general outline of the algorithm was explained to me. By sweeping a mathematical function around an imaginary axis, a solid surface could be produced by maintaining an upper and lower horizon in two FORTRAN arrays. After some experimenting I could produce surfaces such as the one shown in figure 26.2. I also implemented isometric projections, 3D histograms, and contour maps.

Collaborations

A number of things happened for me between 1975 and 1980. First, I met Chris Briscoe and Darrell Viner at the Slade School of Art. Second, I was invited to undertake some computer animation by BBC Television, and, third, a graphic design student, Paul Ashdown, became interested in computer graphics.

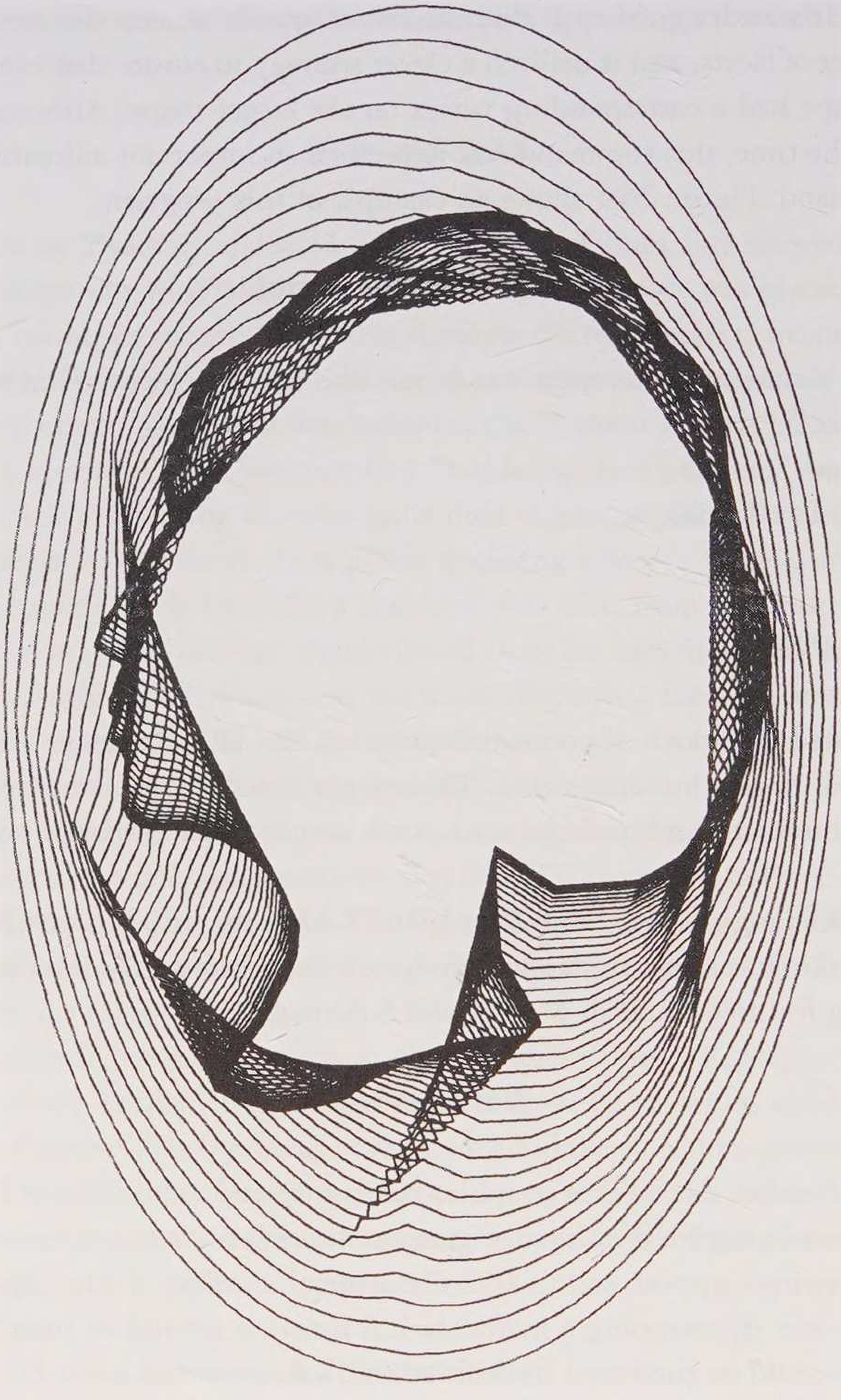

Figure 26.1 Example of an image made using a general transforming program called TRANSH.

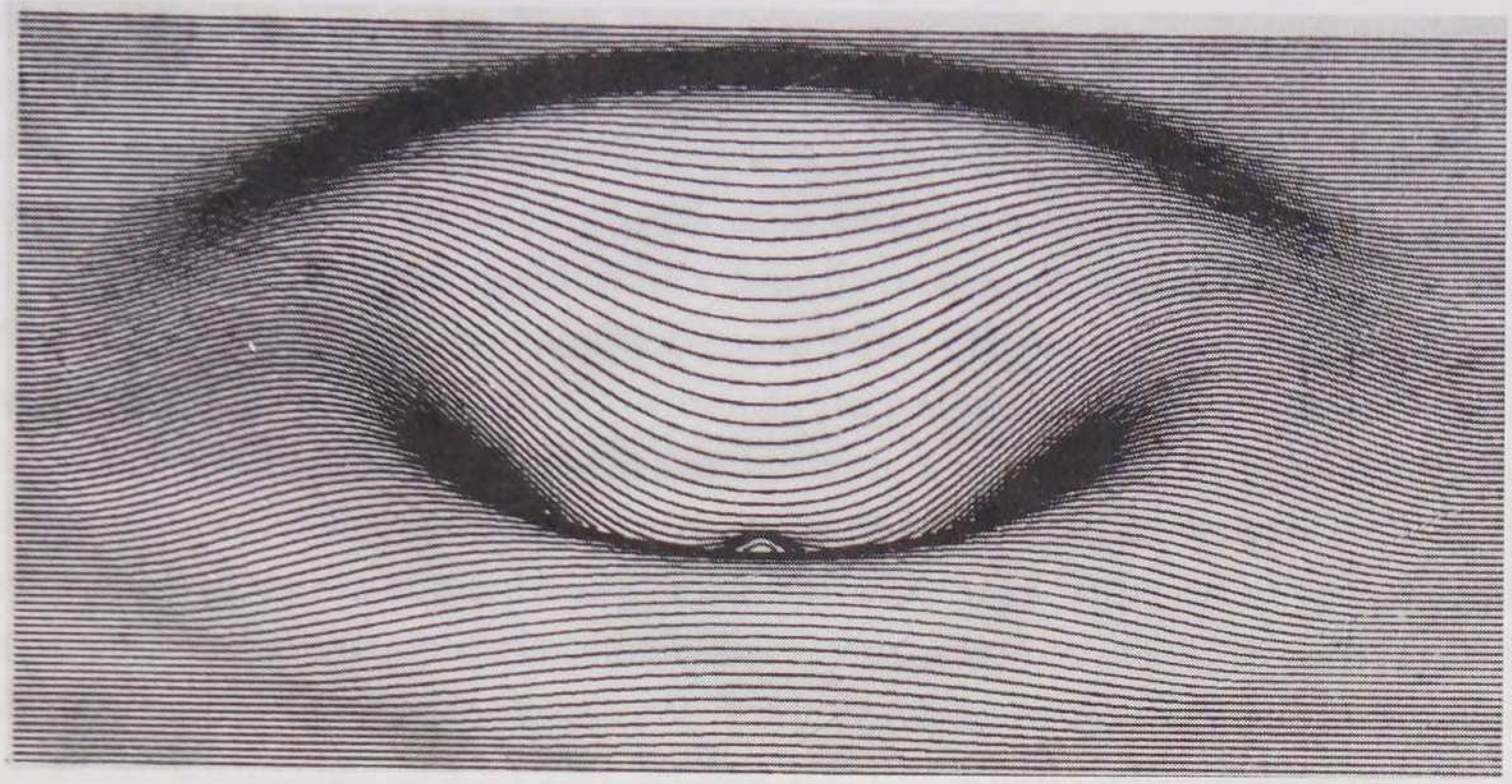

Figure 26.2 John Vince, image of solid surface produced by maintaining an upper and lower horizon in two FORTRAN arrays, 1974.

Chris Briscoe

I first met Chris Briscoe at the Slade School of Art in London where he was working on his Data General computer with a soldering iron. Not only was he a fine artist, he could program and could also repair computers! I also discovered that he was building his own flat-bed plotter. Eventually, Briscoe designed his own 35mm slide scanner so that he could integrate computer-generated images with live action. Nothing seemed to be too difficult for him to undertake.

When Briscoe was planning to set up his special effects company, Digital Pictures, he asked me to join him, together with other colleagues. I was to be responsible for the database design. I turned down this offer as I did not believe I had the experience to hold down such a position. Eventually, he did form the company and Digital Pictures become renowned for its groundbreaking animation.

Darrell Viner

Darrell Viner, an artist who had not yet discovered the potential of computers, came to see me at the Polytechnic. Once he saw my high-speed plotter in action he asked me to help him produce an image based on a tessellated design. The final image was drawn on cel, which was then engraved onto two transparent Perspex 24-foot-diameter disks. The idea was to create an interference pattern by holding one disk stationary, while the other disk was slowly rotated. When the disks were backlit and viewed from a distance, the interference pattern was stunning. The device was often left on my mainframe computer, where visitors confused it for a peripheral that reflected the activity of the computer's processor!

Viner's requests were challenging and helped me extend PICASO in various directions. One such request was based on PICASO's *ROUGH* and *SKETCH* features, which transformed the clean, clinical, computer-generated, plotted lines into believably hand-drawn lines. He asked me to design a program that created a collection of random lines from a collection of numbers. These lines were not displayed but stored for further processing in the form of cross-hatching. PICASO's cross-hatching feature could become confused with this jumbled collection of lines, but this added to the texture Viner was seeking. Even these cross-hatched lines were not displayed, but subjected to further cross-hatching, which were finally displayed. The resulting image was extremely complex, comprising thousands of lines of different length, spacing, and angles.

For the next step we wrote a master program that produced dozens of $4' \times 6'$ images on an A0 sheet of paper based on different combinations of random numbers. This program would be left to run over several hours. Viner would then select the ones he thought would successfully transfer to a larger format.

The program was then rerun with the selected random numbers to produce the desired effect. The output was drawn with gold and silver pens on high-quality cards. The effect was amazing! The final stage was to mount and frame the images and sell them in Italy! Unfortunately, I never managed to secure one of these images.

Eventually, Viner mastered FORTRAN and PICASO and went on to produce some animated films. He then discovered that the University of London possessed an even larger computer that could output direct to 16mm film. Nothing could stop him consuming ever more computer time in his goal to discover new forms of artistic expression.

BBC Television

During the 1970s, Middlesex Polytechnic's fine art faculty was located at Alexandra Palace, which, coincidentally, housed part of BBC Television's graphic design department. The BBC was also developing a computer-controlled rostrum camera at the Palace, which was destined to play a significant role in animated television sequences.

Somehow, designers at the graphic design department became aware that I was working on computer graphics and approached me with a project to animate two historical models of the planetary system: Ptolemy's geocentric vision, in which the earth is stationary and the sun and the planets move around the earth in circles and epicycles; and the Copernican model, in which the planets, including the earth, rotate around a fixed sun. This was quite easy to animate and was drawn onto large sheets of cel that were mounted on the CalComp plotter, attached with masking tape.

One day I was introduced to Chris Feines from BBC Television's graphic design department in London. Feines showed me an animator's peg bar, which was used by animators to keep cels in registration during the animation process. He suggested that I should mount this bar on the plotter with masking tape so that sheets of cel could be mounted, which were also held down with masking tape; the drawing would be made, the cel removed, and another attached. This became the way I worked for several years producing animations for film and television.

Feines then commissioned me to animate a spinning "£" symbol as part of the opening titles for the *Money Programme* he was working on. I accepted the commission, producing the output on registered cel. These images were then processed and integrated with other images and became the BBC's first computer-animated title sequence. The success of this project brought us a succession of other graphic designers who all wanted to use computer animation as part of their program title sequences.

Spreading the Word

It was now the late 1970s and I decided to spread the word of computer animation in the form of a one-week course. I would take a dozen graphic designers at a time and introduce them to the delights of computer animation over five days. The first day covered the keyboard, the UNIX operating system, and how to submit a PICASO program for processing. The remaining four days covered the principles of computer graphics, designing PICASO programs, digitizing, 3D modelling, and animation. By Friday afternoon, everyone had produced several animation sequences that they took away with them.

This brief exposure to computer animation really whetted their appetites. Some designers returned to rent time on the computer so that they could undertake their own animations, while other designers returned and commissioned me to produce animations for them. These were then broadcast on United Kingdom television.

PICASO and PRISM

By 1980 PICASO contained about five hundred subroutines and was being used by over twenty-five academic institutes in the United Kingdom. It was also being used by a few government and research agencies as a general graphics system. However, PICASO could only produce line drawings. With the Polytechnic's newly acquired video frame store I set about designing a complementary system—PRISM. PRISM stood for Picaso's Rendering Imaging SysteM.

Much to my surprise, I discovered that I knew nothing about color; only after reading an Open University text on color theory did I learn about the primary additive colors: red, green, and blue and was able to start programming a renderer. Paul Hughes played a significant role in designing PRISM, which incorporated Gouraud and Phong shading, a depth buffer, and texture mapping.

It is still difficult to appreciate just how slow these systems were in 1980. To begin with, it took several seconds just to clear the frame store, and could take up to an hour rendering even a simple image. Once, I wrote a ray tracer and tested it by rendering a dodecahedron. After several hours of rendering only a small part of the image was complete. I abandoned the idea completely. Today, such images can be rendered in real time!

The move toward rendered images introduced us to film output devices, video disks, and single-frame video recording systems. All of them were fraught with technical problems, and presented a new challenge every day.

Paul Ashdown and Gareth Edwards

While teaching students at the Cat Hill campus of Middlesex Polytechnic, I met Paul Ashdown, who was a graphic design student. Ashdown discovered that he possessed a natural ability to program, and he found PICASO very easy to use. He learned FORTRAN and very soon was writing very sophisticated software.

While I was working with Ashdown, the Polytechnic purchased one of the first video frame stores in the United Kingdom. It was called the Bugstore, and contained 0.75 megabytes of video RAM and cost £50,000. Ashdown wrote his own renderer and for his undergraduate major project modelled the space shuttle and animated it taking off, flying and landing. I believe that it was the first such project undertaken by a student in Europe. Ashdown worked with me on several large animation commissions, and when he left the Polytechnic he worked for a number of animation companies in London. He eventually went to Industrial Light and Magic, where he wrote software for the film *Jurassic Park*. He now lives and works in the United States.

Gareth Edwards joined me in the late 1970s. He could program in BASIC and was familiar with the BBC microcomputer, which were excellent credentials at the time. Edwards, like everyone who collaborated with me, had an impact on PICASO especially in the design of new commands. He was a fine artist and had recently left the Royal College of Art. He helped with the animation commissions and was a natural animator.

Alas, after three or four years, Edwards decided to seek his fortune in London and secured senior positions one after another in most of the animation companies. He was responsible for many of the advertisements and television title sequences seen on United Kingdom television for many years. Eventually, he created his own animation company and is now an independent animator.

The End of the Plot

By the early 1980s Middlesex Polytechnic had secured an international reputation for computer animation and London was becoming the home of video and animation companies. Nevertheless, some of these companies were still coming to Middlesex with their projects. One such project was the first *Superman* film, for which we were asked to show an animation of Superman displayed as glowing green lines. We were presented with a two-foot-high plaster model of Superman cut into slices, which were to be digitized and assembled as a semi-transparent image. Unfortunately, the collection of plaster slices had no point of reference, and was useless. The model was remade and cast within a box containing a colored medium. This time it worked and we completed our first piece of animation for a major film.

A second film followed in which I had to show a collection of cells multiplying and dividing, while Sean Connery viewed them under a microscope. The animation was dreadful, but so was the film's storyline!

The early 1980s was a busy time for us and we were receiving commissions from most of the United Kingdom's television companies. At one point, one could see three or four or our animations on television during a week, and we were very proud of this record.

All of this production work was being undertaken while I had a full teaching timetable and involvement with normal academic life, and to make life even more difficult, I decided to design a Master of Science course in computer graphics, which was to become Europe's first course in this subject. Alas, I was to leave Middlesex before it began, and a colleague, Huw Jones, became its first course leader.

Although computer animation at Middlesex continued until the 1990s, an era had come and gone. The service that we had offered was now available from a growing commercial computer sector in London that could undertake much larger projects. During this time I met some wonderful people who introduced me to graphic design, typography, technical illustration, fine art, and traditional animation, which is why I still have very fond memories of my time at Middlesex; I will never regret being at the right place at the right time.

27

From 0 to 1: Art Made between the Times of Having and Not Having a Computer

Brian Reffin Smith

We think we know the past, present, and often the future of computers. Advertisements tell us the latter, for the future is always with us, available for purchase.

And the future of computer-based art is always with some of us, though this too is malleable and subject to market forces, and I don't mean the art market. It is constantly changing, yet constantly normative. At various times, if you weren't using fractals, you were one stone short of a coastline; if your thing was not shiny spheres reflecting other shiny spheres, preferably on chessboards, it was checkmate for your career; if you weren't into rigorous systems art, then you were hopelessly fuzzy unless you were Fuzzy, which was once de rigeur; and if you weren't in Austria hooked up to someone in Canada at a silly time of your morning or their night doing graphic arm-wrestling or writing an interactive haiku together, then you weren't on the editorial board of *Leonardo* journal.

And since the Zeitgeist in which "computer art" is an element has almost always been technologically determined, with people using state-of-the-art technology to make state-of-the-technology art, then computer art was usually just the decorative, more or less hip edge of what was going on more "seriously" everywhere anyway.

My contribution here is to go back, not strictly in time but in evolutionary terms, to discuss art made, and the feelings and systems surrounding its making and teaching, in the stages between not having, and then having, a computer. To do this objectively, as well as being impossible, would be beside the point.

We cannot even agree on when computer-based art began (I would take a chance with 1951 and John Whitney's sound and color works; if this is accepted then the history of the field is longer than that of pop art, video art, conceptual art, and so on) (figure 27.1).

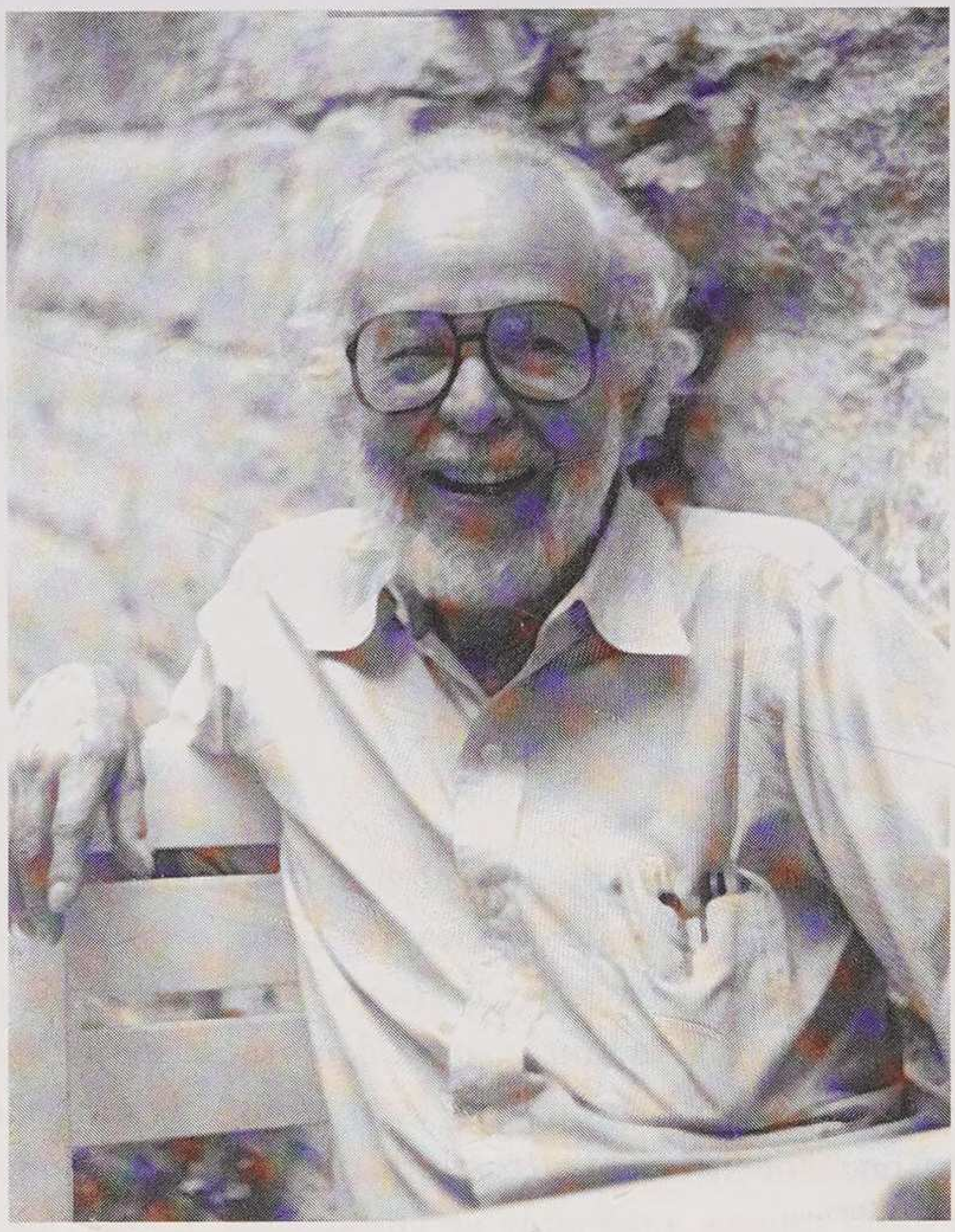

Figure 27.1 John Whitney Sr., Villeneuve-Lès-Avignon, France, 1981.

The first computer joke, however, seems to have been in 1835 when Mr. Wakely, MP "enquired of the Minister when it was likely that Mr. Babbage's calculating machine would be completed. The Minister jocularly recommended him to set the machine to calculate the answer," which must have been a boot-strappingly challenging idea at the time.

Everything Is Possible (Except Nothing Is Possible)

Self-similarity could be—can still be—discerned in the relatively short cycles of "progress" in computer-based art. I mean that the signs and wonders, the determining factors and the selling (in various senses) of the results in more or less obvious ways are pretty similar in their form. They usually lasted about three years, from "pushing the frontiers of contemporary art" to "old hat." In Kuhnian terms, there are only very short consensus phases of normal activity between periods of paradigm shift and upheaval.

Or, rather, the paradigm is "revolutionary" change; the revolution would be if we actually stopped and did something in contemporary art, instead of breathlessly illustrating what we can do in terms of computing technique.

In contemporary art terms much computer art is the most conservative, boring, reformist art, its language being that of technology, not art, its history one of technical, not artistic advance, and its paradigms often seeming to be those of business.

One might say: Has this not applied to all art, not just computer-based art? But I would argue that it is only this kind of art that, overwhelmingly, is about itself, and not in a good way. It says: I can do this, and here's a picture of it. The change in painting around 1420 that David Hockney has suggested was due to a mirror form of the camera obscura enabled wonders, but was not the point in itself and indeed was apparently kept secret.

I believe that a generosity and responsibility must be offered vis-à-vis the place of the art work in a huge matrix of historical, political, cultural, and sociological dimensions. Presenting computer graphics or the results of experiments in person-computer communication as "art" is just not good enough.

I blame the parents: the sponsors and the curatorial spasm that needs to see shining, technological art in shining, technological frames such as the foyer of an electricity company or the Centre Pompidou. It was never really taken seriously. Where are the fractals, the holograms, the interactive works or even the videos of them in action? Heaped in the basement, the good along with the bad and the ugly. Look at what happened to the *Senster* and its traces, that wonderful piece of robotic or interactive sculpture or whatever you want to call it (now thankfully being reinvestigated) that was not a showpiece (and hence, conceptually, fitted so badly into Philips's *Evoluon* showcase) but actually was an embodiment of what Edward Ihnatowicz believed about intelligence and action. It had monumental status. I watched a newly married couple having their wedding photos taking in front of it. The best interactive art always makes you look at the participants, not the piece itself.

Before 1950, no artists had any kind of access to any digital computers. John Whitney built his first devices from parts of analogue machines left over from World War II. But even in the late 1970s most artists had no possibility of using any computers at all, despite nearly twenty years of computer-based art activity here and there, and some large-scale exhibitions.

So the stage to which I am referring, the "0" in the 0 to 1 change, was at some times, for some artists, at a point where there was little or no theoretical context, and no practical context at all, and for others a time of access to theory and to exhibitions or articles about computer-based art, but still to no computer. For me that changed between about 1966 and 1975.

It was all terribly frustrating. The first time I could literally lay hands on a computer was during a research internship that was part of my metallurgy course at Brunel University, at the Lucas Research Group laboratories outside Birmingham. They had, as I remember, an English Electric Leo Marconi machine, filling several cabinets, with both punched card and perforated tape inputs.

One of the outputs was sound, ostensibly so that the programmers could get an idea of what was going on, but it was relatively easy to cause the machine to do various useless things for a long time during which a certain sound would be made. Thus it could, in a way, make music, because the punched cards could be stacked up so that it almost made a scale, or some other recognizable sequence. Once assured that no harm could be done to the machine, I was struck with the idea of shuffling the cards (random sounds) and of ordering them according to ideas other than the sounds they made. Occasionally this even worked. It was the first time I had used processes from "outside" the domain of art to produce results inside it, and it was, though not remotely new, an exhilarating thought for me.

Thus from relatively trivial exercises sprang ideas that might feed into art per se or into later art made with further and better access to a computer.

Around this time, too, a friend wrote a program to my loose specifications that he ran on his university's computer. All it did was print about five hundred pages of random 0s and 1s on large, fan-fold printout paper. I had some vague idea of using it as wallpaper. *Plus ça change . . .*

The patterns of 0s and 1s were fascinating. I knew they were random, or supposed to be, but wondered what this meant. Of course I could "see" all sorts of structures in it, and mused about cutting each sheet into horizontal lines and sliding them over each other until I could "make" some image. I wondered what this might mean, too, referred back to the original program. (This was probably the basis of an idea I had much later for an item for BBC Television's *The Computer Programme* when the presenter Chris Searle's sweater, knitted with a picture on it, was gradually unravelled to show the idea of pixels.)

The truth is of course that neither idea meant much at all, but it was by little musings like this, rather than by grandiose schemes, that one started thinking, however basically, in computer terms about art-like processes. And, too, in art terms about computer-like processes.

While I was doing this work I was also teaching "Science and Technology for Artists" at a number of art schools, and since the Zeitgeist made use of terms and concepts from cybernetics, I found myself increasingly saying things that started with, "Imagine you had a computer . . ." I decided that, because I was highly unlikely ever to have a computer myself, this approach was in fact preferable to anyone having one at all: I think there's a psychological name for this. I also read, a bit later, of Stafford Beer's having advised the Indian government that they should *pretend* they had computers for economic steersmanship, when everything—systems of data collection, ways of presenting information from the bottom up (or indeed making use of heterarchy rather than hierarchy or anarchy)—might change to fit what the nonexistent computers "needed."

There was, for me, a political element in my thinking about computers in art, and it was not so much that computers might enable things directly but rather that they might provide metaphors and analogies for what might be done in art. The metaphors seemed to me subversive.

Although everything was possible, and yet nothing possible as yet (or very little), I thought that when computers operated—stuff going in, things happening to the stuff, and then stuff coming out again—then instead of them being information processors, which all the books said they were, they might be considered to be *representation* processors. At some point my silly sounds and random patterns were already in the machine, just not perceptible yet. Given more time and knowledge, one could act on these representations in ways that were more artistic than technical. Later came the thought that if that was true, then everything inside a computer—scientific calculations, payrolls, missile guidance, or whatever—was also—must be—a representation . . . of something . . .

Who are the people supposed to be best at handling representations, of engaging in irredundant holism, of seeing the grand design and its possibilities? Well, clearly, designers, artists, poets, musicians, and others.

At a time when computers and what they enabled in, for example, military or industrial terms, could seem to be very threatening indeed, these thoughts somehow *reclaimed* them for "us." I thought that they might be revolutionary in that sense, and started to say so, based on pitiably little evidence. I do claim, though, that a few of us were instrumental via education, magazine articles, books, and television programs, in presenting the idea that computers were as much art machines as anything else.

I was teaching part time in the liberal studies, cultural or art history departments of a number of art institutions, such as Chelsea College of Art and St. Martin's School of Art, as well as Canterbury College of Art in the general studies department of Toni del Renzio. I taught things about crystals and electrons in metals, light, some ill-digested cybernetics, and the beginnings of computer studies, based more on what I'd read than what I'd done. It was bracing to be surrounded by colleagues who were interested in computers from sociological or cultural as well as technical or artistic viewpoints, and who could develop new and strange arguments about them.

But it was at Canterbury, when the first "small" computers or rumors of small computers were abroad (mostly in America), that I met and started teaching with Michael Baldwin of the excellent Art & Language group of conceptual artists. They had a sort of machine-gun approach to art in general, mowing down the merest hints of curatorial or proprietorial attachments, whether from the art or the technology side, to the outward appearances of art. They were concerned with what was really going on in the studio, gallery and academy, and thought that art and art movements should always refer to the first appalling moments of their creation, which were to be laid open to scrutiny, often within the artwork itself.

To Baldwin, computer "art," the quotes clearly audible in his voice, was easy meat, and his stringent opposition to any of it, anywhere at all, meant that I played a computer Trotsky to his (just in this area) Lenin. To justify what I could discern as constant revolution I had to think up increasingly extreme justifications, sometimes inventing works not yet made as examples. This was very useful.

Other critics of the area included those who said that computer-based art was inevitably tainted by its frequent sponsorship and that it could not be judged in any way, there being no critical discourse, no history, no language even, from within which to do so. Others asserted that it was all too often judged merely in technical terms. I took all these devastating remarks on board and, driven by some sense that it *was* the area in which to find a motor for contemporary and especially conceptual art, tried to sort and sieve out all the dross including my own to see what was left, and what I might do and encourage others to achieve.

Everything was possible if you imagined you had a computer. Yet since nothing was possible (because you did not have a computer), you were in a sense completely free and ideas could fly, approaches and theoretical frameworks being readied for the day when . . .

Parallel Areas

To start with, I fell into the trap of appreciating computer-based art—and justifying it, and celebrating it—because it was "like" other kinds of art. Text-based output was like textual art; systematic, combinatorial, or rule-based output was a reflection of systems art (which I loved, finding constraints liberating), and so on. But then I realized that if I was justifying it that way, a computer was somehow irrelevant. It just enabled more or faster or, often, inferior, versions of existing art forms to be produced. It was already clear that art that would scarcely be justifiable, were it made on paper by hand, was being defended and even lauded just because a computer had been involved. If you criticized the quality, people said, "Yes but look how *much* there is, and anyway this is research really, you cannot expect stunning results yet . . ." and then moved swiftly on to the next area of artistic incompetence.

This is in general still true. People don't have *time* to make art, only to master the technical means of its production. *Faut de mieux*, the results of their mastery are presented as art, and people begin to accept that that is how it is, that is what computer-based art *is*.

Then I began to understand that there were certain things being done that could not have been conceived of without the computer. The computer was a metaphor-machine, in a general or specific sense, even if thereafter the technology wasn't necessary for the actual execution of the work (though it might help). In other words, I flipped the picture from one of art made in a computer that did not need to be, to one of art perhaps made by hand whose inception had necessitated only *prior* use of a machine, or knowledge, experience, or consideration of some aspect of the machine.

I started to name "computer-based art" that which was produced by, with, or in spite of the computer, which stood in some relationship to it, and not necessarily a conventional productive one.

If a computer was essentially a device into which you shoved representations, changed them, then pulled them out again, this was a rich area indeed. People such as Gordon Pask were celebrating all sorts of sideways attributes of computers and computation and, it seemed, feeding back these insights into actual metal machines with knobs and dials (which, if not wholly redundant, were certainly irredundantly holistic and which added theater and atmosphere to the—yes!—*performance* of computation).

Professor Pask is sadly missed, particularly for what he might have done to change Web-based exercises. He held that intelligence could be a property of any sort of system, whether biological or not, and would have gone on, I think, to challenge our stupid one-way "interactions" with others' authoritarian systems, so falsely inclusive and democratic.

In 1975 I started an MA at the Royal College of Art in the wonderful Department of Design Research. There were more staff than students, and (no doubt the reason it was swiftly closed in the 1980s when a new rector came to power, Thatcher- and glossy-magazine-friendly) it was completely inter- and trans-disciplinary.

Among the teaching and research staff were John Lifton and George Mallen, as well as Patrick Purcell. Lifton had famously made (and in 1975 exhibited at the Whitechapel Gallery) a piece called *Green Music*, in which the microvoltage changes in plants' leaves were used via a computer and synthesiser to produce music. As people approached the installation, their presence affected the tiny currents, which changed the sounds, which pushed air from the loudspeaker baffles, which affected the leaves, which changed the music, which made the people move differently . . .

The plants were not very interesting in themselves, and the technology was relatively opaque, but the behavior of people around it was fascinating.

Lifton—who was on the board of the Institute for Research in Art and Technology (IRAT), where I later also found myself—was working in an architectural context in the DDR, but it rapidly became clear that labels were not what the department was about. George Mallen was working on cybernetic approaches to decision making and interactive design. Patrick Purcell was working in design and architectural areas too, but along with cognitive psychologists, computer experts, artists, working designers, game theorists, and philosophers, the whole cabal or caboodle was inventing its own territory that went, really, everywhere. This generalist approach, both horizontal and vertical, across and inside disciplines, became for me a model of computer-based at activity.

There were huge metal modems giving rates of 100 bits per second to Imperial College around the corner or the ARPANET—the forerunner of the Internet—across the ocean. Even the present author did not worry too much about the D for Defense that had been dropped off the front of that acronym.

Although I was resolutely if not stridently in favor of a revolutionary art, I was sufficiently naive to think that when Nicholas Negroponte came over from his MIT lab with interactive laserdisks that showed you how to mend a bicycle, it was actually about bicycle mending, and not missiles. (As a sort of guilty corrective, I once, in a foreword to an article I wrote for *Leonardo*, ironically thanked the Naval Ordnance Laboratory of the then German Democratic Republic for sponsorship. My phone got tapped.)

One of the things you could do on the link to Imperial College was to program in BASIC. I learned this programming language and wrote profoundly unstructured routines to do all sorts of things that represented ideas of cooperation, of sharing concepts, and of using aspects of cognitive psychology to aid or to make art and design.

The paper tape clacking through the teletype machines was somehow, in inverse proportion to its decibels, secretive, spy-like, and naughty. You could have anything represented on that tape, and noone would have been the wiser. Especially if it was data for a program that only you could fathom.

Thus came the idea of furtive representations that—an idea from conceptual art of the time—could not be known but whose secret status might be displayed. As Ted Nelson, the father of hypertext, once told me: Artificial intelligence is saying, "I know something you don't know that will enable me to make a computer do things I don't understand."

Logically, one did not have to do anything except run a bit of gobbledygook and claim art and/or programming status for it. "It is all inside the machine . . ." But, anyway, a cathedral or the letter C, once represented in a machine, were equally wondrous to me. Simulation needed output, but modelling strictly speaking, did not. Of course, to know whether the model is useful and valid in the real world is another matter; but its mere existence might be more powerful than any provisional truth it contained. Duchamp's 1917 urinal, *Fountain*, recently named the most influential piece of modern art, may well be a model of the artist's input being what counts, and of the cultural systems that militate against this idea. But it is the work's existence qua model that counts, or counted at the time, not the efficiency of its modelling power and representation, *q.e.d.* The man who added his own input by pissing into it was making a category mistake, among other things.

I made actual programs which did what I claimed they did, but with no output. Any answers to problems, and the algorithms that engendered them, and the forms of representations of all of these, were secret and hidden inside the machine. But I told anyone who would listen about what was going on inside the computer, somewhere in the process. (At a conceptual stroke, this "virtuality" justified, for me, a lot of other computer-based art too.) This was just as well, since apart from printing ASCII characters on teletype paper or trying to make a creaking Tektronix graphic terminal draw lines, one had no output of note.

Peeks and Pokes

Even in the early years of mini- and microcomputers it was rare to find a computer in an art institution, and before about 1975 almost unheard of in the United Kingdom (outside, perhaps, the Slade and the Royal College of Art). There were terminal links, but few of the necessarily large machines were installed. So a course entitled "Computing in Art" dealt in much theory, slides, photocopies, and anecdotes, but little if any hands-on experience. But if one could not lay hands on the beasts themselves, one could pretend. I got a room full of art students to become the component parts—input, output, CPU, memory, and clock—of a computer, and we (literally) ran programs that did sort of creative things. There was much reliance on sheets of paper as data storage devices. We peeked and poked at computing ideas but still were not actually using them.

Joseph Weizenbaum's ELIZA had been known of for a number of years, and sketchy ideas of artificial intelligence could be assembled into a (deeply human) robotic device that, much like the chess-playing automaton with a person inside it, was capable of provoking questions about creativity and responsibility. Who's doing it—person or machine? Is it creative to make a machine do things that look creative?

Then in the mid-1970s the first kit-based personal machine appeared. Apples, Commodore Pets, Research Machines, and other "small" computers were not far behind, and by 1977 the Royal College of Art had a variety of machines: something old, something new, something borrowed, and something (an Altair 8800B with twin floppy disk drives) blue.

I begged or borrowed some of the first portable devices that would run a line of BASIC across a liquid crystal display, beep a certain number of times, choose words, manipulate coded artworks or give instructions to make one. In retrospect, it was far better to have (had to have) this approach than to have instant access to more powerful machines because, again, the lack of technology enhanced ideas. In 1980, for example, I was teaching liberal studies (I think it was called) at St. Martin's School of Art with a Sharp PC 1210 computer in my pocket, and they were glad to see me.

By the end of the 1970s I was also carrying a black Research Machines 380Z into St. Martin's School of Art and plugging it into a TV monitor there (figure 27.2). I once dropped it from the platform of a number 73 Routemaster swinging around Hyde Park Corner and it lived to tell the tale, which fact was subsequently used by RML in their publicity ("Can be dropped from a moving bus"). RML's loans and cut-price sponsoring I found (since I was the recipient) to be not at all corrupting, and started, in a small way, to replicate on such machines aspects of interesting works of computer-based art from the previous two decades or so. Dialogue with students then suggested not only variations but completely new ideas.

These machines all ran BASIC and it really lived up to its name of Beginners' All-purpose Symbolic Instruction Code, for it really was all-purpose. Just as one could, in departments of cultural studies, fly over vast tracts of sculpture, painting, film, theory, photo, performance, conceptual art, linguistics, or science, anything really, so with a computer in such a department one could try nearly anything. Whereof we could not speak, thereof we rarely remained silent, but got into discussions of non-computable problems, the differences between ill- and well-defined problems, the beginnings of expert systems, artificial life, and even what would now be called neural networks, in a playful kind of way.

I also took up a research fellowship at that time and then became the first College Tutor in Computing in Art and Design at the Royal College. There too BASIC played a large part, running on everything from Imperial College's monsters to an RML 380Z, an early Apple, and the good old Altair. Students and staff from every school and department presented crazy ideas and asked impossible questions, which of course led to much innovation and fun.

I strongly believe that it was best when computers were introduced in generalist departments or in a trans-disciplinary way, driven not from available techniques but from outside problems—the ideas, not the techniques, having priority. A computer in a painting department (though very rare) was a good thing, in cultural history or liberal studies was better, in a multidisciplinary setting was great, and in a special computer room was terrible. Revolution in more than one studio! was the slogan.

Numidia

The phrase "new media" drives me mad. I prefer to hear the word "Numidia," the ancient Roman province fuzzily coextensive with Algeria. This spatial or nominal

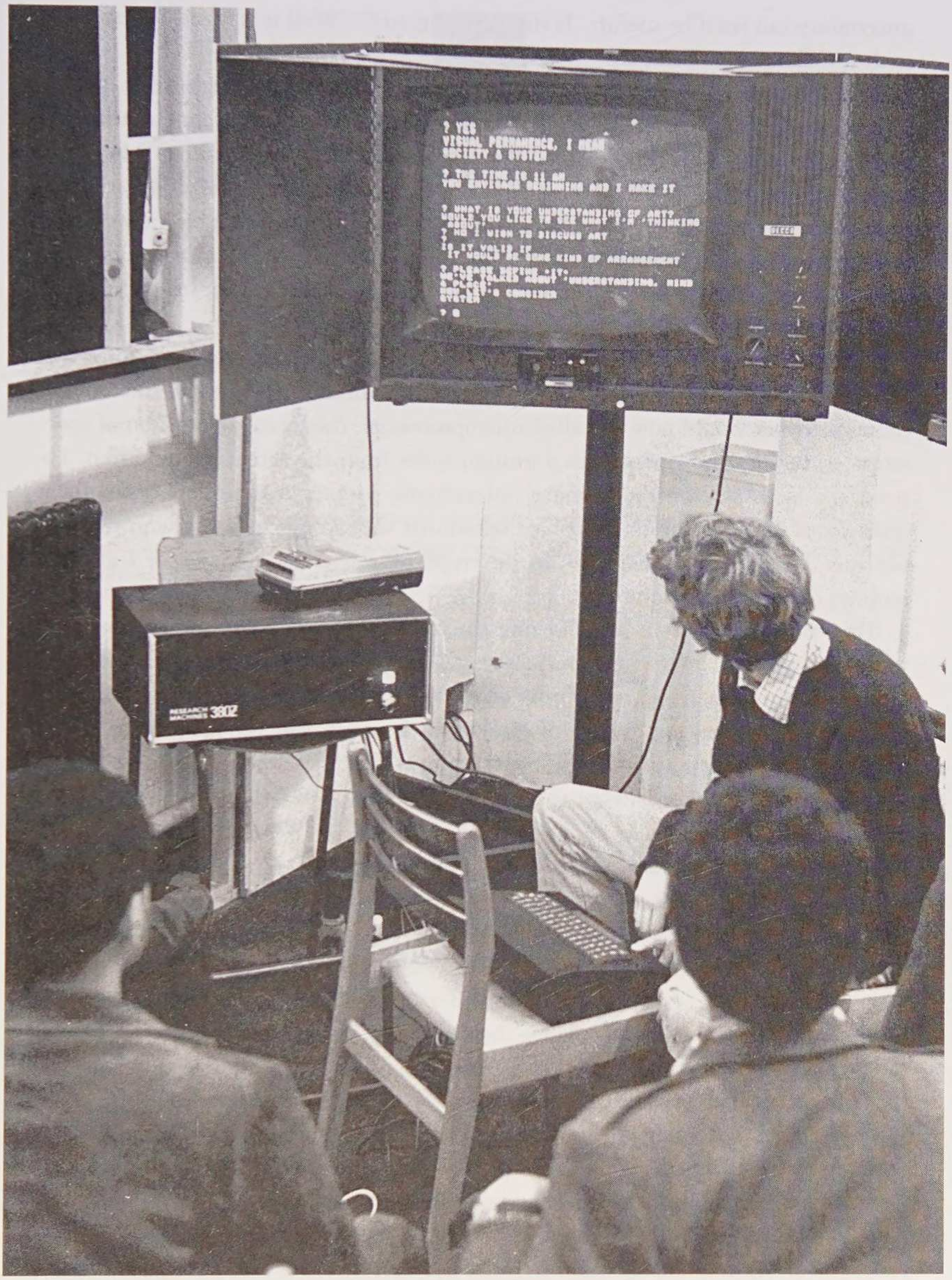

Figure 27.2 Students at St. Martin's School of Art using a 380Z computer, 1980.

uncertainty can itself be useful: "Is this your car, sir?" "Well it is fuzzily coextensive with it Officer . . ." "I see, sir."

Fuzzily coextensive with the mad, technological rush toward the bright, shining tomorrow of computers has been the parallel universe of artworks and art teaching that grumpily or gaily acknowledged the machines' power to provide metaphors and analogies. These arose from the ways they worked, the algorithms they worked with, or the forms of data they worked upon. Alongside the development of "new media" was a growing use of *transformation* of forms of information in art, using various systems and machines including computers, but which was by no means technologically determined.

As far back as 1968, Gordon Pask's *Colloquy of Mobiles* in the ICA show *Cybernetic Serendipity* was about cooperative action and self-organization. Although the mobiles contained what would now be called microprocessors, the locus of attention of spectators or, better, participants was a million miles from the actual computation. Instead the focus was on the mobiles' interactions with each other, the rules (in a quasi-social rather than computational sense) that they might be using, and the possibilities for human participants to interrupt or subvert the beams of light the mobiles needed to communicate.

This was a far cry from just showing the technology and doing something fancy with it, however interactive, and calling it art. Fuzzily coextensive with the machines came ideas and new forms of representation embedded not only in the machines but also in the forms and systems of their use. But the medium is not—has never been—the message, which is mainly culturally, determined. And this culture need not be in thrall to the computer, though it often has been.

It Is Not Too Late

I believe that we need to follow 1960s and 1970s models of creative activity, where invention was tested in the real (art) world, which produced new ideas, leading to new embodiments, . . . that might be reclusive instead of all-singing and dancing. Computers are most powerful when they engender debate and sideways-artworks rather than enabling the latest technological wizardry to be meretriciously exposed.

There is a mine, a treasure trove, a hoard—I cannot emphasize this too strongly—of art ideas that emerged in the early decades of computers that still have not remotely been explored. We know how this happens. The next big thing comes along and the Zeitgeist has its demands; things get left behind . . .

We need to carefully re-examine, restore, analyze, document, and then use computer-based arts and art made by, with, or in spite of the computer, from earlier times. It is all there. We may not need the computers from those times but I believe we do need the ideas, and the ways of making sense of the technology.

28

The Aftermath of Early Computer Art: A Painter's Odyssey

Jeremy Gardiner

> We must expect great innovations to transform the entire technique of the arts, thereby affecting artistic invention itself and perhaps even bringing about an amazing change in our very notions of art.
> —Paul Valéry, *Aesthetics, The Conquest of Ubiquity*, trans. Ralph Manheim (New York: Pantheon, 1964)

Paul Valéry's words echoed my transition to using computers, which took place at the Royal College of Art. Maybe it is the inadequacy one begins to feel when confronted with the product of a very capable machine, like a computer, that sparks the desire to compete with one's own human skills. A medium like paint can only be handled by the interaction of the eye and the hand, which behave with more dexterity than all the algorithms in all the computers in all the world.

The first half of the 1980s is seen by some as one of the most exciting periods for ideas in computer art. Experiments in image-making were carried out exuberantly. They were the halcyon days for artists working with computers. Use was made of the many technological innovations by a handful of contemporary visual artists and people in the advertising industry. In the early 1980s artists using computers, including myself, fell into one of the following categories:

- Contemporary visual artists who utilized computers to develop an algorithmic aesthetic of complex visual forms
- Artists who had developed their own personal pictorial language and embraced computers to accomplish a specific task
- Artists who saw the computer as a powerful servant for the advertising industry, fabricating fictions that flourished in a culture where real experience was being replaced by electronic representations

This essay is a painter's odyssey in which I have decided to isolate situations and events that connected my artistic practice with the technological innovations of computer image-making during the early 1980s. Images are the preferred repositories for my concept of values. Through my practice as a painter I wanted to find out how art created with the help of a computer could express the inner world of human feeling and subjectivity. In the course of working with computers we might come to believe they exhibit characteristics of intelligence. We can see they are capable of processing information, obeying rules, are competent assistants and useful tools. However, watching other artists working with them during this period I noticed two distinct aesthetics evolving.

The first was an algorithmic aesthetic, based on randomly generated geometric patterns: work done by a machine that has taken accident for its bride. These images were algorithmic in their nature because they were made using a program that resembled a cookbook solution to a problem: you do A, you do B, you get C. This was one kind of aesthetic prevalent at the time, the aesthetic of the technician.

The other approach was heuristic, where working with a computer involves having a strategy or point of view toward your work. In this case, the computer is a studio in which to work and where you can learn from your mistakes. This is my approach, the aesthetic of the artist pursuing his vision.

As Jasia Reichardt pointed out in the catalogue for *Cybernetic Serendipity*: "Computers cannot replace the dialogue between the artist, their ideas and the canvas. They cannot make abstractions because they are devoid of the three prime forces behind creativity, intuition, emotion and imagination. These are what each of us must supply when we come to use them."[1] While studying fine art at the University of Newcastle upon Tyne I embarked on a foundation course first introduced by Walter Gropius into the curriculum of the Bauhaus at Weimar. The course aimed at developing modes of thinking that were designed to induce a self-critical attitude in the student. I soon learned to question the significance of every mark I made. Malevich, Klee, Maholy-Nagy, and many other artists have considered the many separate factors which contribute to a work of art: plane, perspective, proportion, kinetic effects, and color—all the elements necessary for a theory of deductive art pedagogy. I was to continue to investigate these ingredients while at the Painting School of the Royal College of Art using the media of painting and computers, which I discovered in the Department of Design Research. This journey in the early 1980s was to lead to the groundbreaking project, *Digital Totems*.

In 1984 I had the opportunity to be a Harkness fellow at the Media Lab of the Massachusetts Institute of Technology. It was here that György Kepes had founded the Center for Advanced Visual Studies (CAVS) and now, as I arrived, Nicholas Negroponte was launching the new Media Lab. I soon organized a collaborative project with Scitex, Lightspeed, and IRIS called *Telegenic Charismas*, which was later shown at the MIT Museum's Compton Gallery.

My odyssey began during my period at the Royal College of Art 1980–1983. Christopher Evans had written *The Mighty Micro* (1979),[2] which sparked my interest in the new technologies he described. This interest was further heightened in 1980 by a major exhibition, *The Challenge of the Chip*[3] at the Science Museum, only a hundred yards from the Royal College of Art painting studios where I was working, which were then in the back of the Victoria and Albert Museum. The exhibition started with the history of the silicon chip and went on to explore its multitude of uses. The most striking example of the chips' versatility was a small, orange industrial robot. It had been given a break from its normal job of handling machine parts to be programmed to draw on a board, wipe it out, redraw it, wipe it out . . . eight hours a day.

From May to June 1981, BBC1 broadcast a five-part series called *Managing the Micro*. This series looked at the applications of microelectronics in industry and commerce in Britain. It explored the opportunities and implications for management and employees and was set firmly in the real world against the background of the recession that was taking place at the time. A key point in all the programs was that managing the micro was about managing change, the change that computer technology was bringing.

By 1981 the luminous graphic imagery of videogames was everywhere. I took some photographs of games called *Tank* and *Space Invaders* at an amusement arcade. It was the graphic language of the images on the screen that I wanted to explore. David R. Clark published *Computers for Imagemaking* in 1980. He saw that there were two distinct modes that could be adopted for drawing images: vector and raster systems. The latest generation of machines were raster-based like the ones used for videogaming, but before that the only worthwhile device had been the calligraphic or vector plotter. The difference between the two systems was not primarily one of technology; Clark saw an important philosophical difference. A rasterized image has the property that the strategies used to encode, transmit, and display it are in principle independent of the content of the image itself.[4] A vectorized image is composed of only that information required to form the image. These fundamental differences relate directly to the computational nature of the images. It was this pictorial language that I was later to refine and combine as I developed a painterly language to reflect these developments.

In 1981 the Royal College experienced a sea change when the chairman of the council and five colleagues resigned and a new rector had to be appointed. The academics blocked two strong candidates, but agreed to Dr. Lionel March from the Open University. He was not the sort of person, to judge by his track record, who was likely to disturb the college traditions. Dr. March, however, did not behave as the academics expected. He actually produced a plan for reform. Concentration on the arts and crafts was no longer enough. Indeed, Dr. March was concerned with introducing a measurable and rigorous approach to creativity, and wanted to use algorithms and generative grammars to do this, as evinced by an essay he wrote in 1983:

> Generative grammars provide the necessary theoretical foundation for design studies, as they do language theory. The sceptic may go far along this path but hesitate over the "imponderables" of design. Granting that formal and functional aspects of design may be subject to grammatical rules, the sceptic may nevertheless wish to claim immunity for the aesthetic dimension. This is the final stand of the spontaneous heart against the scheming mind.[5]

With the year 2000 beckoning, the college had to haul itself into the computer age. Dr. March was constrained by government budget cuts, so he sought economies in staffing, including voluntary redundancies. Nonetheless he appointed George Stiny from Stanford University as dean. Stiny had written about computer-based visual aesthetics in his book (with James Gips), *Algorithmic Aesthetics*. He proposed a structure for algorithms that could to be used both in art criticism and in the design of art works. These algorithms used the aesthetic components of description, interpretation, and evaluation, and could be expressed as mathematical functions,[6] although Stiny was careful to add that an extant work of art could not be produced from an algorithm nor critiqued simply by applying one.[7]

Prior to March's appointment, the locus for computer-based design at the RCA was the Design Research Unit, run by Patrick Purcell who died in 2007. Purcell was the senior research fellow in the Unit and attracted many important Science Research Council projects from the 1970s onwards. Other major British computer imagery research performed at the unit under Purcell's aegis included the Department of Environment's CEDAR computer-aided building design projects and the Natural Environment Research Council's Digital Cartography Unit.[8] He provided an important link between the computation facilities at Imperial College and the artists at the RCA and was later acknowledged by Sir Christopher Frayling, RCA rector and chairman of Art Council England: "Patrick was a pioneer of computing and design . . . long before art and design education caught up with the digital age. As a result he was something of a prophet without honour in his own country."[8]

During the spring term of 1982 I went to the Department of Design Research and met Purcell and Brian Reffin Smith. Smith was offering a workshop to introduce visual artists to the computer. He had written a paint program called "Jackson," after Jackson Pollock.

Smith has said that one of the most frequent modes of interaction between artists and computers is as follows: A person would come into the computer lab with a problem that they might normally try to solve using pen and paper, paint, film, or any other medium. They then use the computer to "worry at" their problem, using graphics on the computer screen, or other, more conceptual, representations of the problem. The person then, as often as not, would go away and carry on using the old materials—but their perception of the problem has changed. It has been externalized from the person to the computer screen a few inches away. So it was with me. Like Smith, I used computers to provide analogies, metaphors, and new ways of seeing. In the lab it was possible to do simple line drawings and print them on a vector plotter. The machine we used was a 380Z Research Machine. I digitized some mechanical illustrations from a book called *How Things Work*. It was packed with interesting diagrams. I processed these images on the 380Z using an inbetweening algorithm and then plotted them out on paper.[10]

On March 24, 1982, the exhibition *Artists/Computers/Art*[11] opened at the Canada House Cultural Centre Gallery in Trafalgar Square. The exhibition looked at the work of seven artists and one production company using computers in different ways, from the use of a computer to translate patterns of information into graphic forms to a computer adapting its behavior to different environments. The Disney feature film *TRON*[12] arrived in cinemas in 1982 demonstrating wireframe and constructive solid geometry to create dramatic visual effects. These techniques would soon be available to me through a unique course at Middlesex Polytechnic.

During 1982 interesting publications and articles were appearing, and I soon realized that much of the groundbreaking work in computer graphics had been started in the United States. On visiting the library of Imperial College it was exhilarating to find a copy of a SIGGRAPH journal packed with informative articles and images. In June 1982 I came across an article in *Audio Visual* magazine called "Poly Attract Auntie,"[13] which talked about BBC personnel who had produced credit sequences for different programs after having completed a computer graphics course at Middlesex Polytechnic. I decided that it was a course that would advance my knowledge of the visualization techniques I had witnessed in *TRON* and bring me closer to the pictorial language I was seeking in my painting. But the autumn term arrived and I could not afford the computer graphics course at Middlesex.

Meanwhile a new cohort of students had arrived at the RCA. Gareth Edwards had brought with him a BBC microcomputer and was writing code to create paint programs, which he invited me to use. During 1981 the BBC had announced it was to commission a microcomputer in connection with its television series on computer literacy. The BBC microcomputer became available in early 1982. Its size and cost made computing power available for personal use, and now, with Edwards's arrival, there was one close at hand. So I borrowed his BBC micro over Christmas. His paint program, TEGEA, enabled me to randomly alter color maps and thereby explore compositional changes based on contrasts of hue and color. I created compositions made from the plots I had developed on the 390Z Research Machine and at this point it was my ambition to translate the pictorial information I derived from the plots into a painterly language.

In the college studio I used acrylic medium to build a network of lines on canvas based on the vector plots. I then stained the resulting mesh with color. The stained background of acrylic gel and raw canvas were the backdrop for the sharply defined painted lines in the foreground. These paintings were useful experiments and finally one painting, *The Mother of Mirages*, established the painterly techniques I would later employ for the *Digital Totems*.

I called and wrote to at least ten companies to see if any would finance my taking the course at Middlesex Polytechnic. To my delight General Electric became my sponsor. The course was a means to create more sophisticated wireframe drawings. Also, at Middlesex I was to have access to a Prime 550 computer and a Calcomp digitizer, which would allow me to store my images in 3D form and have plotters draw out the resulting images.

During the spring of 1983 I produced a series of five-foot-square paintings for the upcoming degree show. I developed a systematic method of painting the canvases based on the plotted drawings and the raster information from the screen. I also produced a series of graphite drawings on paper that involved mixing graphite with acrylic gel to produce a rigid grey line that was raised from the surface of the paper. I then burnished the drawings, which gave the effect that they had been made with steel wire. The titles for this body of work were based on Angela Carter's book, *The Infernal Desire Machines of Dr. Hoffman* (1972).[14] All the work in my college degree show sold out with two of the drawings being purchased for the Imperial College Art Collection while one of the paintings, *The Coast of Africa* (figure 28.1), was bought by Dr. Wendy Baron for the Government Art Collection.

When I delivered the work to the Government Art Collection, Kenneth Baker, then Minister for Information Technology, was looking for artwork for his office; he chose *The Coast of Africa*. This meeting proved to be an important one for me because later in 1983, when I was working on the General Electric commission, he visited my studio on Tabernacle Street with a group of his colleagues and bought work for his own collection.

In June 1983, Dr. March resigned along with George Stiny, due to pressure from the academic staff. Jocelyn Stephens became rector thereafter and closed the Design Research Unit as part of a sweeping change in the RCA's direction. Much of the forward-thinking work initiated by Patrick Purcell and the others was terminated and computers as part of the curriculum at the RCA were still a long way off. Even later in 1992, when I was invited by Robin Baker to take up the post of Tutor for Computers in Printmaking, the professor who taught printmaking at the time

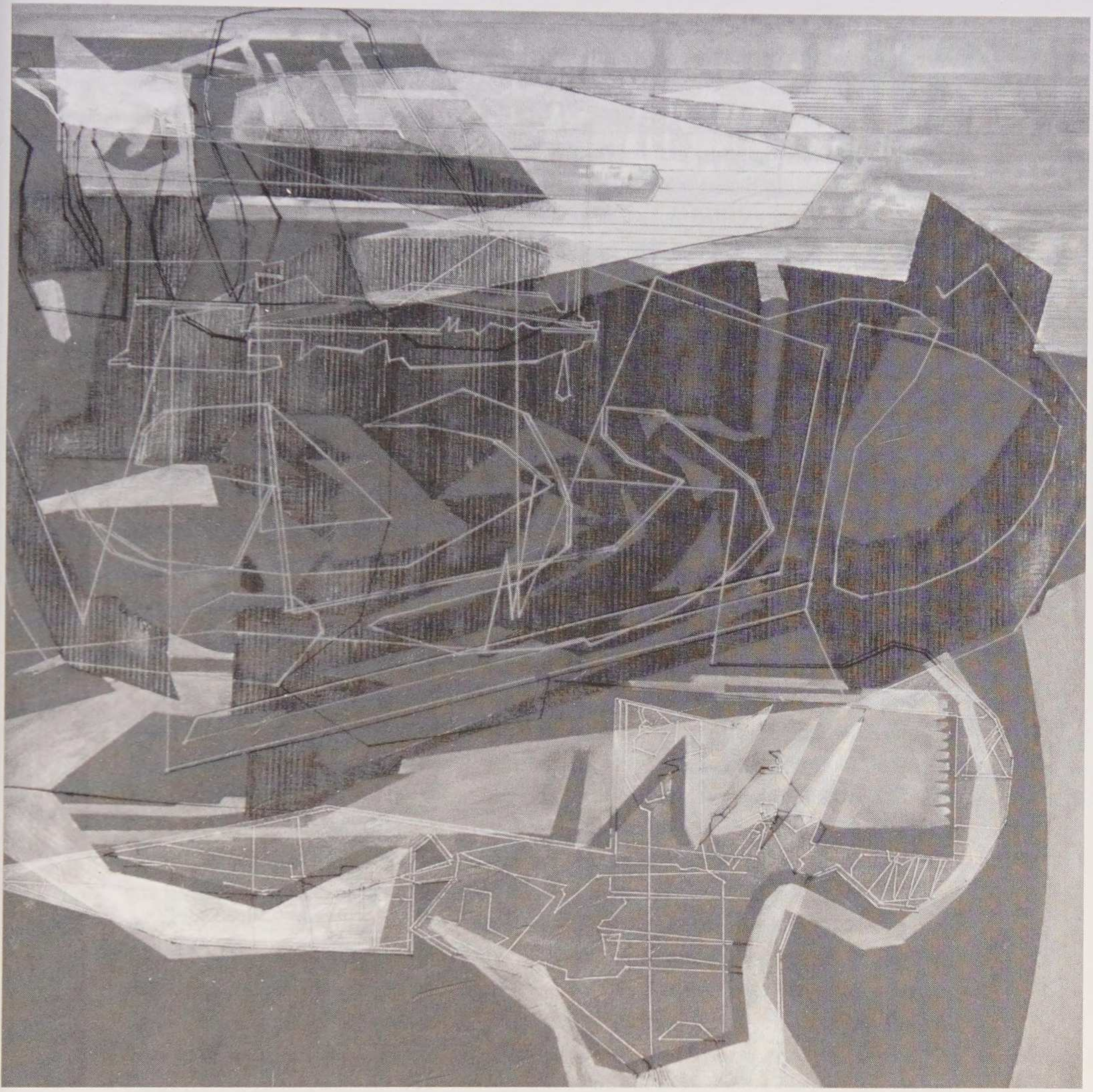

Figure 28.1 *The Coast of Africa,* acrylic on canvas 152 cm × 152 cm. Purchased by the Government Art Collection (www.gac.culture.gov.uk) from the Royal College of Art degree show exhibition, May 1983. Copyright © Jeremy Gardiner.

was not enthusiastic about the possibilities. Yet the students thrived on the opportunity to experiment with new image-processing software using the resources of the computing department.

There were other avenues to explore outside the RCA. For instance, in June 1983 Harold Cohen's one-person exhibition opened at the Tate Gallery.[13] The drawings his machines accomplished were the product of chance combined with set reactions. Produced by software called AARON using a Digital Equipment Corporation VAX 750 linked to plotters, Cohen was producing twelve works an hour. The exhibition was described as "more of a freak show than an art show" by art critic Marina Vaizey, who concluded that machines were only as good as their input. At that same time, Dr. Jim Howe at Edinburgh University's artificial intelligence department had developed a drawing device known as a "turtle." This computer-driven machine had been developed as an aid for children and the handicapped, and was capable of drawing sophisticated diagrams from a few basic commands. Originally a mathematician, Seymour Papert worked on cognitive development with Jean Piaget in Geneva in 1958–1963, where he first began his work of using mathematics in the service of understanding how children think and learn. Moving to MIT in the 1960s, he worked with Marvin Minsky, helping to found the Artificial Intelligence Laboratory and invent the programming language LISP. He also helped invent a simpler form of LISP called LOGO, which he constructed to allow children to program "turtles" to draw intricate geometrical figures.

The year 1983 also marked a dramatic step in my research thanks to a relationship with General Electric. Daryll Hooper, the director of the General Electric Hirst Research Centre, had generously supported my request to fund a short training in PICASO software based at Middlesex Polytechnic. He had visited the degree show in April 1983 and suggested a commission for the Hirst Research Centre. After an initial meeting the terms were agreed upon and I started the project in June. Martin Reiser, a lecturer in Electronic Arts at the City of London Polytechnic had seen my degree show at the Royal College and mentioned the possibility of using the computer facilities in the department where he worked for the GE project. They were using the same CAD software I had experimented with in my short course at Middlesex Polytechnic.

In the 1940s the painter John Tunnard had painted translucent planes interpenetrating one another with tension and equilibrium. He had used precision instruments, strange optical devices, forms of motion, the transformation of materials by lenses or rays to build a pictorial language. Inspired by Tunnard's work while working on the General Electric commission, I developed a new visual vocabulary that was based on what I learned from visiting many of GE's research departments, including x-ray crystallography, chip design, and telecommunications. I went through a collection of ancient plan chests that contained engineering drawings of GE designs from vacuum cleaners to missile guidance systems. My idea was to select component parts from these drawings and create vector plots in two and three dimensions.

I was able to process hundreds of these digitized drawings at the City of London Polytechnic. I used Gareth Edwards's new paint program TEGEA for the color studies. I was then able to develop a series of totemic paintings and drawings that encapsulated the spirit of research at GE and also embodied the exciting new graphic language of image-making with computers.

My workspace was the top floor of a SPACE studio at 47 Tabernacle Street in the City of London. SPACE is a registered charity founded in 1968 by artists Bridget Riley, Peter Sedgley, and Pete Townshend to provide affordable studios for artists in London. It was here I worked on the GE commission, which incorporated imagery from network protocols, man-machine systems, robotics and automation, and high performance chip designs. This body of work, called *Digital Totems*,[16] was displayed at the GE Hirst Research Centre in December 1983. Two of the paintings were exhibited at *Electra 83*[17] at Musee d'Art Moderne de la Ville de Paris. The exhibition was also seen at Galerie 39 on George Street, London; opened on April 10, 1984, at the Artshow Gallery in Fulham, London, in January 1985; and then opened at the Boston University Art Gallery in December 1985.

Like Odysseus, my explorations took me overseas, in my case to America and Canada. I arrived in Boston in June 1984 on a Churchill Fellowship. The brief for the fellowship was to "investigate computer graphics applications in art education." My first stop was MIT in Cambridge, Massachusetts. Here Patrick Purcell had found a new home (since leaving the RCA) in the Visible Language Workshop, part of the Media Lab, founded by Nicholas Negroponte, where he worked with projects involving motion capture and expert systems. Patrick was highly enthusiastic about the workshop, informing me that it had been fostering creative design in a range of graphic and visual applications, and encouraged and assisted me in applying for a Harkness Fellowship to study at MIT. Muriel Cooper was the guiding light of the workshop but she tragically died in the early 1990s while still presiding over this department of the Media Lab. The Harkness Fellowship enabled me to work at the Visible Language Workshop, at MIT's Media Lab, though this meant foregoing an opportunity to work at György Kepes's Center for Advanced Visual Studies, also at MIT. I was able, however, to attend Joseph Weizenbaum's class, "Computers and Society," which was actually taught by Sherry Turkle, who was about to publish her seminal study of the psychology of computer use, *The Second Self*.[18] While in the United States I was able to meet pioneers of computer art such as John Whitney Sr. and David Em; to make work; and to participate in shows in Boston, New York,

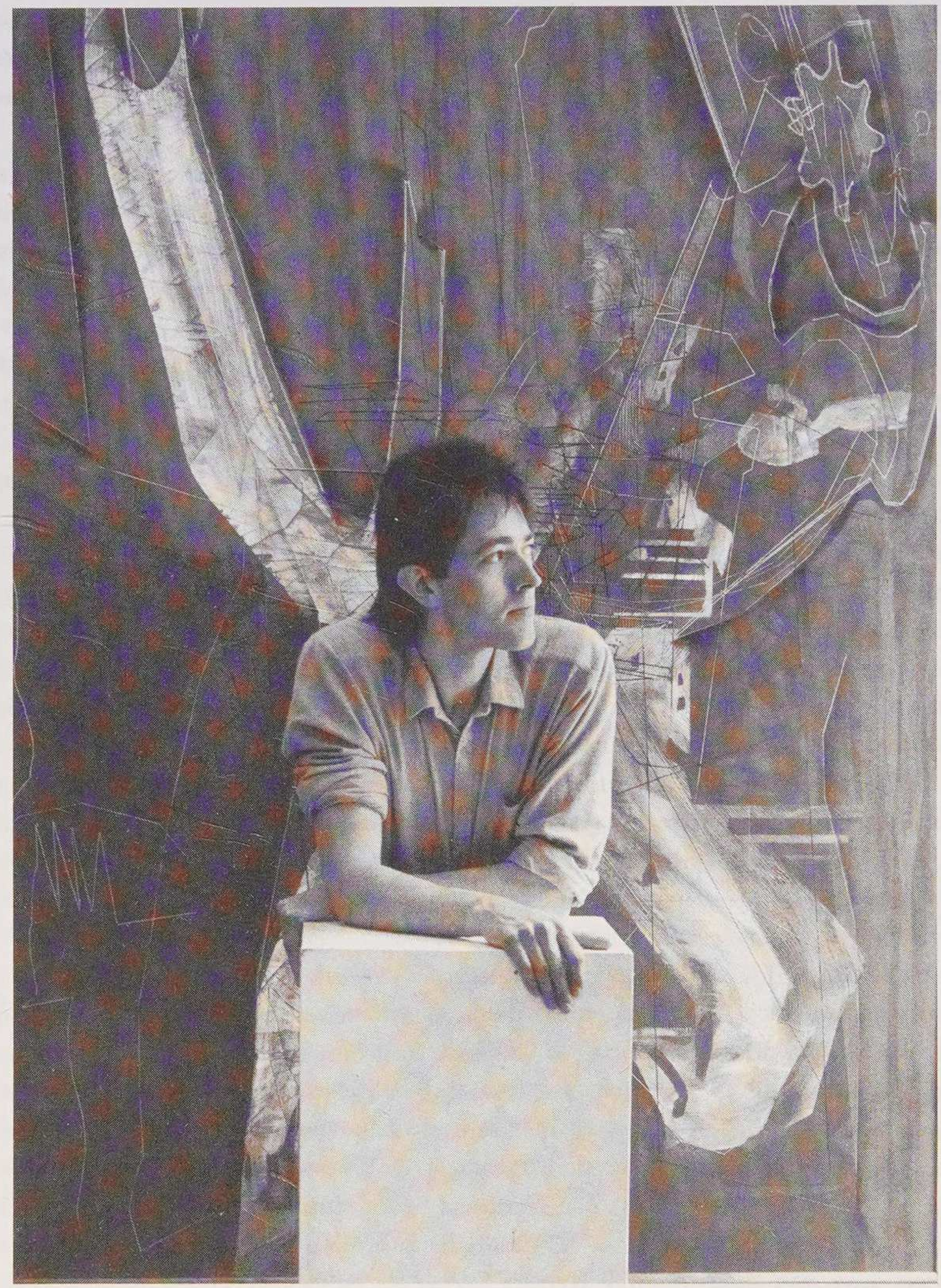

Figure 28.2 Jeremy Gardiner, *Digital Totems* exhibition, Hirst Research Centre, General Electric, Wembley, London, December 1983. *Farralone* (*Digital Totem*), acrylic on canvas 213 cm × 152 cm in the background. Copyright © Jeremy Gardiner.

and at SIGGRAPH '85, as well as the *Venice Biennale*—but all that is a later part of my odyssey.

By the end of 1985 I had collaborated with many different people, institutions, and corporations, investigated different kinds of hardware, explored the software then available, and had invented systems of my own to achieve the results I wanted.

The nature of my research had evolved as the tools had changed, but one aspect remained the same due to the complexity of the medium, and that was problem-solving. A small part of my odyssey was completed but there was a long way to go. For artists in the 1980s the search was fascinating, with emerging technologies offering the possibility of expanding painting in exciting new ways. For me the quest is ever fresh; the excitement continues.

Notes

1. Jasia Reichardt, *Cybernetic Serendipity: The Computer and the Arts* (London: Studio Vista, 1971).

2. Christopher Evans, *The Mighty Micro* (London: Victor Golancz Ltd., 1979).

3. *The Challenge of the Chip* exhibition, Science Museum, Exhibition Road, London 1980.

4. David R. Clark, *Computers for Imagemaking* (London: Pergamon Press, 1980).

5. Lionel March, "To Grasp Creativity," Private View 2, 4–5, quoted in UCLA Symposium on Design and Computation White Paper, ed. Lionel March (1997). Available at http://lmarch.bol.ucla.edu/shape/main.html.

6. George Stiny and James Gips, *Algorithmic Aesthetics: Computer Models for Criticism and Design in the Arts* (Berkeley: University of California Press, 1978), 4.

7. Ibid., 5.

8. From the obituary written for Patrick Purcell by George Mallen, Monday, March 5, 2007, for the Computer Arts Society, collated at http://sunnybains.typepad.com/patrick_purcell/.

9. From the obituary written by Dr. Sunny Bains for the Imperial EEE Department, Thursday, February 15, 2007, collated at http://sunnybains.typepad.com/patrick_purcell/.

10. Brian Reffin Smith, *Soft Computing, Art and Design* (N. Reading, MA: Addison-Wesley, 1984), 132: *The Mother of Mirages*, Illustration Plate 5.

11. *Artists/Computers/Art* exhibition, Canada House Cultural Centre Gallery, London, March 24–April 20, 1982.

12. *TRON*, directed by Stephen Lisberger (Walt Disney, 1982). Several computer graphics companies were involved in the making of *TRON*: MAGI Synthavision, Robert Abel and Associates, Digital Effects Inc., and Triple 1.

13. "Poly Attract Auntie," *Audio Journal* (June 1982).

14. Angela Carter, *The Infernal Desire Machine of Dr. Hoffman* (London: Chatto and Windus).

15. *Harold Cohen* exhibition, Tate Gallery, London 1983. The exhibition comprised four computer-driven drawing machines, programmed to make original drawings.

16. *Digital Totems* exhibition, Hirst Research Centre, Wembley, Middlesex, December 1983.

17. *Electra: L'Electricite et l'electronique dan l'art Xxe siecle* exhibition, Musee d'Art Moderna de la Ville de Paris, 1983; catalogue pp. 408–409. *A Republic of Insects and Grass* (Digital Totem). Acrylic and graphite on canvas, 183 × 152 cm. *The Devil's Alternative* (Digital Totem). Acrylic and graphite on canvas, 183 × 152 cm.

18. Sherry Turkle, *The Second Self* (New York: Simon and Schuster, 1984).

29

The Ironic Heirs to Serendipity: British New Media Art, 1980s to Now

Beryl Graham

The problem with net.art is that it is old hat. The problem with net.art is that it is too new.
—Steve Dietz, 1999

Discussing British "new media art" since the 1980s in the context of the history of "computer art" might sound like a pedestrian academic task, but it involves a quirky chronology. The artworks may have been around for decades, but the field seems to be permanently at a difficult stage in relation to institutions. As the curator Steve Dietz points out (albeit in relation to net.art), the reasons given for lack of acceptance by art institutions can be chronologically contradictory. Even the geography is a challenge to address in a field that is inherently international. The task also necessarily involves the quixotic quest of naming and categorizing the flailing arms of the offspring of . . . what? Are these lively artworks the heirs to computer art, technological history, conceptual art, or Dada?

Altogether, these challenges of taxonomy and chronology put this chapter at the spinning center of the difficult relationship between computer art and the wider art world. This is therefore not intended to be a comprehensive tracing of developments, but a making of links. Amid these difficulties, it is perhaps best to start with the most obvious reasons for thinking that these challenges are worth the trouble: the artwork and the artists, who lead where curators, critics, and historians can only stumble after.

Starting with the Art

Three artworks in the 2001 show *Art and Money Online*[1] exhibited a typically ambivalent chronological position: they were all recent artworks, by "established" artists

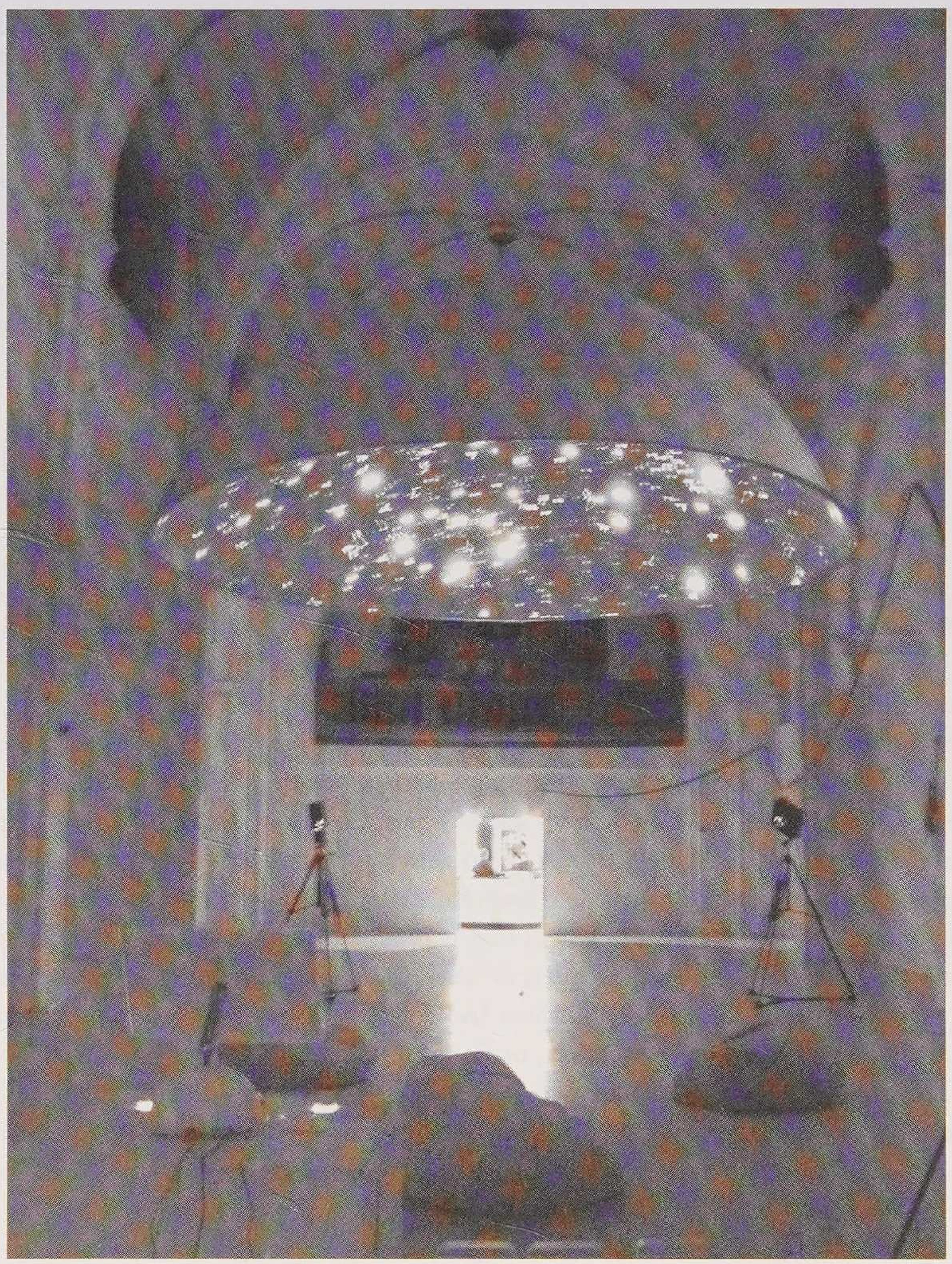

Figure 29.1 Lise Autogena and Joshua Portway, *Black Shoals Stock Market Planetarium*, 2001. Installation shot.

in the field, and yet they formed the very first exhibition of new media art in any Tate physical gallery space.[2] They also illustrated interesting naming problems—primarily, could any of these artworks be described as "computer art"? These are issues that are further explored in the following sections on taxonomies.

Black Shoals Stock Market Planetarium (2001) by Lise Autogena and Joshua Portway (figure 29.1) used the online stream of live stock market data to make a visualization of stars in the night sky, which became brighter or died according to volume of trading. The stars also moved to form constellations, according to the relationship between companies. In addition to this direct visualization, the artists made small abstract graphics that exhibited artificial life behavior by feeding off the light of stars and evolving through survival of the fittest. The graphics were projected up into a ceiling dome, and the audience were provided with beanbag chairs for reclining, to contemplate the slowly moving drama in the dark. This artwork certainly involved computer programming, and could not exist without the algorithmic and generative behavior of computer programs, or the live online datastream via the Internet. Autogena is an artist who has worked on sculptural and conceptual projects, including one on concrete radar dishes, and Portway has worked on commercial design projects including computer games. So, is this straightforward computer visualization, art, or design?

CNN Interactive Just Got More Interactive (2001) by Jon Thomson and Alison Craighead (figure 29.2) was a software addition to the existing CNN news website. Users were able to select their own "audio mood" music to accompany the news item they were viewing. Moods included "jubilant," "melancholy," and "dramatic," which could dramatically change the meaning and reading of the news, and challenge the idea that online news is a neutral and transparent "window" on the world. Again this artwork involved computer programming, and could not exist without the live data of the Internet. It combined sound and images was time-based, offered basic interaction, and enabled the user to exert "choice." Both Jon Thomson and Alison Craighead studied fine art and taught themselves programming.

Free Agent (2001) by Redundant Technology Initiative (figure 29.3) was a low-tech, mismatched video wall of recycled discarded computer monitors, displaying the word "free." (Images were taken from video footage of shopping centers and from the Internet.) The words were rendered semi-abstract by distortion, and the installation had a functional aesthetic of metal shelves and trailing cables. Some of the image content for this artwork came from websites, but the display was not using live Internet data. Free software was used in the process of programming of the images and coordination of the screens, but was not necessarily evident in the installation. Is this therefore computer art, media art, or "abstract art"? Is it art or a community project? Redundant Technology Initiative, based in Sheffield, United Kingdom, are a group workshop who recycle discarded outmoded computers into workable tools, using and making free software, offering an open-access computer

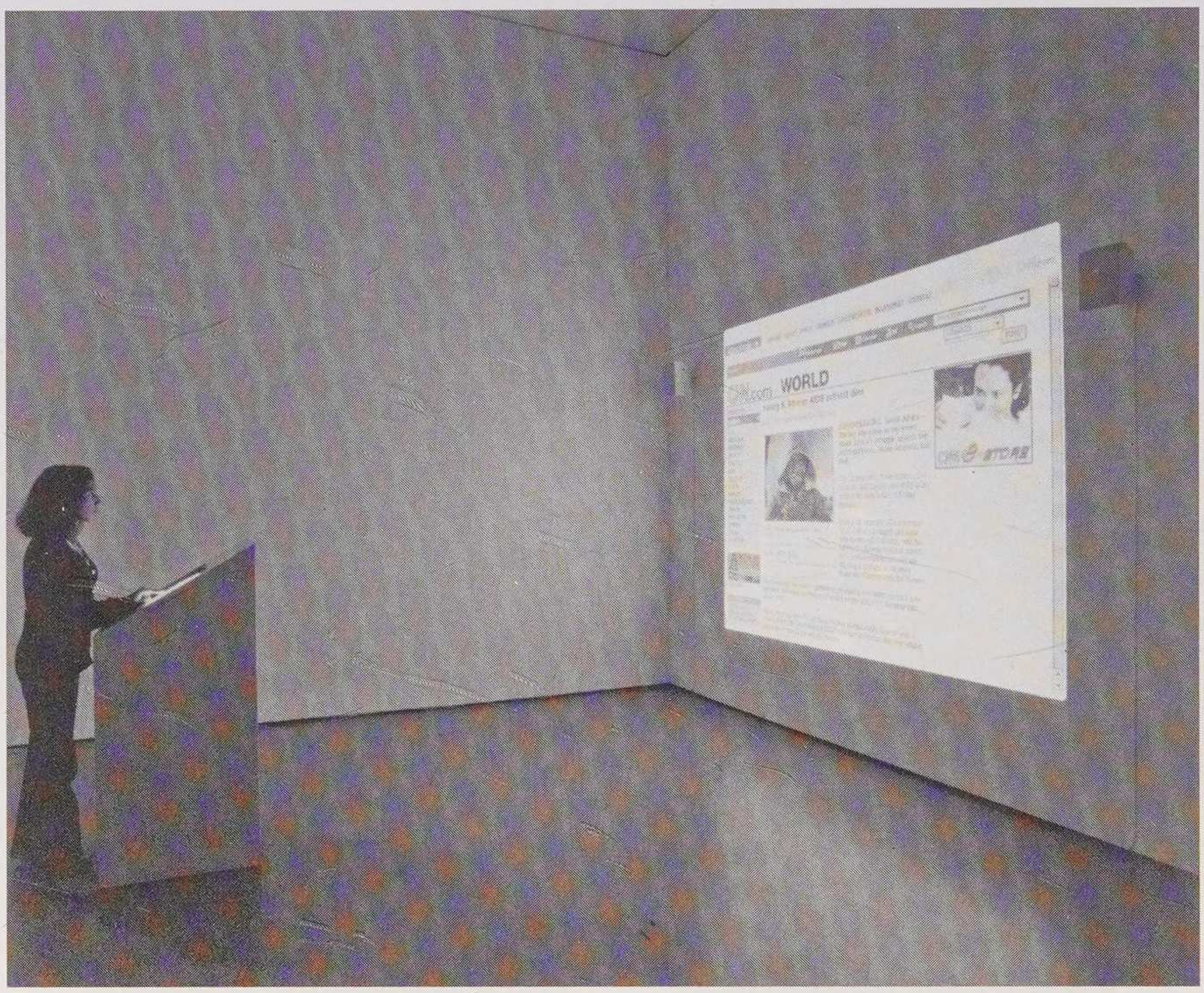

Figure 29.2 Jon Thomson and Alison Craighead, *CNN Interactive Just Got More Interactive*, 2001. Installation shot.

lab, and paying volunteers with non-cash local barter credits. They do make art installations, but would not necessarily describe themselves as artists. James Wallbank, a founding member of RTI, has an MA in art and design, and a background in sculpture and public art.

The position of the exhibition as a whole was also characteristic of the "difficult stage" of new media art. *Art and Money Online* was curated for Tate Britain (rather than Tate Modern), by Julian Stallabrass, former Paul Mellon Centre fellow at Tate Britain, and hence a visiting academic (part of "research" rather than a permanent member of curatorial staff). The show was part of the *Art Now* program of exhibitions "that aims to generate discussion and promote awareness of new art in Britain," and was located in two rather small rooms at the end of a larger gallery.

So, what do these artworks have in common, apart from computers, wit, strong vision, a diversity of backgrounds, and a pattern of collaborative work rather than

Figure 29.3 Redundant Technology Initiative, *Free Agent,* 2001. Installation shot.

solo production? And how does it relate to the older tradition of computer art? In order to explore these questions, it is necessary to tilt at the windmills of taxonomy.

Proper Names—Turing-land or Duchamp-land

Before moving on to the more complex categories of taxonomy, there is the nagging question: "Why isn't this called computer art any more?" The term "computer art" seems to have fallen into disuse for two reasons: One is the dumb chance of it being overtaken in the fashionable stampede of sexier words such as digital art, art and engineering, emerging technologies, unstable media, variable media, interdisciplinary art, memes, artsci, art that you plug in, or (a term with a restricted lifespan if ever there was one) "new media art."[3] Each new term may have been attempting to be more accurate as well as more modish, but none has been particularly satisfactory. The other more serious reason is a rejection of the term because of its associated value systems. As Brian Reffin Smith pointed out in 1984, a caricature of "computer art," perhaps thanks to bad marketing and the tradeshow mindset, could be painted as

a) meretricious
b) falsely portentious
c) crassly "thrusting" and futuristic.[4]

Another value system particularly connected with computer art is that of modernism, as identified by Paul Brown in 2004: "In consequence the computational work was identified with technological absolutism and the modernistic emphasis on intrinsic media qualities. If it had occurred later it might have been more correctly identified with more postmodern concerns like non-linearity and emergence."[5]

Artists who grew up with postmodernism, such as Keith Tyson (a Turner Prize winner and hence much scorned by the British popular press) have no problem using any media necessary to make their art. His work includes paintings, the *Artmachine* system (1999), and an early Internet art piece, *Replicators* (1996). *Expanded Photographic Encapsulation* (1999) consists of 101 touch-sensitive light units spread across a large area of the floor, each one containing a microprocessor wired and connected by word association.

Thus, while the artworld has tended to caricature computer art, the computer art world has in turn been unnecessarily suspicious of postmodernism,[6] and hence isolated itself from contemporary art by sticking to modernist categories of abstracts/portraits, or the 1960s emerging technology of geometric computer graphic prints. In 1996, after considering the International Symposium of Electronic Arts (ISEA) and Ars Electronica festivals and the discussion of "convergence," Lev Manovich posted a short article called "The Death of Computer Art," in which he set up the opposing categories of Duchamp-land and Turing-land: "In the following, I will refer to art world—galleries, major museums, prestigious art journals—as Duchamp-land, in analogy with Disneyland. I will also refer to the world of computer arts, as exemplified by ISEA, Ars Electronica, SIGGRAPH art shows, etc. as Turing-land."[7] Manovich outlines three major indicators which define "contemporary art" as admitted by Duchamp-land—indicators which have their opposites in Turing-land. I'll paraphrase these, and try to relate them to some British art.

1. *Content (in Turing-land the emphasis is on what the technology can do)* In 1995, Harwood's Installation, *Rehearsal of Memory*, got a lot of attention at ISEA, despite a simple technological interface, of point-and-click single screen, because of its strength of content. The artist had worked with residents of a high-security mental

hospital and scanned in body parts to make a collective map of body surfaces, complete with scars and tattoos. Clicking on the scars revealed painful stories of self-harm and childhood abuse. The strong content meant that the point-and-click interface became a probing into wounds, totally changing the value of the interaction. In 1996, Ann Whitehurst's *NetEscape* used physical game trails, and Internet-based messages to explore physical presence and absence, including issues of disability (people with disabilities being some of the first users of computer-enabled communication devices). In both of these cases, as well as in the three *Art and Money Online* artworks, the art has strong content in addition to using the unique characteristics of the media.

Steam Powered Internet Computer (2002) by Jeremy Deller and Alan Kane, is, as the title suggests, a computer offering free Internet access in a gallery space, powered by a scale-model working steam engine (usually run by local model train enthusiasts). Here, the content of the work is about computers, and "art in technological times,"[8] although the work would not necessarily be described as new media art, because it is not made using the unique characteristics of the media. Like some other art/science projects, the content is consciously *about* science or technology, rather than being made or distributed with the technology.[9]

2. *Complicated (Turing-land works are simple and lack irony)* This is perhaps the most difficult of Manovich's characteristics. Some art is elegantly simple, some Internet art makes very minimalist points, whereas some computer art refers to a multitude of technological cultural codes (which may not necessarily be understood by art curators).

However, if Manovich's "multitude of cultural codes" is taken to mean a wider understanding of culture, then the rise of cultural theory during the 1980s means that anyone who was doing an art, media, media studies, or culture course in the United Kingdom at that time was also likely to be very informed on the politics of representation concerning gender, race, class, and power. Some of the community-based political media workshops of the 1980s metamorphosed into new media workshops in the 1990s; for example Artec, based in London, where Graham Harwood worked for a number of years, and which trained and supported others. In 1994, at the Digital Dreams conference in Newcastle, Peter Dunn of *Art of Change* (formerly the *Docklands Community Poster Project* 1981–1990) described how the new tools for photomontage and internet communication matched the new politics of globalization and empire.[10] Roshini Kempadoo is another artist from a political media background who moved into Internet art with *Virtual Exiles* (2000), and Heath Bunting of the politicized artists' group irational (*sic*) is just one of the younger generation of artists moving between media, Internet, hacking, activism and physical journeys for his artwork, such as *BorderXing Guide* (2003), which concerns illegal routes for immigration.

Those doing computer programming or design courses or who studied art before the 1960s, are perhaps less likely to share the political understanding of culture exemplified previously, and hence this is a potential divide between Duchamp-land and Turing-land. For example, when examining the work of Harold Cohen, contemporary art critics may be struck more by the content of the work, such as his representations of women, than by the technology and techniques.

3. *Ironic (Turing-land takes technology seriously and is distressed by malfunction)* The ironic point of view is self-referential. It takes a Destructive Attitude toward its Own Material, and a Dada-esque Enjoyment in Things That Go Wrong. British culture, as well as being political, is nothing if not ironic. This might explain why British artists often reference Eastern European artists such as Olia Lialana, Vuk Cosic, and Alexei Shulgin for their low budget approach and wit, rather than more utopian California technophiles, or new age followers.[11] Shulgin, in his Internet *Form Art* competition (1997), uses the mundane functions of online check-boxes to satirize both technology and modernist art. Shulgin is a computer programmer who manages to challenge Manovich's division by being immaculately, wittily ironic throughout his work. In the United Kingdom, Richard Wright's *Bank of Time* (2001) is a fine example of programmed irony. Here, plants grow across your computer screen, not as a celebratory showcase for generative software or efficiency, but as an illustration of how much idleness your computer logs. *Black Shoals Stock Market Planetarium* (2001), for all its use of powerful and expensive data, has ironic readings that depend on whether or not you see any similarity between parasitic competitive artificial life, and stockbrokers.

It could be argued that British computer artwork is particularly strong in the indicators of Duchamp-land, and yet, still, the only new media art permanently on display in any museum in London is in the Science Museum.[12] There are plenty who disagree with Manovich's binary division, and argue for a self-defining field, including Clive Gillman in 2001: "In Lev's scenario Duchamp-land holds most of the deeds and Turing-land is on the streets. This view could be equally be expressed in terms which favour the alternative; Duchamp-land is barren, Turing-land is fertile, but unfulfilled. Why should they want to get together?"[13]

As Gillman also points out, the borders are not yet closed between the two lands, and, as covered later in this chapter, cross-country adventures are still possible, along with hybrid vigor and interdisciplinarity.

Working Taxonomies: How Did We Get Here from There?

I've been referring to artworks that might be described as Internet art, interactive installations, media art, or software art, but in order to explore who might be the contemporary British heirs to computer art, I'll briefly summarize some current debates on taxonomy. In 2005, I wrote a paper for *Museums and the Web 2005*,[14] and a key point of reference was some admirably fluid artist-led taxonomies such as the University of Openess's (sic) Wiki-based *Faculty of Taxonomy*. Elaborating on this, my 2007 chapter in *Theorizing Digital Cultural Heritage*[15] also looks in more detail at some binary categories, including

- Digital Art/Art Interpretation
- Production/Distribution
- Art/Science, Art/Engineering
- Net/Not Net (Immaterial/Material/)
- Tool/Medium
- Archiving/Preserving

To summarize the conclusions: curators have found it useful to consider the broad range of new media, digital, or computer art not in terms of media but in terms of "characteristics" or "medium independent behaviours."[16] Of these characteristics, Steve Dietz's "Interactivity, Connectivity, Computability"[17] were found to be usefully applicable, and have been "translated" into art-world language by Sarah Cook in 2004,[18] with additional considerations of production and distribution (figure 29.4).

To look at Dietz's three characteristics in more detail:

"Computability" is how Dietz terms the particular characteristic of a software-driven computer, which is "unique, among media, in its ability to understand and act upon symbolic instruction sets algorithmically." He also mentions "procedural authorship," which leads to the "generative" nature of instruction sets. The artwork *Black Shoals Stock Market Planetarium* (2001) for example, starts with a set of instructions and procedures decided by the artists, but the behaviors of the images that are generated by those instructions are not fully under the control of the artist, as they are generated and evolve over time.

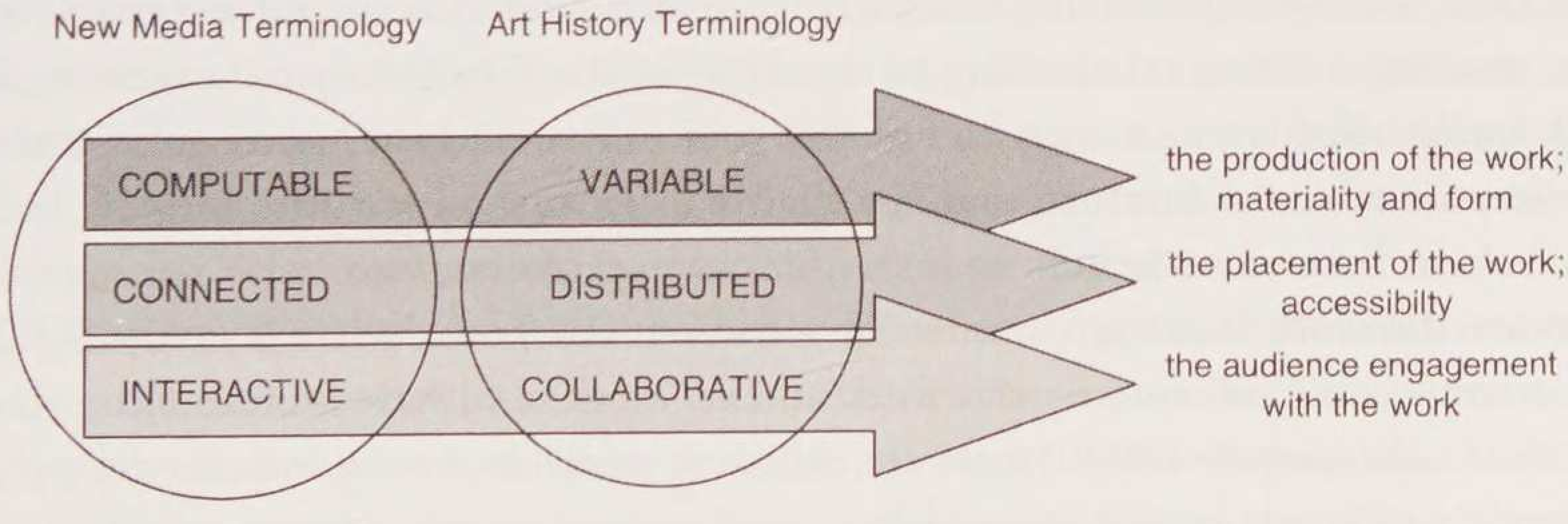

Figure 29.4 Sarah Cook's 2004 diagram giving art-world parallels to Steve Dietz's three characteristics of net art.

"Connectivity" usefully encompasses telematic, locative or GPS technologies, web streaming of media, and any networked or Internet artwork. Thomson and Craighead's *Telephony* (2000), for example, uses both old and new technologies of connection to link lie-detector software to the voices of automated telephone speaking clocks of various countries, and produces reams of print-outs evaluating the likely truthfulness of those voices.

"Interactivity" is a notoriously loosely used term, but it has received serious attempts at more accurate definition.[19] Interactivity ranges from the kind of simplistic choices satirized by Thomson and Craighead's *CNN Interactive Just Got More Interactive* (2001), to participatory projects where people can contribute creative input online.

These characteristics in combination can roughly describe the "new media art" field, but might exclude some "digital art" that simply uses software, such as digital photography/video/sound, computer graphics, computer animation, etc. On the computer art side, this might also exclude purely scientific or engineering/mechanical projects that have no "computability." So, to look at computability in particular . . .

Is Computability the Heir to Computer Art?

Both "software art" and "generative art"[20] have Dietz's characteristic of computability, and both areas will be looked at here. In 1992 the Prix Ars Electronica specifically encouraged those who "develop those custom programs necessary for the creation of their images,"[21] but contemporary understandings of those who make software art are less likely to fit the older model of an artist making straightforward software tools that offer ersatz, digital versions of painting, and are more likely to live between Duchamp-land and Turing-land.

Adrian Ward, for example, made *Autoshop* and *Autoillustrator*, both softwares designed to ironically comment on commercial software, and to play creatively with ideas of control and authorship.[22] Software art such as *The Web Stalker* (1997) by I/O/D, are not only visually innovative, but designed to be useful, accessible and free, showing a strong relationship to the ethics of the Free Software movement. *The Web Stalker* offers various ways to visualise and understand the power relationships between data on the Internet, and is a highly experimental software project, living somewhere between research and art. Software projects often raise questions of whether the work is art or commercial software. The London-based group SODA, for example, do both commercial work and art work, and have won design awards for their *sodaconstructor* (2000) software, which is available on the Internet for people to freely participate in and use on-line.

As Olga Goriunova and Alexei Shulgin explored in 2002, a key feature of software art is the tension between the rational and the non-rational, and the joy of chance exploited by the dadaists.[23] If games can be considered part of this, then there are some key inheritors. Tom Betts in QQQ (2002) for example, takes a Doom-type computer game and radically alters the way that it looks, while allowing the interaction to be recognizable. Ruth Catlow, conversely, has made *Rethinking Wargames* (2003–), a computer chess game for three that very deliberately changes the interaction—the pawns are no longer, well, pawns in the game. Artists Simon Yuill and Chad McCail are currently working together on *spring_alpha*, a very complex simulated city environment with a dystopian world view.

Artworks with algorithmic characteristics of computability (including evolution through time) but which are not necessarily "tools,"[24] tend to be called "generative." Jane Prophet's *Technosphere* (1995) could be looked on as an early example of this, where creatures designed by the user must survive and evolve in a world where the starting rules are decided by the artist. Sneha Solanki's *The Lovers* (2002) sends a software virus between an installation of two computers bathed in romantic red light, gradually corrupting the text of "My Love Is Like a Red, Red Rose" into a gibberish of letters and symbols.

Solanki's work reminds us that computer art can also exist in the physical world, the algorithmic instruction sets of software can control objects, and in the spirit of computer art in the twenty-first century, robotics have not been forgotten—although the power and spectacle of technology is more likely to be replaced by or approached with irony. In Cavan Convery's *Vertical Scroll* (2003) the user can control, from a computer, the robotic movement of a scroll of paper with hand-drawn images, which can be watched in on-screen video. Crispin Jones's *An Invisible Force* (2002) is a computer-controlled robotic fortune-telling desk with a deliberately sinister interaction; the user must press an uncomfortably hot interface slot if they wish to see the end of their prediction.

So, is software art the purebred heir of computer art? It is certainly the genre involving most raw code programming. Computability is certainly the characteristic that can only be offered by computers (it could be argued that both connectivity and interaction have some analogue equivalents). However, this does assume that software art is not already a hybrid between Turing-land and Duchamp-land, and that computer art was purebred in the first place. In practice, it tended to include analogue engineering, physics, mechanics, poets, sound concerts, and ballet dancers in tutus. The connectivity characteristic would be perhaps the most unfamiliar to the older generation of computer artists (the Internet, mobile phone, and locative technology being relatively recent), and there is still a certain amount of skepticism concerning Internet art. Nevertheless, Dietz did specify a *combination* of characteristics.

Spencer Roberts and Anneke Pettican's current work-in-progress *Newsdrip* (2005–) is an example sitting interestingly at the intersection of the three characteristics. Software was written to draw live data from Internet news pages and evaluate the frequency of mentions of news from particular parts of the world. These are logged onto maps, so that the most news-active areas at that time appear to be actively rippling. The physical installation will involve computer-controlled drips of water over a physical map (a sort of liquid robotics). The work will be basically interactive via a website that enables users to input proper nouns and to see graphs of the frequency of news mentions for that word. Thus, it could be said to be fitting into all three of Dietz's characteristics. Might this have gained the approval of computer art forebears, keeping in mind the cross-disciplinary nature of the original venture?

The spirit of early computer art could be said to have some surviving heirs, even if the political value system of that time does not. If the artworks can be described as a combination of characteristics rather than of media, then all three of Dietz's characteristics can be said to present new challenges to curators, even those familiar with media such as video.[25] In considering software art in particular as compared to computer art of the 1960s, then in addition to Manovich's 1996 indicators of the distance between art and computer art, there are more recent differences of context. Inke Arns pointed out in 2005 that there are differences both in concept (computer art primarily considered software to be a tool in the process of creating a finished art object, whereas in software art, the software *is* the art) and in context (in the 1960s, the computers were in specialized and inaccessible academic cultures, whereas now they are nearing ubiquity, and have created their own popular culture).[26] However, if the *combination* of all three of Dietz's characteristics are considered, then there is the possibility that the heirs who most fondly remember computer art are more hybrid or interdisciplinary than purely algorithm-based.[27] In which case, then, the question arises: which disciplines are combined?

Which Disciplines?

As I explored in my 2005 paper,[28] the categories, development, and understanding of new media art tend to be heavily influenced by the discipline a person comes from. As postmodernism tends to encourage interdisciplinarity, there are plenty of examples of artists crossing media throughout their careers: Keith Tyson as already mentioned; Stephen Willats and his "systems," both analogue and computer; Nina Pope and Karen Guthrie, who had work on the early *Toybox* CD-ROM in 1994[29] and have also worked with online journeys, participatory community projects, Internet broadcasting, and performance in historical costume; and Rod Dickinson, whose work includes making the huge fantasy machine the *Air Loom* (2003) and video documented re-enactments of *The Milgram Experiment: Obedience to Authority* (2002).

An obvious crossing over has been from old media (photography, video, film) into new media, notably: Tim Head's move from media installation into the aesthetic qualities of computer screens; and Keith Piper's inclusion of CD-ROM work.

Even within new media art, there is a great deal of interdisciplinarity: Tessa Elliot and Jonathan Jones Morris's early dance-influenced interactive video installations; Nick Crowe's Internet art, installations of etched glass plates, and Internet "radio station" of policemen's selections; Greyworld's interactive sound and telematic installations; and Squidsoup's interactive sound and visuals.

Squidsoup, along with SODA, bring up another binary category very relevant to new media art: art/design. The vast majority of computer courses concern design rather than art, and interdisciplinarity in this area often causes consternation in the minds of art curators over the positioning of the work in the class hierarchy, as well as consternation in the minds of designers over the "useless utilities"[30] of ironic software art. As Lisa Haskel cogently states: "The difference in cultural and economic currencies attached to the'pure' and the'applied' has been a persistent problem in European culture' and is of particular importance to new media art."[31]

Hybrid Vigors

The inspiring thing about the heirs of computer art is that despite the different lands and the difficult hierarchies, cross-fertilization and true interdisciplinarity[32] does manage to take place. The Arts Council of England, to its credit, funded both SODA and Jon Thomson and Alison Craighead when it had a New Media Projects Fund.[33] The Lansdown Centre for Electronic Arts (home of one of the few computer art courses to encourage raw programming rather than using software) has alumni in Squidsoup, SODA, The Media Centre Huddersfield, and on the editorial team for this volume. The i-DAT center has taken the inheritance of Centre for Advanced Enquiry in the Interactive Arts (CAiiA) and hybridized the specialist computer art approach with fine art and contemporary curating expertise.[34] Catherine Mason's research very usefully identifies the important role that educational institutions have on facilitating the experimental approach needed for production,[35] but it is also important to note that many of the most interesting artists have a background that is "other": to cite artists in this chapter, Graham Harwood's background is in graphic novels; Nick Crowe studied English literature and drama; and Spencer Roberts's first degree is philosophy.

An important lesson to learn from the interdisciplinary roots of computer art is that instead of the traditional solo model, working in small teams (still rather unusual in the art world) can truly enable the collaborative process of production, such as Joshua Portway and Lise Autogena, Jon Thomson and Alison Craighead, and irational. It is notable that those who *make* the artwork, in both Turing-land and Duchamp-land, often find that they have more in common than those who curate or theorize about the different disciplines. Unsurprisingly, it is often small artist-led agencies such as low-fi (who commissioned the Cavan Convery work mentioned here) or Furtherfield (including Ruth Catlow) that understand the process, and that, despite lack of resources, can move fast to make good work happen.

Those in Turing-land tend to look for the blockbuster media-specialist show as a sign of artworld acceptance, but it could be argued that being included in mixed shows is more of a sign of equal footing.[36] It is worth considering that *Cybernetic Serendipity* in 1968 was not a show of computer art: it was a show of computer art, computers, paintings of computers, technological objects, and included Bridget Riley paintings along with computer graphics. In 1996, the exhibition *Serious Games* included no-tech interactive art alongside new media art. In 2002, *Art For Networks* included both Internet art, and the no-tech systems art of Stephen Willats; *Generator* (2002) likewise included Yoko Ono's "generative" artwork. *Database Imaginary* (2004) featured Hans Haacke's questionnaire work, and *RISK* (2005), exhibited both Internet-based and analogue activist art. However, it is notable that the reverse still more rarely applies; for example in 2005, *Open Systems: Rethinking Art c. 1970* explored thirty-two artists' "experimental aesthetic systems across a variety of media"[37] from the 1960s and 1970s, and included Hans Haacke's work, but included no work made using computers.

On the other hand the 2007 exhibition *FEEDBACK* at the Laboral Centre for Art and Industrial Creation in Gijon in Northern Spain, curated by Christiane Paul, Jemima Rellie, and Charlie Gere, was a show devoted to art involving "art responsive to instructions, input, or its environment," which featured work by technological artists such as Edward Ihnatowicz and Paul Sermon, but also by artists more readily associated with Duchamp-land—Lygia Clark, Sol LeWitt, and Duchamp himself. In this case the aim of the curators was not to assimilate art from Turing-land into Duchamp-land, but to suggest an alternative genealogy of artistic modernity, leading to new media art.

So, if the approach of interdisciplinarity is as important as "pure" software art, then the communication between the disciplines is of key importance. While a certain amount of convergence is slowly taking place, there is still a definite problem of ignorance of each others' histories, and as we all know, those who control the past control the future . . .

The Slightly More Remote Future . . .[38]

As Pauline van Mourik Broekman has wittily illustrated in a diagram of the development of *MUTE* magazine, evolution does not always happen in a straight timeline. Tamas Banovich pointed out in 2001 that the problem of lag is a serious schism in the relationship between art institutions and new media practitioners.[39] Hence Heath Bunting has described himself as "retired" while some curators are still struggling with the idea of video art. The peaks and troughs of blockbuster shows followed by individual curators moving on, and poor documentation, means that exhibitions are often forgotten, and critical mass is never reached.

In 1998, thirty years after *Cybernetic Serendipity*, freelance curators Lisa Haskel and Helen Sloan proposed a major exhibition at the ICA that would reflect critically on the history of computer art in relation to contemporary work. Problems of funding, institutional support, and the lack of preservation of older work led to a more contemporary exhibition, *star.dot.star*.[40] In examining the documentation of past exhibitions, certain recurring factors can produce a feeling of déjà vu—in particular, issues of press coverage and funding. In 1968, press coverage of *Cybernetic Serendipity* stressed family fun and futuristic technology, at the expense of critical response.[41] In 1996–1967, the same could be said for *Serious Games*,[42] and in 2001 for San Francisco Museum of Modern Art's *010101*.[43] With all three of the foregoing exhibitions, as well as with *Art and Money Online*, considerable costs meant, "the need for corporate involvement was considerable,"[44] which led to a tension between art ethics and corporate expectations.[45] All this makes public funding even more important, but this periodically comes under critical examination in itself.[46]

To return to the quirky chronology of computer art mentioned at the start of this chapter, the development curve of the field has been hampered by patchy documentation, leading to recurring issues of critical responses that are not informed by technological histories, and so are often simple reactions to the newness of new technologies. A lack of understanding of the characteristics and behaviors involved in new media art, which work across media rather than being safely confined to one medium as understood by art history, compounds this problem of critical response. Books like this one, and the ability of new media artists to describe, debate, and document themselves via discussion lists and websites, are starting to improve the documentation of such histories, but the question remains of how much of this is admitted into the annals of Duchampland.

In order to translate between the two lands of Turing and Duchamp, cross-disciplinary practice is necessary, and to an extent this has been supported by both art and academic funding sources.[47] Contemporary British software artists, with their understanding of networks or systems, and their politicized, ironic views of both art and technology, serendipitously might find themselves as translators between lands, and heirs to early computer art. It should not be assumed, however, that all the traffic is Turing artists wanting to enter the land of Duchamp: Matt Fuller in 1998 pointedly described software art such as *The Web Stalker* as "not-just-art"[48] because of the multiple cultural codes involved—much wider than just the field of art. There is therefore a strong British tradition of artists seeking for software art and Internet art to be judged and distributed on their own terms, rather than on the terms of art institutions.

As new technologies become more ubiquitous, even within the portals of the museum, the "slightly more remote future" has reasons to be cheerful. Art using computers has started to change the ways that some institutions work and think,[49] and the improving documentation of such work means that such knowledge can feed into the future. Curating courses in the United Kingdom have started to become interested in understanding the demands of new media art, and can only realistically be led by the artists in this.[50] The unpredictable, flailing and illuminating nature of the art, and the politicized, ironic nature of the art scene in the United Kingdom, promises that British new media art will continue to live in interesting times.

Notes

1. Julian Stallabrass discusses this exhibition in Sarah Cook, Beryl Graham, and Sarah Martin, eds., *Curating New Media* (Gateshead, UK: Baltic Centre for Contemporary Art, 2002), 17–43.

2. The Tate had by then already commissioned its first net art piece: Harwood@Mongrel's *Uncomfortable Proximity*; discussed in Sarah Cook, "An Interview with Matthew Gansallo," *CRUMB: New Media Curating Resource*, 2001. Available at http://www.crumbweb.org/getinterviewDetail.php?id=1.

3. Although imperfect, I'll use the term here because it is a widely understood contemporary word for the approximate area of artwork included in Stephen Dietz's three categories explored later in this chapter. My selections for this chapter have a bias toward visual arts, reflecting the bias of the major arts organizations referred to. Issues for naming and curating new media art are widely addressed on the *CRUMB* website, in its publications, and on its discussion list. Sarah Cook and Beryl Graham, eds., *CRUMB: New Media Curating Resource*, 2000. Available at http://www.crumbweb.org.

4. Brian Reffin Smith, *Soft Computing: Art and Design* (N. Reading, MA: Addison-Wesley, 1984), 73.

5. Paul Brown, "The Computer Arts: Origins and Contexts," *PAGE: Bulletin of the Computer Arts Society*, 57 (Summer 2004): 11–13. Available at http://www.bbk.ac.uk/hosted/cache/PAGEnew.htm.

6. As a rather presumptuous PhD student, I took Frank Popper's 1975 mapping of "democratic" art, and suggested parallels informed by postmodernism. Others who have discussed modernism/postmodernism in relation to computer art are Beverly Jones and Richard Wright. Beryl Graham, "A Study of Audience Relationships with Interactive Computer-Based Visual Artworks in Gallery Settings, Through Observation, Art Practice, and Curation" (unpublished PhD thesis, University of Sunderland, 1997). Available at http://www.sunderland.ac.uk/~as0bgr/cv/sub/phd.htm; Beverly Jones, "Cultural Maintenance and Change," *Media Information Australia*, no. 69 (August, 1993): 23–37; Frank Popper, "The Place of High-Technology Art in the Contemporary Art Scene," *Leonardo*, vol. 26, no. 1 (1993): 63–69; Richard Wright, "Technology is the People's Friend: Computers, Class, and the New Cultural Politics," in *Critical Issues in Electronic Media*, ed. Simon Penny (New York: SUNY Press, 1995), 75–104.

7. Lev Manovich, "The Death of Computer Art," 1996. Available at http://www.thenetnet.com/schmeb/schmeb12.html.

8. This was the subtitle of the 2001 exhibition *010101* at the San Francisco Museum of Modern Art, a show that included photography, sculpture, and painting, but all of whose works related to the subject of technology.

9. Siân Ede's book gives a useful overview of British artSci projects, as well as the websites: http://www.sciart.org/ and http://www.artscatalyst.org/. Siân Ede, ed., *Strange and Charmed: Science and the Contemporary Visual Arts* (London: Calouste Gulbenkian Foundation, 2000).

10. Peter Dunn, "Digital Dreams: A New Visibility?" *Digital Dreams*, 1994. Available at http://www.arte-ofchange.com/Talks_list-1.asp.htm.

11. Julian Stallabrass describes those with such a utopian approach as "techno-art boosters." Julian Stallabrass, *Internet Art: The Online Clash of Culture and Commerce* (London: Tate Publishing, 2003), 153.

12. The Wellcome Wing artworks at the Science Museum (http://www.sciencemuseum.org.UnitedKingdom/on-line/wellcome-wing/digitopolis/art.asp) include works by David Rokeby, Tessa Elliot and Jonathan Jones-Morris, and Gary Hill. The National Museum of Photography, Film, and Television in Bradford (http://www.nmpft.org.United Kingdom/) also exhibits Paul Sermon's work.

13. Clive Gillman, "Re: Net Art and Large Museums—Assignment Number One," *NEW-MEDIA-CURATING Discussion List*, March 8, 2001. Available by email: new-media-curating@jiscmail.ac.uk.

14. Beryl Graham, "Taxonomies of New Media Art: Real World Namings," in *Museums and the Web 2005: Proceedings*, ed. Jennifer Trant and David Bearman (Toronto: Archives & Museum Informatics: 2005). Available at http://www.archimuse.com/mw2005/papers/graham/graham.html.

15. Beryl Graham, "Redefining Digital Art: Disrupting Borders," in *Theorizing Digital Cultural Heritage*, ed. Sarah Kenderdine (Cambridge, MA: MIT Press, 2007), 93–112.

16. Jon Ippolito, "Accommodating the Unpredictable: The Variable Media Questionnaire," in *Permanence Through Change: The Variable Media Approach*, ed. Alain Depocas, Jon Ippolito, and Caitlin Jones (New York: Guggenheim Museum, 2003), 47–54. Available at http://www.variablemedia.net/e/preserving/html/var_pub_index.html.

17. Introduced by Steve Dietz in 1999 and further defined in 2000. These three categories are used by Sarah Cook and Beryl Graham to examine the particular challenges that they present to curators. Steve Dietz, "Why Have There Been No Great Net Artists?" *Through the Looking Glass: Critical Texts*, 1999. Available at http://www.voyd.com/ttlg/textual/dietz.htm. Steve Dietz, "Signal or Noise? The Network Museum," *Webwalker #20: Art Entertainment Network*, 2000. Available at http://www.walkerart.org/gallery9/webwalker/ww_032300_main.html. Sarah Cook and Beryl Graham, "Curating New Media: Net and Not Net," *Art Monthly* (November 2002): 44–45; Sarah Cook and Beryl Graham, "Curating New Media Art: Models and Challenges," in *New Media Art: Practice and Context in the United Kingdom, 1994–2004*, ed. Lucy Kimbell (London: Arts Council of England, 2004), 84–91.

18. Sarah Cook, "The Search for a Third Way of Curating New Media Art: Balancing Content and Context in and out of the Institution," PhD thesis, University of Sunderland, 2004.

19. Those with useful taxonomies of interaction include Stroud Cornock and Ernest Edmonds; S. C. D. Bell; Beryl Graham; Martin Lister, Jon Dovey, Seth Giddings, Iain Grant, and Kieran Kelly. Stroud Cornock and Ernest Edmonds, "The Creative Process Where the Artist Is Amplified or Superseded by the Computer," *Leonardo*, vol. 6, no. 11 (1973): 11–15; S. C. D. Bell, "Participatory Art and Computers: Identifying, Analysing and Composing the Characteristics of Works of Participatory Art that Use Computer Technology" (unpublished PhD thesis, Loughborough University, 1991); Graham, "A Study of Audience Relationships"; Martin Lister, Jon Dovey, Seth Giddings, Iain Grant, and Kieran Kelly, eds., *New Media: A Critical Introduction* (London: Routledge, 2003), 40–44.

20. Inke Arns usefully differentiates between the two. Inke Arns, "Read_me, Run_me, Execute_me: Software and Its Discontents, Or: It is the Performativity of Code, Stupid," 2004. Available at http://www.runme.org/project/+executeme/.

21. As pointed out by Wright, "Technology Is the People's Friend," 96.

22. Adrian Ward and Geoff Cox, "How I Drew One of My Pictures: Or, The Authorship of Generative Art," 1999. Available at http://www.generative.net/papers/authorship/; Cook and Graham, "Curating New Media Art: Models and Challenges," 84–91.

23. Olga Goriunova and Alexei Shulgin, "Artistic Software for Dummies and, by the Way, Thoughts about the New World Order," *Read_Me 1.2*, 2002. Available at http://macroscenter.ru/read_me/teb1e.htm.

24. Christiane Paul splits her book into sections on "Digital Technologies as a Tool" (i.e., tools for digital imaging; photography and print; sculpture) and "Digital Technologies as a Medium" (i.e., installation; film, video and animation; Internet art and nomadic networks; software art; virtual reality and augmented reality; sound and music). Christiane Paul, *Digital Art* (London: Thames and Hudson, 2003).

25. For example, the question of whether interactive work was "too interactive" for museums was discussed on the *CRUMB* discussion list in November 2001. The ethics of free software, and exhibiting software art and Internet art, are also widely discussed, and useful writings can be found at *Runme* (http://runme.org) and in Armin Medosch, ed., *Dive* (Liverpool: The VIRTUALCENTRE-MEDIA.NET and FACT, 2003).

26. Other contemporary artists who use a hybrid of old and new technologies include Calum Stirling's sound works using homemade records and microscopes, Simon Lewandowski's parasitic robots, Eva Verhoeven's printer-tinkering, and Paul Mulvihill's interdisciplinary hybrids.

27. Inke Arns, "Tricky Affinities: Notes on the Relation between Early Computer Art of the 1960s and Current Software Art," paper presented at Curating, Immateriality, Systems: A Conference on Curating Digital Media, June 4, 2005, Tate Modern, London. Available at http://www.tate.org.uk/contact/forums/onlineevents/.

28. Graham, "Taxonomies of New Media Art."

29. Lisa Haskel and Lowena Faull, eds., *Video Positive 95* (Liverpool: Moviola, 1995), 30.

30. Saul Albert, "Useless Utilities," in *New Media Art: Practice and Context in the United Kingdom, 1994–2004*, ed. Lucy Kimbell (London: Arts Council of England, 2004), 206–214. Available at http://twenteenthcentury.com/saul/useless.htm.

31. Lisa Haskel, "Selling Out—Buying In: Art vs. Design in UK Media Culture," in *New Media Art: Practice and Context in the UK 1994–2004*, ed. Lucy Kimbell (London: Arts Council of England, 2004), 120–125.

32. Anne Nigten usefully distinguishes between "multidisciplinary" and "interdisciplinary" methodologies in code-based art. Anne Nigten, *Human Factors in Artistic Research and Development in Multi- and Interdisciplinary Collaborations*, 2002. Available at http://archive.v2.nl/v2_lab/papers_general/2002_nigten_humanfactors.pdf.

33. Lucy Kimbell, ed., *New Media Art: Practice and Context in the United Kingdom, 1994–2004* (London: Arts Council of England, 2004).

34. i-DAT at Plymouth University are unusual in running a joint MA/MSc course; they also have graduates from Goldsmiths' curating course and RCA MAs on the staff. Other universities also do interdisciplinary computer-based work, including the Computer Related Design course at the Royal College of Art, Duncan of Jordanstone College of Art, University of Dundee, and Central St. Martins.

35. Catherine Mason, "Routes towards British Computer Arts: Educational Institutions," *PAGE: Bulletin of the Computer Arts Society*, 57 (Summer 2004): 5–8. Available at http://www.bbk.ac.uk/hosted/cache/PAGEnew.htm.

36. Rather than big museums and big shows, it has often been mobile, regional, office-based agencies such as New Media Scotland that have been most active. It has also tended to be smaller galleries and arts organizations that have given new media art firm and critical support over a long time period, by including it within a general contemporary art program. These organizations include Grizedale Arts in Cumbria, Stills in Edinburgh, Watershed in Bristol, Cornerhouse in Manchester, Barbican Art Gallery in London, and Site Gallery in Sheffield. Helen Cadwallader usefully lists the key institutions, conferences, and open access spaces in England that helped to develop the new media art scene from 1994 to 2004. However, less visible than the institutions are the highly mobile organizers, with specialist new media art knowledge, who have helped instigate and make visible the field. These include Helen Sloan, Lisa Haskel, Peter Ride, Kathy Rae Huffman, Honor Harger, Tom Holley, Iliyana Nedkova, and many more. Helen Cadwallader, "Arts Infrastructure of New Media in England: Some Background Notes," in *New Media Art: Practice and Context in the United Kingdom, 1994–2004*, ed. Lucy Kimbell (London: Arts Council of England, 2004), 106–110.

37. See http://www.tate.org.UnitedKingdom/modern/exhibitions/opensystems/. This exhibition is also discussed in relation to computer art in the Tate's *CodE of practice: Online Panel Discussion*. Available at http://www.tate.org.UnitedKingdom/contact/forums/onlineevents/thread.jsp ?forum=45&thread=2932&tstart=0&trange=45.

38. Pauline van Mourik Broekman, "Mute: Ceci n'est pas un magazine," in *New Media Art: Practice and Context in the United Kingdom, 1994–2004*, ed. Lucy Kimbell (London: Arts Council of England, 2004), 272–273.

39. Tamas Banovich, "Tamas Banovich," paper presented at Curating New Media, Seminar, May 10–12, 2001, Gateshead. Available at http://www.crumbweb.org/getPresentation.php?presID=3.

40. The exhibition was curated by Helen Sloan and researched by Sloan and Lisa Haskel. There was also a seminar programmed by Haskel, Dialogues with the Machine, June 27–

28, 1998, at the ICA, London. This information is also based on email correspondence with Sloan and Haskel, May 2005. Helen Sloan, ed., *star.dot.star* (Sheffield: Site Gallery, 1998).

41. Rainer Usselmann, "The Dilemma of Media Art: *Cybernetic Serendipity* at the ICA, London," *Leonardo* 36, no. 5 (2003): 390.

42. The press coverage of *Serious Games* is explored in Beryl Graham, "Serious Games—Case Study," in *Curating New Media*, ed. Christiane Paul (Berkeley: University of California Press, 2008).

43. Beryl Graham, *Curating New Media Art: SFMOMA and 010101*, 2002. Available at http://www.crumbweb.org/getcrumbreports.php?&sublink=2.

44. Usselmann, "The Dilemma of Media Art," 390.

45. *Serious Games* was in 1996–1997, *010101* was in 2001, and sponsorship issues for *Art and Money Online* are discussed by in Cook, Graham, and Martin. Graham, "Serious Games"; Graham, *Curating New Media Art: SFMOMA and 010101*; Cook, Graham, and Martin, *Curating New Media*, 33.

46. Lucy Kimbell, ed., *New Media Art: Practice and Context in the United Kingdom, 1994–2004* (London: Arts Council of England, 2004); Pamela Jennings, *New Media Arts | New Funding Models*, report. (New York: The Rockefeller Foundation, 2000). Available at http://www.rockfound.org/display.asp?context=3&SectionTypeID=16&DocID=528&Preview=0&ARCurrent=1; *CRUMB*, *New-Media-Curating Discussion List*, 2001–. Available at http://www.jiscmail.ac.uk/lists/new-media-curating.html.

47. In addition to the Arts Council of England and the universities supporting cross-disciplinary work mentioned in this chapter, there is a particular British context that is important: in the 1990s "Art-practice-led" doctorates developed in many art schools and former polytechnic universities, and the new Arts and Humanities Research Council supported long-term research projects that saw art practice as an important research method. This has enbled CRUMB to work with arts organizations such as BALTIC Centre for Contemporary Art on research projects, and has also encouraged work across arts organizations, science or technology organizations, and universities; for example, the *user_mode: emotions and intuition in art and design* conference in May 2003 involved Tate Modern, the Science Museum, and Central St. Martins. Although arts institutions may be cautious about letting new media art directly into their galleries, forums for debate such as conferences often act as showcases for new cross-disciplinary work that would otherwise struggle to be placed in a venue.

48. Matt Fuller, "A Means of Mutation", 1998. Available at http://bak.spc.org/iod/mutation.html.

49. For example, *Futuresonic* in Manchester (http://www.futuresonic), or groups working around Limehouse Town Hall in London (http://twenteenthcentury.com/uo/index.php/LimehouseTownHall).

50. For example, research at SFMOMA showed a shift in the pattern of interaction between technical and curating departments. *Prix Ars Electronica* added categories of freestyle and Internet culture to its Turing-land original categories, and ACM SIGGRAPH has started to move toward individual curators and invited artists into its exhibition section. Beryl Graham, *Curating New Media Art: SFMOMA and 010101*, 2002. Available at http://www.crumbweb.org/getcrumbreports.php?&sublink=2.

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Victoria and Albert Museum, and the Institute of Contemporary Arts in the United Kingdom; the Adelaide Festival; ARCO in Spain; and the *Venice Biennale*. His work is represented in public, corporate and private collections in Australia, Asia, Europe, Russia, and the United States. In 1984 he was the founding head of the United Kingdom's National Centre for Computer Aided Art and Design before moving to Australia in 1988. From 1997 to 1999 he was chair of the Management Board of the Australian Network for Art Technology and is currently on the editorial board for *Digital Creativity* (Routledge) and *Leonardo Electronic Almanac* (MIT Press). During 2000 to 2001 he was a new media fellow of the Australia Council for the Arts, and from 2002 to 2005 he was a visiting fellow in the School of History of Art, Film and Visual Media at Birkbeck College, University of London, where he worked on the CACHe (Computer Arts, Contexts, Histories, etc.) project.

Stephen Bury Stephen Bury is the head of European and American Collections at the British Library, where he initiated Web archiving of the UK domain. He was the Brackenbury Scholar in modern history at Balliol College, Oxford, from 1972 to 1975 and won the H. W. C. Davis University Prize for History in 1973. He was the head of learning resources at Chelsea School of Art from 1985 to 2000, where he was also a postgraduate tutor and research supervisor. He published *Artists' Books* (1995) and *Artists' Multiples* (2001), and he edited *Breaking the Rules: The Printed Face of the European Avant-Garde 1900–1937* (2007). He writes regularly for *Art Monthly*. He is the chair of the board of trustees of Book Works, London, and on the board of Matt's Gallery. He is researching a book on text engines and artists' books.

Harold Cohen Harold Cohen is professor emeritus in the Visual Arts Department at the University of California, San Diego, and was chairman of the department as well as founding director of the Center for Research in Computing and the Arts (CRCA) there. He has represented the United Kingdom in the *Venice Biennale* in 1966, *Documenta 3*, the *Paris Biennale*, the *Carnegie International*, and many other important international shows. He exhibited regularly at the Robert Fraser Gallery in London and the Alan Stone Gallery in New York. He has continued to exhibit internationally with work made with the AARON artificial intelligence program, including exhibitions at the Tate Gallery in London, the Computer Museum in Boston, the Los Angeles County Museum, Documenta_6, the San Francisco Museum of Modern Art, the Stedelijk Museum in Amsterdam, the Brooklyn Museum, and the IBM Gallery in New York. He represented the United States in the Japan World Fair in Tsukuba in 1985.

Ernest Edmonds Ernest Edmonds currently is professor of computation and creative media at the University of Technology Sydney, where he leads a multidisciplinary practice-based art and technology research group, the Creativity and Cognition Studios. He has exhibited throughout the world, from Moscow to Los Angeles. He is represented in Sydney by the Conny Dietzschold Gallery. He has over two hundred refereed publications in the fields of art, creativity, and human-computer interaction. He is the author of *On New Constructs in Art* (Artists Bookworks, 2005). Since the 1970s he has pioneered the development of practice-based PhD programs in art, systems, and digital technology, first at what was when Leicester Polytechnic and subsequently at Loughborough University and the University of Technology Sydney.

María Fernández María Fernández is assistant professor of art history at Cornell University, where she teaches courses in the history of digital art, visual studies, critical theory, and Latin American art. Her research interests include the history and theory of digital art, postcolonial studies, Latin American art and architecture, and the intersections of these fields. She has published essays in journals such as *Art Journal*, *Third Text*, *nparadoxa*, *Fuse*, and *MUTE*. Her work is included in several volumes including the *Companion of Contemporary Art since 1945*, edited by Amelia Jones (Blackwell, 2006); *At a Distance: Precursors to Art and Activism on the Internet*, edited by Annmarie Chandler and Norie Neumark (MIT Press, 2005); and *Alzado Vectorial/Vectorial Elevation*, edited by Rafael Lozano-Hemmer (Conaculta e Impresiones y Ediciones San Jorge, 2000). With Faith Wilding and Michelle Wright, she edited the anthology *Domain Errors: Cyberfeminist Practices* (Autonomedia, 2002).

Simon Ford Simon Ford is research associate in craft and design and curator of the Design Council Slide Collection at Manchester Metropolitan University. He was formerly a curator at the Victoria and Albert Museum, an assistant editor at *MUTE* magazine, and a freelance writer and editor. He received his PhD in the history of art from the Courtauld Institute of Art, University of London, in 2000 for a dissertation on avant-gardism in Britain from 1969 to 1981. He is the editor of *Information Sources in Art, Art History and Design* (K. G. Saur, 2001) and the author of *Wreckers of Civilisation: The Story of COUM Transmissions and Throbbing Gristle* (Black Dog, 1999) and *Hip Priest: The Story of Mark E. Smith and The Fall* (Quartet, 2003). His most recent book is *The Situationist International: A User's Guide* (Black Dog, 2006).

John Hamilton Frazer John Hamilton Frazer is head of the School of Design at Queensland University of Technology. Previously he was international research coordinator for the Gehry Technologies Digital Practice Ecosystem. He holds honorary professorships from the Universities of Dalian, Fudan, and Shandong in China, and is a visiting professor at Salford University and a visiting research Fellow at RMIT. He is a fellow of the Royal Society of Arts and the Chartered Society of Designers. His work has been presented worldwide in lectures and conferences and published extensively in journals and books. He is founding chair of the *d_city* international research network to develop dynamic, digital data designs for future cities.

Jeremy Gardiner Jeremy Gardiner is currently senior research fellow on the AHRC-funded project, Computer Art and Technocultures, at the Victoria and Albert Museum. He has shown his artwork in major exhibitions worldwide. He was a founding member of the computer graphics department at Pratt Institute of Art and Design in New York and director of CyberArts at the New World School of the Arts in Miami. He was tutor for "Computers in Printmaking" at the Royal College of Art and program leader for the master's in Computer Art at the London College of Music and Media. He has been a consultant for the National Trust, Clore Duffield Foundation, British Council, and the Department of Art, Design and Media at Nanyang Technological University in Singapore. His artwork has been commissioned by General Electric, IBM, and NYNEX and is held in numerous private and public collections including BNP Paribas, Glaxo Smith Kline, Ente Nazionale Idrocarburi, Government Art Collection, Imperial College, and the Victoria and Albert Museum.

Charlie Gere Charlie Gere is reader in new media research and head of the department at the Institute for Cultural Research, Lancaster University, is chair of Computers and the History of Art (CHArt), and was the director of Computer Arts, Contexts, Histories etc (CACHe), the three-year research project looking at the history of early British computer art that led to the publication of this book. He is the author of *Digital Culture* (Reaktion Books, 2002) and *Art, Time and Technology* (Berg, 2006), as well as a number of papers and book chapters on the relation among art, culture, and technology. In 2007, along with Christiane Paul and Jemima Rellie, he helped curate *FEEDBACK*, an exhibition focusing on art responsive to instructions, input, or its environment, at the Laboral Centre for Art and Creative Industries in Gijon, Northern Spain.

Adrian Glew Adrian Glew is a senior archive curator, primarily responsible for acquisitions, at the Tate Archive. He has curated numerous displays at various Tate sites—most recently, on the Fluxus Collective, Correspondence Art, Outsider Art and the Guyanese/British artist, and Aubrey Williams. Adrian's publications have included a selected edition of Stanley Spencer's letters and writings (Tate, 2001) and a new introduction to Wassily Kandinsky's *Concerning the Spiritual in Art* (Tale, 2006). He has published widely in periodicals such as *The Burlington Magazine* and *Art Monthly*. Glew is currently a director of the Public Monuments and Sculpture Association, a trustee of the Musgrave Kinley Outsider Art Trust, a committee member of the Society of Archivists' Specialist Repositories Group, the Aubrey Williams Committee, and is a founding member of the Kurt Schwitters in England group, which has recently purchased the Merzbarn site in the Lake District.

Beryl Graham Beryl Graham is professor of new media art at the School of Arts, Design, Media and Culture, University of Sunderland, and co-editor of the *CRUMB* website resource for curators of new media art. She is a writer, curator, and educator with many years of professional experience as a media arts organizer, and she was head of the photography department at Projects UK, Newcastle, for six years. She curated the international exhibition *Serious Games* for the Laing and Barbican art galleries and has also worked with the Exploratorium, San Francisco, and San Francisco Camerawork. She is the author of *Digital Media Art* (Heinemann, 2003), and she is coauthoring with Sarah Cook a book on curating new media art for the MIT Press. She has chapters in the books *New Media Art: Practice and Context in the UK 1994–2004* (Arts Council of England, 2004), and *The Photographic Image In Digital Culture* (Routledge, 1995).

Stan Hayward Stan Hayward is an animator and a pioneer in the use of computers for animation, and he is currently working on websites for and about animation applications, particularly in education. In the 1960s he worked with Halas and Batchelor animation studio on educational films, using computers for producing artwork. Later in the same decade he became involved in computer arts and applications of computers to film production. In 1970 he won the New Scientist Award for "New Applications of Computers," in which he proposed using computers at all stages of film production. This was shown on BBC's *Tomorrow's World*. On the basis of this, he successfully applied to the Department of Trade and Industry for funding to develop programs for film production. He set up a studio, Video Animation Ltd., at Imperial College London in 1971 in the Nuclear Power Engineering Department, which had suitable computer equipment, with the backing of TV International, a video service house intending to use the programs for advertising. In the 1980s Hayward applied computer animation to education, and to running workshops in schools, and he returned to writing traditional animation for TV.

Graham Howard Since 2000 Graham Howard has been design director of System Simulation Ltd., designing interfaces for new applications, from museum collections management systems to digital asset management systems. He also creates innovative public access environments from websites and kiosks based upon large datasets with structured metadata to digital exhibition design. Howard was a member of the artists' group Art and Language in the early 1970s. He has published widely and exhibited internationally and acts as an external examiner and validator for postgraduate art and design courses. Having run Europe's first master's course in electronic graphics at Coventry University, he started his company Art of Memory in 1989 to continue to research and develop new modes of communication enabled by the emergent technologies. In the late 1990s he both ran the master's in computer-related design at the Royal College of Art in London and worked with the Open Society Institute in Budapest setting up and running courses in electronic publishing across most of the old Soviet bloc from the Czech Republic to Mongolia.

Richard Ihnatowicz Richard Ihnatowicz plays clarinet, flute, and saxophone professionally, and he has conducted many West End shows. However, music copying has remained an important means of earning in lean years. He eagerly embraced the technological advances in music, and he was one of the first people in England to use computers for copying and arranging. Unusually, he has been in demand for his computer skills in several European countries and has been called upon several times to speed the preparation of new music, especially for musical theater and film. He enjoys computer games and cinema, likes to travel (especially if there is plenty of wildlife), and is a keen ornithologist.

Nicholas Lambert Nicholas Lambert has a DPhil in the history of art from Oxford University and is principal investigator on the AHRC Computer Arts and Technoculture Project at the School of History and Art, Film and Visual Media, Birkbeck, University of London, which is a joint project with the Victoria and Albert Museum. He is also technical adviser to the AHRC Archigram Archival Project at the School of Architecture and the Built Environment, University of Westminster.

Malcolm Le Grice Malcolm Le Grice is an artist working in film and video, author, and professor emeritus of the University of the Arts London. He has shown his work regularly in Europe and the United States, and his work has been screened at many international film festivals. He has also shown in major art exhibitions such as the *Paris Biennale No. 8; Arte Inglese Oggi*, Milan; *Une Histoire du Cinema*, Paris; *Documenta* 6, Kassel; *X-Screen* at the Museum of Modern Art, Vienna; and *Behind the Facts* at the Fondacion Joan Miro, Barcelona. His work has been screened at the Museum of Modern Art, New York; the Louvre Museum, Paris; and the Tate Modern and Tate Britain, London; and it is in permanent collections including the Centre Georges Pompidou, Paris; the Royal Belgian Film Archive, Brussels; the National Film Library of Australia, Canberra; German Cinamatheque Archive, Berlin; Canadian Distribution Centre, Montreal, and Archives du Film Experimental D'Avignon. Le Grice has written critical and theoretical work including a history of experimental cinema *Abstract Film and Beyond* (1977, Studio Vista and MIT Press). For three years in the 1970s he wrotea regular column for the art monthly *Studio International* and has published numerous other articles on film, video, and digital media. Many of these have been collected and recently published under the title *Experimental Cinema in the Digital Age* (British Film Institute, 2001).

Tony Longson Tony Longson teaches animation at California State University, Los Angeles, and makes and exhibits three-dimensional constructions. He has been a British Council scholar in Den Haag, Holland, and an artist-in-residence in the Computer Science Department of Hatfield Polytechnic (now the University of Hertfordshire), funded by the Arts Council. In 1980 he was awarded one of the Bicentennial Arts fellowships (British Council/U.S. National Endowment for the Arts) to live and work in the United States. He has been teaching art and technology since he discovered the creative potential of computers in 1973, and he initiated the first U.S. courses in computer graphics for artists and designers in the early 1980s.

Brent MacGregor Brent MacGregor is vice principal, Edinburgh College of Art, having previously been its first professor of visual communication, a joint appointment with Heriot-Watt University. Educated to a master's level in Canada, he holds a doctorate in critical theory from the University of Oxford. Prior to moving to Scotland, he was a founding member of the Institute of Communications Studies at the University of Leeds. He has written extensively on the effects of new technologies, taking the view that they are positively enabling rather than negatively determining. He worked for a number of years in BBC Television and then, as a freelancer, returned to the academic world to teach and research moving image culture using this experience of practice to inform his work. He has published on the effects of new technology on television news production, on multimedia development, and on interactive narrative. In addition to his films for broadcast television, he has created gallery installations, both digitally enabled and of the old-fashioned wood and metal kind.

George Mallen George Mallen, BSc, PhD, FBCS, CEng, CITP, FRSA, is founder and managing director of System Simulation Ltd., a software development company specializing in multimedia information management systems. From 1964 to 1970 he worked with the cybernetician Gordon Pask at System Research Ltd., and his PhD explored the extension of simulation techniques to the study of information flows and intelligence in organizations and learning processes. He was a founding member of the Computer Arts Society. From 1971 to 1981 he held a research fellowship in the Department of Design Research at the Royal College of Art, and in 1977 he founded the College's first Computing Activities Unit, introducing art and design students to computer graphics and animation techniques. From 1983 to 1985 he was the first head of the new Department of Communication and Media at Bournemouth University. Since 1985 he has concentrated on the development of System Simulation Ltd.'s business activities. He has carried out consultancy assignments at senior levels for both government and industry. He has published articles and papers on computing, its applications, and its implications. He is a fellow of the British Computer Society, a chartered engineer, a chartered information technology professional, and a fellow of the Royal Society of Arts.

Catherine Mason Catherine Mason is a freelance art historian with a background in adult education and the commercial art world. From 2002 to 2005 she was the researcher on the CACHe Project in the School of History of Art, Film and Visual Media at Birkbeck, University of London. She continues to research this underrepresented field of art history and is currently writing a book, *A Computer in the Art Room*, which uncovers the history of this artistic practice within art schools and academic institutions.

Jasia Reichardt Jasia Reichardt is a writer on art and an exhibition organizer. She was assistant director of the ICA in London from 1963 to 1971, and director of the Whitechapel Art Gallery from 1974 to 1976. She has taught at the Architectural Association, as well as at other colleges, and has written several books. She is interested in art that encroaches on other fields—science, music, and literature—and has spent many years following up the connections between art and technology. Among her exhibitions staged in Britain, the best known is *Cybernetic Serendipity* (1968), about the computer and the arts. During the 1990s she collaborated on art and technology projects in Japan, and she has spent the last few years cataloguing the Themerson Archive.

Stephen A. R. Scrivener Stephen Scrivener became head of research at Chelsea College of Art and Design in July 2005. Since 1976, he has been conducting design- and design technology–related applied research. In 1982 he co-founded the Human-Computer Interface Research Unit at Leicester Polytechnic and in 1986 the Loughborough University of Technology Computer-Human Interface Research Centre. In 1992 he founded the Design Research Centre, University of Derby. Following appointments at De Montfort and Loughborough Universities, Scrivener joined the School of Art and Design, University of Derby, in 1992 as assistant dean, and was appointed director of research for the university from 1994 until moving to Coventry in 1999, where he later directed the VIDe Research Centre. In July 2004 Scrivener moved to Central Saint Martins College of Art and Design where he served as a cross-college research manager. Scrivener is a fellow of the Design Research Society and a member of EPSRC and AHRC Peer Review colleges, and he has served on a numerous research-related national and international boards and panels. He is founding editor-in-chief of the international journal *CoDesign*, published by Taylor and Francis. He has produced over 150 publications, including edited books, book chapters, journal and conference papers, and professional articles on these topics.

Brian Reffin Smith Brian Reffin Smith lives and works in Berlin and France. Since 1986 he has been a French civil servant, working for the Ministry of Culture and teaching at the École Nationale Supérieure d'Art in Bourges, France, where he runs the Atelier Art + Info and teaches computer-based conceptual art. He is a regent of the Collège de 'Pataphysique, Paris, holding the chair of catachemistry and computative metallurgy. He was educated at Brunel University and later at the Royal College of Art in London, where he was appointed to a research fellowship in 1979 and served as college tutor in computing in art and design from 1980 to 1984. He also taught, in the 1970s and early 1980s, at the Open University, St. Martin's School of Art, and Wimbledon Schools of Art, and Chelsea and Canterbury Colleges of Art. In 1987 he won the first ever Prix Ars Electronica in Linz, Austria. His artworks and performances are presented internationally. Smith was also involved in the influential *Computer Programme* on BBC TV, and he appeared frequently on television and radio. He has written a number of books for children and adults about computers, with an emphasis on their creative aspects. In 1998 he became a Zombie.

Alan Sutcliffe Alan Sutcliffe is a composer, designer, and computer programmer. He started computer programming in 1961, working first for English Electric Computers, then for International Computers Limited. He also composed music during these years, particularly electronic music, and he attended Darmstadt new music summer course and took short courses with Luciano Berio in England. In the 1960s Sutcliffe worked with electronic music composer Peter Zinovieff and, in 1968, was a founding member of the Computer Arts Society (CAS), which he chaired for ten years. In 1969 he spent three months in the computer music studio of the University of Illinois in Champaign-Urbana. In 1973 he joined Zinovieff's Electronic Music Studios Ltd. as a part-time director, mainly programming for the studio but increasingly involved in the synthesizer business. In 1973 to 1980, he was a part-time director of System Simulation Ltd., with colleagues from the CAS; in 1978 he undertook computer animation for Ridley Scott's film *Alien*. From 1980 he became a freelancer on software mainly related to graphics for Cambridge University, The RAF, and for UNESCO in Vietnam, among others; he also became an expert in CAD systems for carpet design. In 2002 he became involved in the CACHe project, which led to the reformation of the Computer Arts Society, and he has recently been elected president. His graphics have been in exhibitions in Austria, Germany, and Spain, with one piece having recently been acquired by the Victoria and Albert Museum. Currently he is working on music and graphics composition software using simple algorithms that give complex results.

Doron D. Swade Doron D. Swade is an engineer, historian, and museum professional, and he is currently visiting professor (of computer science) at Portsmouth University and honorary research fellow at Royal Holloway University of London where he is researching advanced computer simulation techniques for historical mechanisms. He has studied electronics, physics, control engineering, philosophy of science, machine intelligence, and history at various universities, including Cambridge University and University College London, where he completed a PhD in the history of calculating engines. Swade splits his time between London and California where he is guest curator at the Computer History Museum, Mountain View, California, responsible for the content of a major new exhibition on computer history. He was visiting professor (of interaction design) at the Royal College of Art in 2004 and 2005, assistant director and head of collections at the Science Museum, London, until 2003, and senior curator of computing at the Science Museum for fourteen years from 1985 on. Swade is a leading authority on the life and works of Charles Babbage and has published three books (one coauthored) and over seventy scholarly and popular articles on curatorship, history of computing, and museology.

John Vince John Vince is emeritus professor of digital media at Brunel University. While studying at Brunel University for his master's and PhD degrees, he developed his PICASO computer animation system, which was widely adopted by U.K. universities during the 1970s and 1980s. During this period he lectured on programming, systems analysis, and computer graphics at Enfield College of Technology, which eventually became part of Middlesex Polytechnic. Apart from his lecturing duties, Vince was commissioned to create numerous animation productions for television and feature films. In 1986 he took up the position of research consultant at Rediffusion Simulation Ltd. where he worked on real-time image generators for commercial and military flight simulators. The company eventually became part of the Thomson Group, and in 1992 he was appointed chief scientist at Thomson Training Ltd. In 1995 Vince returned to academia as professor of digital media at Bournemouth University. In 2005 he was awarded a DSc by Brunel University for his contribution to computer graphics. During his career Vince has written fifteen books on computer graphics, computer animation, virtual reality, and mathematics and has edited a further sixteen books. He also co-founded the Virtual Reality Society and the *VR Journal*.

Richard Wright Richard Wright is an artist and researcher working in the fields of animated media, digital moving image, and networked interaction. During the 1990s, Richard was one of the pioneers of digital animation as a distinct artistic form and over the last twenty years his work has been exhibited and screened at numerous festivals and exhibitions and broadcast by television channels around the world. In 1998 he received a PhD in the aesthetics of digital filmmaking and has published nearly forty book chapters, articles, and reviews. Since 2004 he has been research director for Mongrel, an artists group internationally recognized for their pioneering work in social software and software art.

Aleksandar Zivanovic Aleksandar Zivanovic is a visiting scholar at the Lansdown Centre for Electronic Arts at the University of Middlesex, where he is researching the work of Edward Ihnatowicz and the perception of animacy in interactive robotics. He is also runs AZ

Consultants, developing products and running educational events based on interaction design. After receiving a BSc (Hons) in computer systems engineering, he stayed on at the University of Kent where he researched behavior-based robotics for his MSc. After a brief interlude, he returned to academia, gaining a PhD in mechanical engineering from Imperial College London in 2000. His research area was medical robotics. He remained at Imperial College as a research associate, developing a number of mechatronic and robotic devices for medical use, before leaving in 2007 to set up a consultancy and continue his research into the life and works of Edward Ihnatowicz.

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