SISEA

PROCEEDINGS

Second

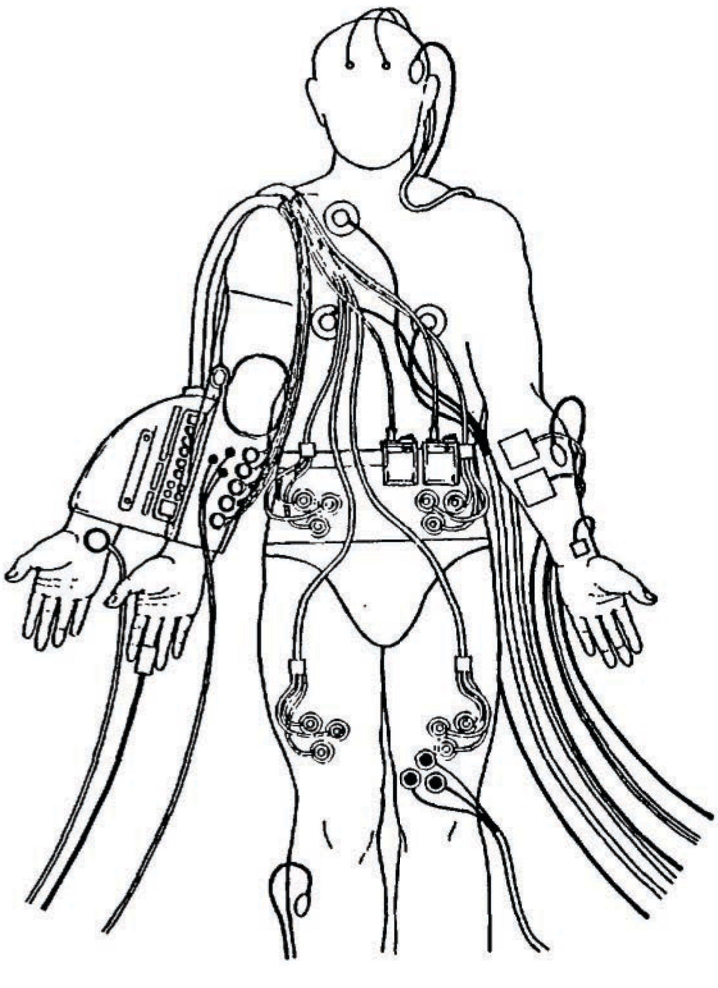
International

Symposium

on

Electronic

Art



GRONINGEN • HOLLAND • 1990

SISEA PROCEEDINGS

Errata Colour Section

Some captions underneath the colour illustrations by E. Zajec have been mixed up:
left hand page, bottom picture is fig. 1d
right hand page, top picture is fig. 1b
right hand page, bottom picture is fig. 1c

The colour illustration by P.K. Hoenich is printed upside down.

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PREFACE

SISEA AND THE SISEA PROCEEDINGS

The Second International Symposium on Electronic Art took place in November 1990, in Groningen, Holland. Participants came from 20 countries, representing every discipline in the field of the electronic arts.SISEA consisted of the following events:
-Workshops
-Scientific Symposium
-General Events

A report on SISEA has been published in Dutch. While these Proceedings are being printed, an English summary of this report is being prepared for publication in LEONARDO. Besides the report and the Proceedings SISEA has made the following symposium documentation materials available:
-Book of Abstracts, containing the complete Final Program, Abstracts by practically all speakers and performers, and Artists Statements by the artists whose work was shown at the SISEA exhibition, at the SISEA Film & Video Show or at the SISEA night of Concerts & Performances.
-SISEA Exhibition Slide Set with Artists Statements
-Best of SISEA Video Tape

The Scientific Symposium consisted of the following parts:
-Lectures by both invited speakers and free papers, selected by the International Program Committee. This includes several Panel Sessions
-Institutional Presentations, during which organisations and institutes from all fields of the electronic arts presented themselves and their work
-Poster Sessions, during which artists lectured about their work.

Of all these items, abstracts are included in the Book of Abstracts. The Proceedings contain the full papers by invited speakers and the selected free papers.

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Proceedings

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ABOUT THE CONTENT

One of the ways SISEA tried to give equal weight to both Art and Science was to invite some of the most important electronic art performers to present a paper during the scientific symposium, along with their performance at the night of Concerts & Performances. The contributions by the Australian artist Stelarc and the American computer music composer Michael McNabb to these Proceedings are quite unique.

These Proceedings are one of the few publications in which technical papers on both computer graphics (among others: Zajec, Robin, Donoghue et.al., Caldwell et.al.), and computer music (among others: Beyls, Haus et.al.), appear side by side. Of course the program committee welcomed quality papers on the integrationof different electronic art disciplines. Several of the papers attempt to build stronger foundations under the efforts towards this integration. To emphasise the importance of this integration, as one of the most promising aspects of Electronic Art, the Program Committee invited John Whitney Sr. to give the key-note speech, which is included in the Proceedings.

SISEA also considered the aesthetic questions connected to Electronic Art. There were several selected papers on this subject. Among others by Frazer and Maxwell. Hoenich's contribution, that is not really on electronic art as such, but on the interplay between nature and machine, fits in the same category. Papers like those by Scrivener and Search are aimed at the practical use of computers for the sake of art history.

Last but not least, there are papers that extend the importance of electronic art beyond the field of the arts in general, and look at the role of computer art in a changing culture, in a changing society. Among those are the contributions by Penny, Brown and Pryor. Stelarc's paper strikes one as being the product of science fiction at first, but careful consideration of his argument, might lead to the conclusion that artists can be ahead of their time, and know how to formulate that in words as well.

The SISEA Organising Committee wishes to thank the International Program Committee for helping select the speakers that are presented in these Proceedings.

Wim van der Plas
April 1991

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ABOUT THE COLOUR ILLUSTRATIONS

All colour illustrations are in one section of the proceedings. Sometimes authors refer to illustrations, without indicating they are in colour and can be found in the colour section of the proceedings.

John Whitney
Pacific Palisades
CA

SOME COMMENTS ON THE VISIBLE SHAPE OF TIME
FOR TELEVISION AND FUTURE MEDIA
A THEORETICAL QUEST

A counterpoint is developing which offers a special complementarity of relationship between musical and visual design. This counterpoint is composed by computer algorithms. I would define such algorithms as the routines of computer instructions that *play out* color design and/or music through solid state memory in time, as an event in time. These algorithms are a performance that could never be performed.

I search for a more appropriate word than *algorithm* or *performance*. In concert, we hear an artist's performance which later may be re-enacted over and over on a laser disc recording. Each time we play the CD, more or less, we relive that original performance. I need a proper word for my own compositions which were never performed, but are still a recording which indeed *relives* my creative choices and temporal options. I offer you my composition, or my set of algorithms, or my recording, or whatever. It must play to you from some form of solid state memory. I'm the composer and performer of this music yet it was never really performed.

Musicians of course resist the idea of *non-performing* music, believing each detail in musical art demands a precious and exclusive effort from a performer. How right they are -- the vitality of all music we have ever known is expressed in acts of performing. Regardless of this perception, however, I refer to an altogether different kind of music. And I must ask: is this new music possible today? Will fast computers allow a genuine musical art that belongs to TV? Will digital visual and audio capabilities permit an art as pure and popular as the diverse artistic musical traditions around the world? In other words, can we find yet another art form able to match our lively musical past?

No doubt with suitable talent we'll invent a new music. It's been done before. Formal pattern interrelations can be composed with algorithmic software today much the way composers created new music in the past employing technologies of their own time. More to the point of these remarks, however, is the idea that there are computer powers promoting a counterpoint in music which involves visual structures possessing the broad temporal architecture of music.

The idea of composing a record in time, similar to music, is already a century old. What about cinema? Moving pictures are like a play or a record of actors or a "CD video" of a dramatic event. But non-performing specialists are involved in creating the temporal architecture of a movie which is filmed scene for scene, one step at a time. Stored in the "solid-state memory" of silver images on reels of film, no one expects movies to play a different tempo and emphasis in front of every new audience, like a stage performer's reactions in live concert. Cinema is a fixed performance, edited by splicing carefully-timed scenes in sequence. More or less, my computer "performances" are fixed like that.

Following a century's growth of technology and new media, the art of film making -- as one example -- has grown into a collective and costly game of chance for everyone involved, from director to actor to best boy. Yet, in contrast to that development, perhaps, we may be arriving full circle: A few special composers are regaining total creative control of a new musical and visual medium. There are vast potentials for music-with-graphics awaiting deployment by a single creative person when allowed the full resources of advanced personal computers.

Color and music have more potential for fusion than the most imaginative composers, poets and artists believed possible. From Aristotle to Alexander Scriabin and Wassily Kandinsky, visionaries have invoked the poetic image of intertwining color with music. Their dream evolved into a kind of collective vision which briefly was called a color organ in the 19th Century and which today is nearer to actual realization, hence the hint of new start up MTV-type programs.

Even so, music combined with visuals on television needs substantiality to realize that ancient collective vision. Computers add content and new integrity by expanding twofold music's formerly exclusive art of TIME. A computer's clock allows compositions in TIME which can be quite as sensitively molded, in their own way, as performers mold their real-time performances. In fact, we've acquired high-resolution numerical control of TIME itself. Solid-state instant replay, faster memory access plus greater speed and band width sharpen all creative potentials. The geometry of pattern, infused with the vitality of color and motion, gains all the emotive power of music.

Systems architecture in this decade has produced music, and graphic generating capabilities combined in one computer instrument. This has become what we rightfully may call the artist's first universal machine: an instrument for combining audio and visual modalities in time.

Founded upon my own vision of a "universal-machine" before the first computers, my study of color-in-motion began as a search for various germinal aesthetic principals useful for developing that essential bifocal instrumentation. With eventual access to computers, later explorations of what I was to call "Digital Harmony" gradually revealed many extensible threads of reasoning. I uncovered aesthetic concepts that suggested how differential functions within a wide variety of geometric algorithms generate order-disorder graphics. Logically, this evolved into my notion for a visual harmony. Mathematical expressions, plotted frame-for-frame on film helped to clarify the principles on a succession of films.

Eventually, it came to my deeper understanding that an arithmetic of resonance and ratio actually embodies the architecture of music. Music's differential arithmetic could complement a graphic differential geometry. Visual patterns, derived from simple periodic geometry, produce order/disorder resonances in actions which relate to the consonances and dissonances, the tensional dynamics and the universal emotive powers of musical figuration, rhythm and harmony. These were summary conclusions I was able to draw from computer film making. They encouraged me to write the book DIGITAL HARMONY - ON THE COMPLEMENTARITY OF MUSIC AND VISUAL ART (McGraw-Hill, NY, 1980.)

Specifically, I was enabled to discover as an operable fact that the basic, quantifiable units of construction for this computer art are: (a) the pixel point of color, and (b) the pure audio sine wave. These two components allow one to compose resonant hetero-senuous art structures as if both elements contributed constructive parts to the whole. With audio and visual components, one constructs a generative graphics in an unprecedented temporal domain formerly belonging exclusively to music. The mathematics which these two elements hold in common provides the basis for the foundation of what may become a true audio-visual art.

Considering such a basic foundation, we may compare two terms used in electronic music jargon: synthesis and genesis. My studies suggested that composing music by computer should stress basic algorithmic or generative processes of genesis. The elementals, pixel and sine wave, can be constructed from "ground up," so to speak, into dynamic visual patterns as well as melodic patterns of unique new timbres and actions, all by algorithms invented and applied by the composer. Heretofore, we viewed each acoustic musical instrument, figuratively, as an algorithm producing its unalterably consistent timbre. Now, as we look at new computer algorithms we see that they may offer *an Einsteinian concept of musical relativity:* a rich domain of variable pitch, time and timber.

This stands in contradistinction to composing procedures of synthesis. Much electronic composing is done on real-time keyboards possessing acoustic wave-form synthesizers. Automatically the emphasis falls upon traditionally fixed scales, timbres, tempos and the live performance.

My own ongoing experience had confirmed that computer instruments offer a unique potential for audio-visual creativity. This potential needn't be bent out of shape in order to synthesize or imitate artworks associated with the art gallery, concert hall or cinema. Compositions like mine belong elsewhere. Dynamic computer art is indeed unique. I've no doubt that future outstanding works will initiate a significant popular audio-visual art medium within electronic arts. Outlets to the public will be on video discs and of course on television which needs this form of audio-visual musical television quite as much as MTV itself needs a lively computer graphics composed and interwoven with new computer music. To this end, we'll employ the computer's expert systems more wisely than merely to imitate or plagiarize the piano, or to simulate some of the present-day highly developed improvisational functions of musical ensembles, which work better without electronics.

The very concept of genesis promoted and clarified ideas about pattern potentials for music with art. My earliest film making had demonstrated that music's methods and traditions, requiring fixed tuning, specified tempo markings and skilled instrumentalists, could be supplanted by inventing and operating with acoustic algorithms in association with graphic algorithms. Here was a new methodology for digital harmony. In sum, I felt I'd uncovered an harmonic basis for audio-visual music.

Located outside instrumental and vocal traditions while retaining a valid harmonic foundation, digital harmony promises to provide a new and different approach for an evolving species of composer/artist. Like a painter's or the sculptor's directness of creative processes, digital harmony is direct. My present composing program, for example, allows direct action with instant feed-back just as a work on canvas or in stone allows for action/reactions -- a kind of performance. Intimate interactions with temporal materials, freely involving tuneable random chance, is a fruitful mother of invention. Vital creative interactions distinguish this composer's relation to material. Resultant works are a sum of countless choices, chance discoveries and revisions belonging to the artist; crucial choices are not subject to outside interpretations.

A work resides in solid-state digital memory with possibilities for instant and almost infinite revision and replay (i.e. playback with the optimum audio-visual detail directed toward a final conception). Such editing flexibility surpasses the interactive direct memory access of ordinary word processors. Music was once the most fleeting and transitory of all the arts. Even in the hands of a *non-performing* composer, and even with an optional graphic counterpoint, music is now a plastic material.

My guess is: a powerful appeal lies within the natural interlace and active coordination of eye to ear, and ear to eye, at the integrated level of digital audio-visual harmony. But who around the world can confirm the expressive power of these relationships until they are brought to life in many, many successful works of art?

Some have doubts about the expressive power of harmonic pattern as presented here, but we cannot forget what is already well known. Examine the twenty or so fugues in Bach's last, great study in counterpoint THE ART OF THE FUGUE to see how dynamic resonant structures, constructed from a mere twelve tones, probe the depths of human feeling.

As for established instruments and methodologies, the refinement of the Baroque family of musical instruments and the generalization of musical notation seemed to open floodgates, producing a great library of ensemble music which is meaningful, fresh and popular today after two to three hundred years. Cherished as this heritage is and will remain, just so, we may expect that the perfection of real-time audio-graphic computer instrumentation (including a feasible interface with TV) offers a development in modern times quite as fruitful as that past.

While Renaissance musical notation permitted an ensemble of musicians to play together in correct time, computer technology has provided simply a total recasting of TIME because of solid state digital memory. TIME, which is the essential dimension of music, which is studied and perfected throughout a performing artist's career; this TIME, in digital memory, can be molded and reshaped over and over like sculptor's clay.

To further summarize and review: a computer's expanded opportunities for an art of color action and music were never well understood. Before the latest, fast digital systems with their real-time generation of both graphics and tones, plus instant replay, beginning in the late 1980s, the options weren't even subject to exploration. Now, overnight, a broad methodology is at hand.

TIME stored in digital memory becomes a malleable material. This singular fact, above all others -- *TIME's new physical tractability* -- has significantly changed musical perspectives. This is what I sought to understand and to control. On film, TIME is fixed into the silver image. But in digital, computer memory, TIME is freely alterable and permanently storable. With access to this new dimension of TIME, a few composers may elect to set aside their here-to-fore cherished and essential musicianship and the ensembles with whom they performed. They'll join ranks with a large fraternity of painters and sculptors.

Since, however, the arguments over art's relation to newly developing instrumentation is an ongoing subject of some controversy, my own experience can provide only this concluding anecdote:

With two homemade devices -- a simple sine wave pendulum array and an optical-printer instrument -- my brother and I composed our first modest international success in the rarified avant-garde of 1940s style "MTV". This early triumph implanted in our minds an urgent, lifelong drive to gain access to a perfected facility that would provide music and graphic capabilities unified within one instrument. All this began at least thirty years before computer technology would make our quest real and possible.

In 1959, I wrote a description of our pendulum and optical-printer methods and theories of composition for the journal of electronic music DIE REIHE Volume #7, edited by Karlheinz Stockhausen. Volume #1 of DIE REIHE included an article by Pierre Boulez in which he raised the question: "Is a concert hall really necessary when the performing artist has been eliminated." As long ago as the 1950s, when electronic music was created by splicing magnetic tape segments, many people puzzled over bothering to enter a concert hall to hear music played over bland loud speakers. Boulez proceeded to ask: "Is it not then necessary to find new conditions for listening or are we to contemplate the reuniting of this 'artificial' music with a 'visual double'? (his quotes)

Reading the Boulez article for the first time, I remember asking myself: "Why must anyone question if this electronic music should have a visual double? Electronic composers hardly need to re-invent the violin or the concert hall. If composers intend to deal at all correctly with their electronic options, they must invent that essential *visual double.*"

Possessing a determination to combine "artificial" music with a "visual double", my brother and I continued to search for the universal instrument. We had conceived an indelible dream of *auralvisuality* within a new art form.

Inwardly, for years I envied Domenico Scarlatti and Antonio Solar who, out of royal generosity or through a Pope's largess, seemed to have been provided with the instruments and the patronage with which to compose many hundreds of simple essays exploring a keyboard sonata form that was largely of their own invention (Scarlatti called them exercises -- a term we adopted). The seemingly blissful continuity of their lifelong creativity was exactly what we longed to emulate. Would that my late brother James and I had had such a "gift" of instrumentation. And yet, it's here!

John Whitney in his studio 1989

BACK DOWN TO EARTH:

Some kind of a disclaimer is probably due at this juncture: The system I have brought to Groningen on which to demonstrate my work is a 1986 IBM type 286 computer. Now, there are 386 and 486 systems that are several times faster than mine. That is to say, they offer a graphics many times richer than mine. Deeply, I regret not gaining the financial support needed to acquire equipment and software to try to fulfil much of the possibilities about which I speak. One example in particular: a computer program on which to compose music by sine-wave algorithms, is presently stalled. My enthusiasm for composing those complex sine-wave algorithmic constructs derives solely from the novel experience of making sine wave pendulum sound tracks in the 1940s.

The wonder is that I have come so far. This is largely the result of my association with Jerry Reed, an expert software consultant, who has contributed every component of software for the project since 1986. While the polar coordinate and differential harmonics concepts underlying the graphics geometry has been with me since the mid 1960s, I am truly thankful to Jerry Reed for the present composing software which is now a well tried and tested foundation for my work. I thank him for providing software with which I have been allowed to compose more works since 1986 than during my entire film making career of forty previous years.

Jerry and I desire soon to develop a saleable program both for university and professional markets as well as a simpler more popular program for retail.

My compositions at best are intended to point a way toward future developments in the arts. Above all, I want to demonstrate that electronic music and electronic color-in-action combine to make an inseparable whole which is much greater than its parts.

CHAOS AND CREATIVITY

The dynamic systems approach to musical composition.

Peter Beyls
Expanded Media Studios
Brussels, Belgium

Extended Abstract

Traditional channels for introducing intelligence in computer music systems are firmly rooted in the knowledge-based approach; methods and computational strategies borrowed from the field of artificial intelligence. Expert systems for composition and pattern-directed inference systems for real-time man-machine improvisation are exemplary. In general, the aim is to introduce independent creative decision making through computer simulation of human creativity. Impressive statements have been produced along these lines, in music as well as rule-based computer graphics. Two observations have led to the consideration of a totally different methods. First, expert systems become problematic if situations occur that were not anticipated by the programmer and sooner or later, the programmer is faced with a complexity barrier. Second, appreciation of the pattern making potential of nature led to the study of concepts like self-organization. Complex dynamical systems are an alternative to the constructivist approach in composition, i.e. the critical assembly of architectures of time according to some explicit scenario. Complex dynamical systems, on the other hand, consist of many elements interacting according to very simple laws but giving rise to surprisingly complex overall behaviour. Composition becomes experimenting with attractors -- instead of creating a rule-base -- as well as designing tools that allow the topology of the composer to interact with the system's internal activity. The idea is to critically push the system out of equilibrium using tactile motor control as to explore the various degrees of freedom of a given system. The implicit behaviour is then mapped to the musical problem domain. Improvisation becomes navigation in a hypothetical world of which the composer is both inventor and explorer. Strange and intricate imagery, in both space and time, is found in physics, biochemistry, fluid dynamics, ecology and nonlinear mathematics. We have implemented and evaluated various models for spontaneous pattern formation, including one-dimensional cellular automata, direct computer simulation of chemical instabilities as witnessed in the BZ-reaction and a spatial model exploring equilibrium behaviour in a society of interacting agents moving in 2D space. The present paper outlines a connectionist-like model, a regular structure of agents engaged in local interaction, using forces of activation and inhibition between neighboring agents. Randomness/determinism and chance/necessity seem at the heart of creativity and happen to be central to the music of our time. We propose to view emergent properties from initial random configurations as a subtle alternative for both constraint-based, reductionist handling of randomness as well as rule-based composition by way of some generative grammar; complex dynamics as a creative, generative principle and a channel toward higher levels of man-machine interaction. This paper was prepared for the Second International Symposium on Electronic Art, Groningen, Holland, November 1990.

1. Introduction.

Ever since the early days of computer music, composers have aimed to introduce musical intelligence in a machine by trying to imitate certain aspects of human musical intelligence in a computer program. Pioneers (Hiller & Isaacson, 59 and others) built programs that simulated a given musical style by establishing musical rules borrowed from existing musical paradigms. Constraints were used to filter the output of a random number generator. This method, generate-and-test, proved to be highly inefficient. More control was needed and by the early seventies, crossfertilisation between the emerging discipline of AI resulted in the adoption of the rule-based method for musical composition. In addition, more sophisticated programming methods, i.e. object oriented programming, were introduced. Style imitation *remained at the heart of much work; consider the Flavors Band (Fry, 84) and, more recent, EMI (Cope, 89). However, tools for explaining musical decision making were now available by tracing the history of the computational process. More important, composers could learn about their own musical objectives from the circular process of rule specification and the appreciation of the rules' consequences. Expert systems have led to powerful statements in the arts in general, for instance, consider the knowledge-based drawings of (Cohen, 79) and intricate compositions guided by very high level musical abstractions (Barlowe, 81). In contrast to music, many visual artists continue to see computer media as tools, with minor interest toward process oriented production methods. Cognitive approaches remain even sporadic. In the field of music, expert system technology has proven to be useful for the creation of composers' assistants and intelligent sound editors, introducing very high levels of abstraction within the man-machine dialogue. In interactive composing, so called pattern directed inference systems allow for real-time composition following a scenario of rules while at the same time keeping channels open for perception and interpretation of outside influence. These programs are capable of expressing an individual musical character while simultaneously accommodating requests for attention of an external, human musician (Beyls, 88). Responsiveness and ease of adaptation to large swings in context determine flexibility. However, if we insist on real-time performance, a clear definition and concise description of the problem area is needed. In addition, only simple representation methods and efficient search techniques lead to successful applications. Rule- based systems represent aspects of the world in symbolic form. The idea is to reconstruct problem solving behaviour (as seen in human experts) in a program which reasons and searches through this symbolic space. Logical inference is at the heart of these programs.*

2. Complex dynamics.

In recent years, two observations have led to the consideration of alternative programming methods in AI. First, conventional expert systems remain helpless when faced with situations where knowledge is missing or incomplete. Moreover, expert systems are constructed "by hand", the expected performance of the system has to be formulated in explicit statements. However, at a certain level of complexity, it becomes very difficult to keep track of this performance as well as to debug such systems. In summary, traditional expert systems do not show graceful degradation when situations occur that were not anticipated by the system's designer and the programmer faces a complexity barrier. Second, observation of the pattern making potential of nature has led to the investigation of the constructive forces behind forms of natural organization. For instance, organized patterns are created spontaneously in biological workspaces. Consider the self-organizing behaviour in societies of termites; large artefacts are constructed without any plan saying which actions should be taken and when. Snow crystals are a combination of order and disorder; they grow according to the delicate interplay of microscopic and macroscopic forces. The geometry of nature was put in perspective (Mandelbrot, 77) by drawing attention to the fractal dimension of naturally grown shapes. These are said to be scale-invariant, which means that detail is everywhere and more detail is seen as we approach the shape. I suggest to view this as a metaphor for zooming in on complexity as such because our appreciation of artefacts seems strongly influenced by dynamic navigation between detection of detail and simultaneous perception of overall appearance. In addition, the dynamics of zooming in and out within the process of creation is characteristic of an exploratory attitude; detail may lead to better understanding of the problem at hand. Incidentally, the most popular images of chaos are mathematical formulae expressing fractals as a static generator of visual design, in sharp contrast to seeing dynamical systems as a metaphor for exploration and discovery. There are many other fields where natural dynamics are observed such as biochemistry, ecology, biology, fluid dynamics, neuroscience and nonlinear mathematics. Any system consisting of many properties evolving in parallel over time may be considered complex if it exhibits emergent properties. Emergent properties are sudden, spontaneous structural changes in a system out of equilibrium and in constant interaction with its environment. Such patterns, in time and/or space, are a product of self-organization, (Prigogine, 84) refers to them as dissipative structures.

3. Behaviour.

So, the idea is to avoid the problems mentioned above and to borrow generative principles *from examples found in nature. Besides, as an artist I am more interested in models of evolution and change than in theories of structural design. What can we learn from the creative forces shaping natural phenomena within the realm of our objective: the introduction of aspect of human creativity in artificial computer music systems? Current approaches to this problem are strongly polarized, some express faith in symbolic computing, adhering to knowledge based strategies of problem solving (Laske, 89). Others claim that only a behavioural approach using methods of subsymbolic computing may lead to successful results when modelling aspects of human musical cognition (Leman, 89). We will not continue the debate but provide evidence of the strength and weakness of both approaches from pragmatic experimentation in the problem domain of real-time improvisation and interactive composing. The differences are briefly summarized in simple terms as follows. Symbolic computing is based on the exploitation of knowledge stated explicitly as facts and rules acting upon symbols under the guidance of a supervising mechanism. Subsymbolic methods use analogical representations, which keep what they represent implicit in their representation. Examples are regular arrays as seen in cellular automata and matrixes expressing weights in connectionist networks. Such distributed representations are attractive because of their direct, visual appeal: what you see is what you get. The activity in these systems is no longer guided by a supervisor but issues from the local interaction of many participating agents. The distinction between knowledge based and behaviour based intelligence is important. For instance, when designing a building, an architect definitely draws on knowledge of materials, construction practice, financial considerations etc. He knows how to tackle very specific problems by reasoning and making choices. Does he use similar knowledge to express himself in words; when he speaks about his problem? Definitely not. Speech, perception, locomotion are all examples where behaviour is at the heart of the activity. Many great jazz musicians are exemplary here; the musical intensity of a virtuoso keyboard improvisation has more to do with spontaneous motor control than, say, declarative knowledge of musical scales. Some cultures emancipate the behavioural idea to its fullest. According to Indian musical practice you have to study raga's for 20 years, yet when going on stage, you forget everything you know and just let it happen. In the Indian language it's called "uppaj", which means imagination or "flying like a bird". You let go of all knowledge you have accumulated and take off. Cognitive activity during real-time interactive composition includes perception, imagination and reaction. Behavioural strategies seem appropriate here since they can establish a direct relationship between perception and action. It takes too much time to interpret auditory stimuli using search and mapping over symbolic representations. In addition, the flux of relationships between performer and computer program may be totally unpredictable.*

4. Creativity.

So far, we have traced the AI-context of our basic problem: the construction of intelligent systems for musical composition while insisting that our system should exhibit aspects of creativity. A creative statement should be new and useful. Something new raises questions in the perceiver, fundamental questions, therefore, are products of advanced creativity. If we expect new ideas, would a program functioning as the logical consequence of a set of rules be considered creative? For instance, Chomsky's theoretical work on generative grammars was inspirational for computer based musical composition (Roads, 84) and computer-aided visualization (Smith, 84). Grammars are devices for advanced productivity, but human creativity is needed to design them. One may add meta-level reasoning about the rules in a wish to change and adapt them according to the circumstances they generate. Again, methods of circular thinking are characteristic in human creative behaviour. Ultimate creativity seems connected to the discovery of new paradigms, new ideas that go beyond the potential embedded in rules. Creativity may be seen as searching through a very large problem space (Steels, 86). However, focus in a creative process is mobile. Perhaps a solution is found for a problem that was not anticipated by the programmer -- and the original problem is forgotten altogether. In other words, creativity works as an unpredictable, non-linear process. Incidentally, non-linearity also happens to be a native characteristic of complex dynamical systems. In a wider context, true creativity has more to do with self-revision than with self-confirmation, i.e. the application of procedures, ideas etc. that have proven to be useful in the past. A way to introduce unpredictability is the use of random numbers. Randomness is often used to simulate musical intuition. However, total randomness, like absolute repetition or total predictability, does not carry much meaning. Incidentally, the paradox is that while some artists express faith *that chance procedures may help to imitate human creative playfulness with originating ideas, others view it in opposite terms. Indeed, surealist artists were confident that random techniques would assure exclusion of personal involvement and intuition in the creative process. In interactive composing, the illusion of musical intelligence is a byproduct of minimal decision making, randomness injects energy, it tries to activate all available levels of activity in a given software defined process. Interactive composing offers schemes where motor activity of a human performer adjusts levels and degrees of freedom in such a process. It is important to note that interaction happens in real-time; a composition emerges from intimate man-machine interaction. The performer/composer provides feedback to a generative process of his own design and the emergenge of musical shapes in this abstract, conversational process may be taken literally in the light of the emergent properties seen in complex dynamical systems. Random methods involve selection by imposing constraints on the output of random generators. Grammars, as mentioned above, are examples of constraints imposed at the generative level. In interactive composing we should be able to provide feedback to such programs. Predetermined rules and constraints would be optimized according to continuous evaluation at both sides of the screen, i.e. the program would learn which suggestions are more successful than others (1) and the performer would learn about the current direction of his musical objectives (2). Such natural awareness of unspoken relationships is still unique to human ensemble improvisation. Here, appreciation of human musical intelligence includes awareness of a collective physicallity where musical intensity radiates from unspoken, deep rules/constraints imposed by culture as well as the topology of the human body. By the way, consideration of physical parameters is extremely well developed in ultra low-tech environments like those found in ethnic music, overdeveloped in many a popular musical idiom, while very often underdeveloped in the avant-garde.*

5. Heuristics.

The task of simulating human musical creativity has been recognized as a very difficult -- if not impossible -- one. In the context of advanced knowledge-based programming methods, composition may be seen as a problem solving process. The idea is to find a solution for a given musical problem by exploring a very large search space. Since the search space is by far too large to be explored by exhaustive search, specialized short cuts, known as heuristics, are needed. Heuristics are formalized in rules saying what to do given certain circumstances, we may think of rules as surface knowledge. However, the deeper knowledge are the constraints which are based on the physical properties of musical material or on a particular esthetic theory (Steels, 86). Composing means scanning a search space looking for a musical structure which satisfies the constraints. This involves the creation of a schedule (Ames, 1983); priotizations of all available options from most to least desirable. The program then evaluates this schedule to find an option that satisfies all constraints. However, in case no single option proves acceptable, the program resorts to backtracking, trying to revise previous decisions in the decision tree and, then, trying to obtain a valid solution from there. Expert composers exhibit a highly developed, natural sense for applying appropriate heuristics facing given constraints. It is exactly this expert knowledge which is extremely difficult to capture because it is active on the subconscious level. This leads many to believe that artificial approaches to creativity are doomed to fail since expert knowledge, referred to as musical consciousness or intuition are missing while these are prerequisites for true imagination. However, intensive work in the field of machine learning reveals the potential of having programs learn their own heuristics, leading to second generation expert systems (Steels and Van de Velde, 85). The idea is to build up a heuristic knowledge base automatically through introspection of the program's own problem solving behaviour. This seems absolutely necessary since heuristics are not consciously available. In addition, we know that even if they were, they would be too complex for handcoding, one of the very reasons that -- apart from the introduction of learning -- led to the consideration of a completely different programming paradigm suggested by interesting behaviour in complex dynamical systems. Indeed, in contrast to the approach expressed above, explorers of non- linear systems believe that the laws of unpredictability, chaos and irreversible time are a key to natural creativity -- the ultimate example might be the emergence of life through natural selection, a process where the non-equilibrium dynamics of the environment leads to self-organized structure. Prigogine even suggests the concept of an entropy barrier, meaning that any system of sufficient complexity will become unstable losing its initial conditions and behave unpredictably. With such systems, time is irreversible, it is *impossible to backtrack previous states, there are too many. This is easily and convincingly demonstrated, even with simple cellular automata rules like those found in Conway's Game Of Life. Life is not backward deterministic, a given pattern often has many patterns that may have preceded it; a pattern has only one future but many possible pasts. The recognition of probabilistic evolution and chaotic propagation as a driving force in creative processes is in sharp contrast to the reductionistic view of creativity.*

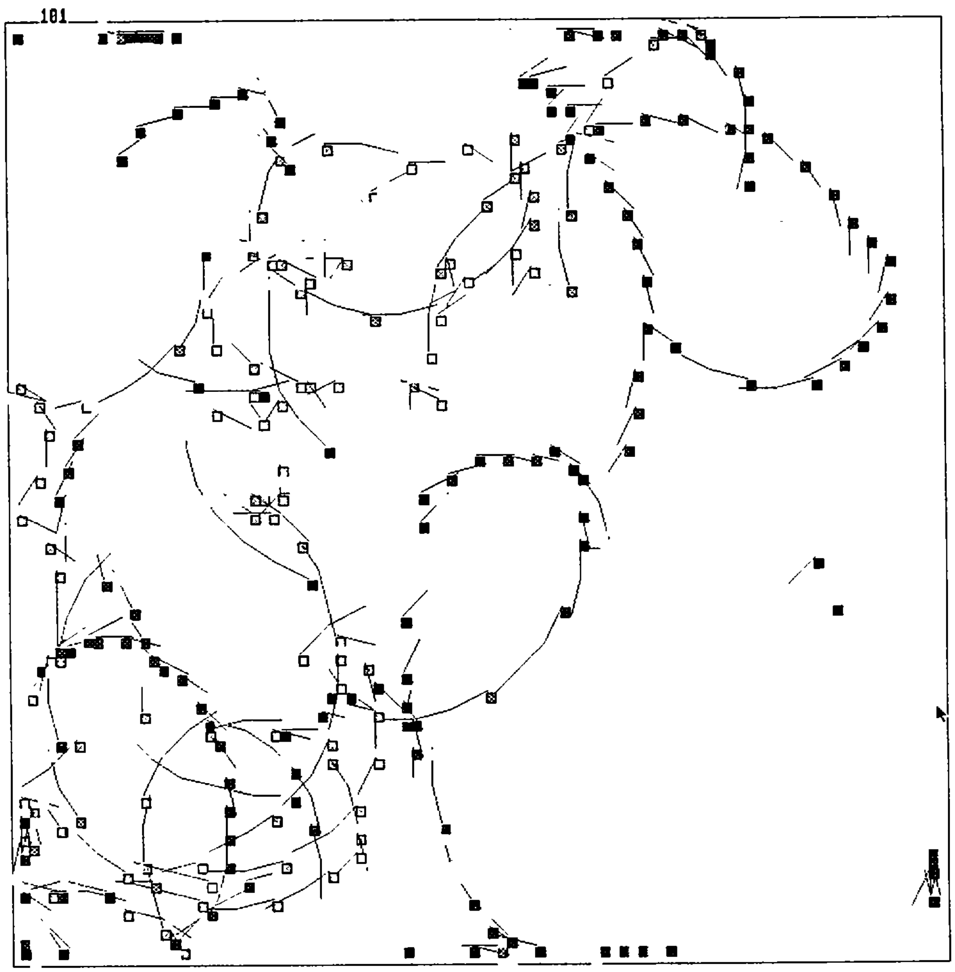

Figure 1: tracing activity in a spatial model.

This figure shows the state of affairs after about 100 generations of 8 agents moving in 2D space. All agents express individual affinities for integration and expression towards all other agents in this virtual society. In addition, agents interact (execute simple rules) when navigating in eachother's neighborhood. As a result, complex macroscopic behaviour results from simple microscopic activity.

6. Randomness & chance.

In a complex dynamical system randomness may be used to explore all degrees of freedom potentially available. However, principles other than constraint-based critical filtering are active for stimulating the birth of automatic musical structures. These principles include: self-organization, activation-inhibition, spreading activation and relaxation. Strong arguments for using dynamical systems is their inherent flexibility and speed of reaction (when compared to rule based systems), they are adaptive by nature, they use distributed ways of knowledge representation (more robust than rule-based systems), in addition to allowing the conception and control over musical structures in terms of underlying images of these structures. These images, known as analogical representations, let us grasp the effect of generative principles in a single picture and, indeed, one picture is worth a thousand words. In addition, gestural techniques, common practice in computer graphics (e.g. pointing, dragging), may directly act upon these images. In fact, any sensory mechanism may be mapped to such representations. For example, in a recent piece for violin with computer extensions (Beyls, 89), sequential melodic material from the instrument is accumulated in a transition network. The content of this network activates a 2 dimensional cellular automaton. Simple local rules push global overall structures to surface. These are then interpreted by a rule-based algorithm that arranges for automatic orchestration of the original monophonic lines into full 8-voice polyphony. In terms of nonlinear jargon, we say the systems exhibits attractors because points of relative stability fluctuate through time and space. The output of such systems ranges from quasi-periodic oscillations to the building up of strange attractors because of internal feedback.

We have studied many methods for acquiring spontaneous activity in environments for interactive composing including one-dimensional cellular automata (Beyls, 89), direct computer simulation of nonlinearity as observed in biochemical processes (Beyls, 90a) as well as a spatial model (Beyls, 90b). The latter case is an example of a combination of constraint-satisfaction and local operations: abstract musical entities, uniquely defined "actors", express individual opinions about each other and engage in interaction when meeting in 2-D space. This micro-world, as a whole, accommodates external gestures from the composer. As a result of both internal spontaneous activity and external goal-directed activity, strange patterns of variable coherence emerge. Figures 1 and 2 provide a snap shot of 8 interacting agents taken after about 100 generations. As a final example we will briefly describe yet another model, inspired by research in fluid dynamics. It is an example of activation/inhibition.

7. A connectionist model.

The initial idea for the current model came from the appreciation of strange phenomena in fluid dynamics such as Benard convection (Babloyantz, 86) and the dripping faucet experiment (Wolfram, 84). Such systems are inspiring because they allow gradual navigation in degrees of complexity by controlling a single external parameter. The suggested model is a connectionist-like structure. You may see it as a specialized cellular automaton, a micro-world represented as a regular array of cells, each cell representing a 'virtual musician'. Cells are active units called agents according to the terminology suggested in (Minsky, 86). These are very simple in themselves but, overall, collective complexity results from mutual interaction combined with external influences. We proceed as follows:

1. design a simple agent, i.e. definition of a native character

2. create initial random affinities between agents

3. specify global constraints acting as global parameters

4. provide gestural input to particular (groups of) agents

The idea is to map the resulting behaviour to our problem at hand; the creation of musical structures from emergent properties in a complex dynamical system. The system is seen as a collective of agents exhibiting evolving connections amongst each other. Any two agents connect of they exhibit sufficient affinity towards each other. The agent's other attributes include individual levels of activation and inhibition, energy and position in space. The principle responsible for pattern formation in such organized networks is known as "spreading activation". Agents are thus linked in a network, the links being of variable strength because every agent features an activation level and an inhibition level. The agent's flexibility to move is a function of its level of activation, which in turn is a non-linear function of external *constraints. In addition, the system as a whole dissipates energy, and the value of the dissipation factor will introduce variable inertia. Figure 2 illustrates the dynamics of 36 agents organized in a regular 6 by 6 array, time runs left to right, top to bottom. For twenty-six generations, activation, inhibition and local gradient (tension) are shown. Notice peculiar, oscillatory behaviour and how the system moves to a different limit cycle from the accommodation of external disturbances at generation 9 and 19. The full potential of this connectionist model is documented in a separate paper (Beyls, 90c).*

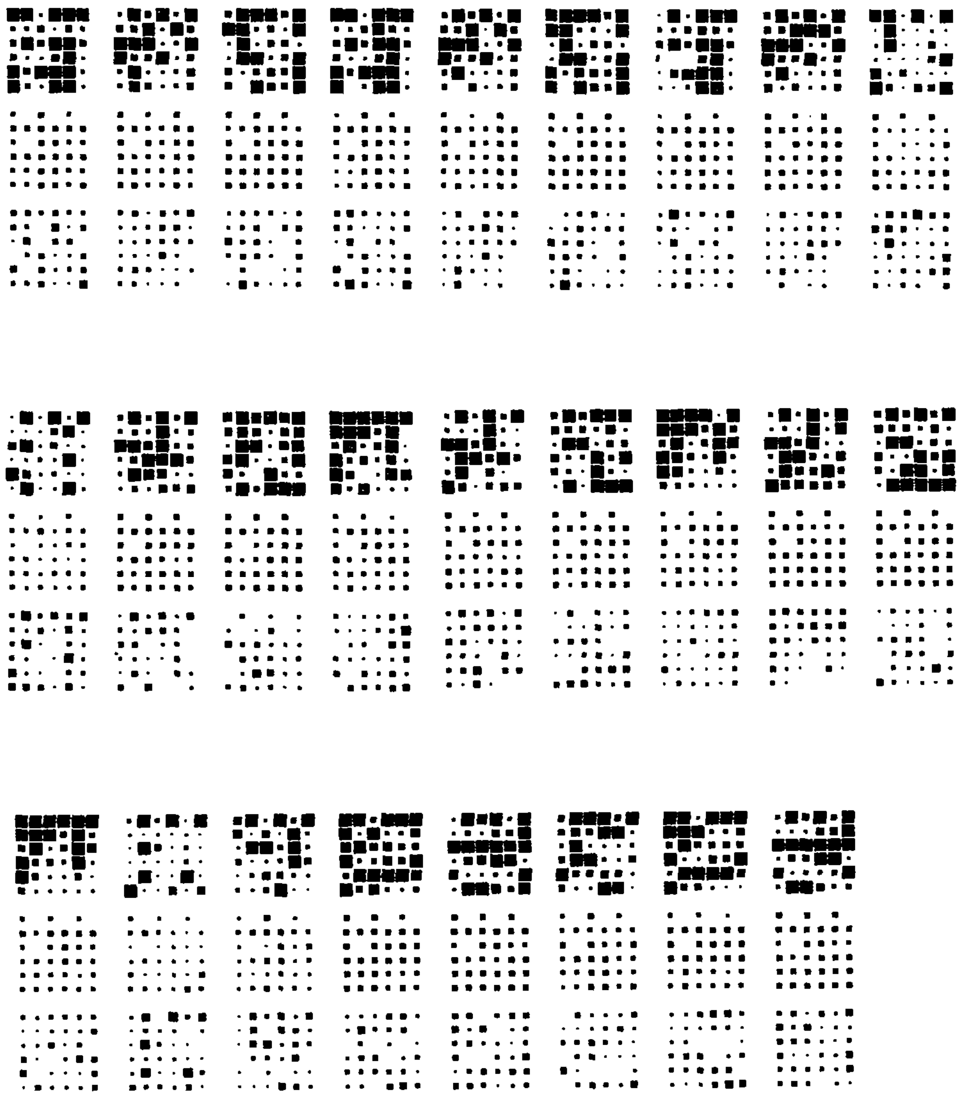

Figure 2: activation/inhibition in regular structure.

Per generation, levels of activation, inhibition and gradient field are visualized.

8. Conclusion.

Does it make sense to view the disorderly behaviour of complex systems as manifestations of true creativity? For the mathematician, the concise formulation of some complex, physical phenomenon in a neat, compact, simple formula may be experienced as an aesthetic artefact. The overwhelming visual complexity of fractal pictures is intriguing. However, our focus *should not be with visual appeal but with what these pictures represent. In addition, the unexpected behaviour of chaotic systems -- the delicate interplay of chance and determinism -- is observed after implementing a computer simulation; that is, possibilities are discovered in retrospect. Self-organization may certainly be seen as a powerful alternative to the constructivist approach in musical composition. We no longer specify recipes for the critical assembly of musical atoms, e.g. the hierarchical structuring of notes, phrases, etc. Here, composition is seen as the architecture of time. In contrast, we aim for spontaneous pattern formation from experimentation with attractor systems. This experimental attitude is strongly related to the invention of hypothetical worlds of which the composer is both inventor and explorer. Composition becomes navigation in attractor fields, the interactive, conversational exploration of levels of stability and sensitivity. In essence, we observe a continuous confrontation of two dynamical systems; one embedded in a computer program, the other as present in the composer's opinion and reaction to its current output. Since the interaction relies heavily on real-time visualization, it is a particular example of the integration of computer music and computer graphics.*

9. Acknowledgement.

I am indepted to the complex dynamics group at the AI lab of Brussels University for instructive feedback. Work described in this paper is supported by Yamaha and Atari Corporation.

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The Composer and the Orchestra - Closing the Gap

Michael McNabb
NeXT Computer

When composers began using computers to make music, the relevant computing conditions were in a state much as they are today for computer graphics. In order to achieve the level of realism, expressive control, and timbral nuance necessary for a satisfying and successful musical art, real-time control was out of the question. Compute ratios of 100 or 200 to 1 were not uncommon, especially when compute-intensive qualities such as digital reverberation were included. But back around 1976 when I began my doctoral work at Stanford, the excitement and satisfaction at working in a pioneering and futuristic medium was great enough to make us abandon good sense and spend the small hours of the morning computing a few tens of seconds of music.

As most of those early works were sans performers and presented on tape, we often questioned the need or appropriateness of the traditional concert presentation. However, there were some good reasons for retaining it at the time. The extreme dynamic range and frequency bandwidth of computer-generated sound required an uncommonly high degree of power and accuracy in audio reproduction. Sound systems also needed to be carefully equalised to minimise the acoustic non-linearities of the listening spaces. Many compositions used four or more discrete channels of audio in order to be able to simulate moving sound sources in space. This technique required the careful control and balancing of the sound system and positioning of the loudspeakers. Even today the precise effects accomplished then cannot be reproduced on home sound systems, even with the increasingly popular film-type surround systems.

It is undeniable though, that the live performance tradition in music is very ingrained and powerful. Pressures soon developed within the computer music community to find techniques for real-time performance of computer music. This led first to the development of large, centralised, expensive, and usually therefore one-of-a-kind digital synthesisers. Notable examples of this class of machine are the Systems Concepts Digital Synthesiser at Stanford University (recently retired in favour of a network of NeXT computers), and the 4X synthesiser at IRCAM in Paris Eventually, commercial activity produced frequency modulation, wave table, and sampling synthesisers, along with the ubiquitous Musical Instrument Digital Interface (MIDI). The commercial technology made available at an affordable price certain discreet subsets of the possibilities allowed by the earlier monolithic synthesisers.

Both developments were seen as a mixed blessing by those accustomed to the total computational flexibility of the general-purpose computers we had been using for synthesis and signal processing. Live performance was fun, and contained the exciting element of the unpredictable. However, because of the newness of the technology, it was also more risky, and many wonderful and expressive computer music techniques were still not available in real-time, or available only at a lower level of quality or expression. I sometimes feel jealous of artists who work in media which have little or no tradition of live performance. For example, I have yet to see anyone coming out of the International Tournee of Animation saying, "Well,it was ok, but it would have been much better as a play". In other words, they are allowed the luxury to refine works until they are completely satisfied with all details, whereas in performed music, even when you think your score is perfect, any one performance always falls short of perfection.

There exists something of a double standard even within the music audience. The same traditionalists who complain about the lack of a performer on stage at a concert of taped works spend hours happily listening to recorded performances at home, without demanding that the orchestra be in their living room. In fact, when works are presented as recordings, there is no inherent difference between synthesised music and music whose sounds came originally from acoustic instruments. In this context, one listens to whatever "performance" is there, whether programmed by the composer or played by humans. There is no reason why the same cannot be true at a concert presentation of taped works, if the audio quality is of sufficient calibre. If taped works fail, it is usually the fault of the composer who, used to having a performer transform his scores into music, neglects to take responsibility for that level of expression himself.

Today though the live-performance of computer music is in the process of making another advance via new generations of computer technology. The latest general-purpose desktop computers and accessories are extremely fast and powerful. They support a great deal of real-time control, and also allow a return to the more general approaches to computer music of the past, wherever commercial synthesisers and signal processors fail to provide needed capabilities. Real-time possibilities now include not only sound synthesis, but also algorithmic composition, the processing and manipulation of live and recorded sound, and the simulated movement of sound in space. The quality of the latest sound synthesis techniques and hardware is also very high. The dynamic range and timbral pallets of the best computer music systems are measurably comparable to that of a symphony orchestra.

Computer music systems can perform sophisticated interpretations and mappings of a performer's gestures in order to control much more music than can be performed on any one conventional instrument. To accomplish this, a repertoire of knowledge of the details of a composition's musical style, harmonies, textures, and other structures can be taught to the computer in advance, so that during the performance the performer may direct events at a higher level of expression. One may envision a musician in such a context as having a role in between that of conductor, composer, and performer. The role can be continuously varying -- as musical complexity increases, the computer assumes an increasing amount of responsibility for the musical details and the performer's gestures are applied at a higher level.

In experienced musical hands, this kind of system has the potential of expanding the performance capabilities of the individual musician from that of a single instrument into the realm of complex orchestral expression. Such a system represents a step in the effort to narrow the gap between the symphonic composer's imagination, and the direct experiencing of his work by others, perhaps even as it is created. This is a liberating concept, in an era where most orchestras are de facto early music ensembles, under the control of conservative benefactors or government agencies, and have no money to pay for rehearsal of new music.

As computers continue to increase in speed and flexibility, these concepts will no doubt be extended into the visual domain as well. It has even been proposed that since computers allow music and graphics to be composed and synthesised using a common set of principles, that this combined medium is inherently superior to music or graphics alone and is destined to supplant both. I believe that this attitude arises from a naive understanding of how art interacts with the listener or viewer. In our renewed enthusiasm for the synaesthetic experience, we must not lose sight of the fact the much of the power of music, or any art form, lies in its mysterious interaction with the listener's own imagination, personal experience, and unique emotional psychology, whatever the creator's intent. If we add a strong visual element to music merely for the sake of expanding the artist's range of expression, we may easily wind up weakening the experience of the listener and viewer, as we have effectively co-opted an element that was previously left to the audience's imagination. The artistic message may become more specific, and the experience more universal, but at the expense of depth of personal experience which the music or graphics alone formerly allowed.

Obviously there is potential in a new art of sound and light under the control of high technology. It is not, though, a successor to or enhancement of either purely musical or purely visual art forms. It is rather another thing, to be entered into with twice the care and thought, and with our eyes and ears wide open.

A SOFTWARE TOOL FOR THE FUNCTIONAL PERFORMANCE OF MUSIC †

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0. Abstract

Music performance is traditionally made up by sequences of events (notes and chords, by example) as the basic objects. In this paper we show how music can be performed at a more abstract level in which the basic music object is a pattern of musical text (i.e. a chunk of a score).

We have designed, implemented and experimented FP (Functional Performer), a software tool that allows the real-time processing of music patterns by means of music functions (e.g. tonal and modal transposition, specular inversion, juxtaposition, superimposition, time shrinking, etc.); functions are activated by the ASCII keyboard keys and are either deterministic or non-deterministic. Patterns obtained by functions may be arguments for other functions during the current performance. Music is generated as MIDI data and real-time executed by MIDI devices controlled by FP.

Therefore, FP is a tool for the performing of music structures and their processing; the executed score is depending on the music patterns previously defined (music objects) and gestural acts we do during performance (music functions). The same sequence of gestural acts may give different results with respect to music patterns; particularly, if we only use the subset of linear functions we have a kind of music which is consistent with the music patterns: if we define serial patterns we get serial music, if we define modal patterns we get modal music. Otherwise, we can use non-linear functions which modify the syntactic characteristics of the music patterns.

At present, the first version of FP is completed and is usually experimented at L.I.M. concerts; it runs on MSX computers. A second version is under development on the Macintosh II family of computers; it has many improvements on graphics, ergonomics, efficiency and functionalities and can import/export Standard MIDI File scores.

1. Introduction

In the music domain, the instruments revolution caused by the coming of digital devices has cast doubt on the classical roles of the protagonists of music production and enjoyment processes: the composer, the performer and the listener. In fact the new informatic music workstation features allow the musician to assume all the three roles either sequentially or simultaneously, according to the features of music systems (interactive systems or real time systems).

Therefore, recent trends in computer music research are devoted to a not yet well explored field i.e. the development of new computer music instruments. Actually, digital systems may be programmed and devices may be connected one each other to build complex systems; this kind of experiences leads to a new idea of music instrument and related making techniques.

Particularly, we have had two main aims in the design of the FP: an original and advanced use of commercially available low-cost devices and the realization of an informatic music instrument for the real time performance.

In the following paragraphs we show the most relevant features of the FP with respect to similar systems; then we briefly describe its working with some examples.

2. The conceptual environment

This research has been carried on in the frame of the more general "Intelligent Music Workstation" Project [Camurri et al., 1989]; within all this project we have accepted as a standard some concepts which seem to have a basic role both in music thinking and understanding i.e. in music creation and perception; therefore, in the following paragraphs we will briefly discuss about: music levels of representation and related languages, music objects and their transformations by operators, evolution of music performance pragmatics.

2.1. Music levels of representation

A relevant feature introduced by computer applications to music is the possibility to describe music information at many different levels of abstraction [Haus, 1984] [Pope, 1986]; those levels may be concurrently accessed depending on the user will; so, one can choice the level which is closer to the activity the user wish to do, without restrictions on moving up and down within hierarchical music descriptions during user-system interaction; we may think as if we have at our disposal a kind of "elevator" to access the various levels of abstractions.

From an abstract point of view, we can think that music can be described by the following levels (see also [De Poli/Haus, 1982]):

structural level: where relationships among music events are defined;
symbolic level: where elementary music events (i.e. notes) juxtapositions and superimpositions are defined (as we can do on the traditional score and also by composing and sequencing software packeges);
timbre level: where the timbre models of music events are defined;
operative level: where operative codes define the timbre models of music events;
audio signal level: where music is simply described as sequences of instantaneous values of amplitude (i.e. samples).

Every common music activity generally involves more than one level of representation: by example, music performance requires actions mostly regarding notes but also timbre models and timing control. Therefore, three levels are involved: symbolic, timbre and operative.

2.2. Music objects

In our research we have adopted the notion of music object [Degli Antoni/Haus, 1983] which is more general than the music event one and it is also less related with a particular level of abstraction. Music object means anything that could have a musical meaning and that we think as an entity, either simple or complex, either abstract or detailed, an entity with a name and some relationships with other music objects.

Starting from this concept we can define as a music object, for example, both a structure of notes and a timbral characteristic. You can see in Fig. 1 four examples of music objects which belongs to different levels of representation.

2.3. Music operators

We assume that music pieces are made up of music objects and their relationships which, in general, dynamically grow from the beginning to the end of the piece [Haus, 1979]; so, more precisely, we can speak of their transformations vs. their relationships, because they can appear and disappear, change or repeat, but anyway they are the information base of the growing process within music pieces, both from the creative and the perceptual points of view.

We can simply say that a transformed music object S' is obtained applying the transforming process P to the original music object S; the transforming process P may be made up of many operators. This schema is shown in Fig. 2.

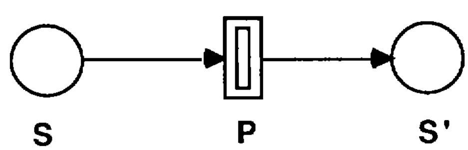
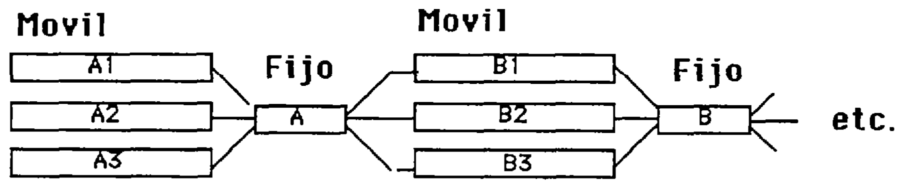
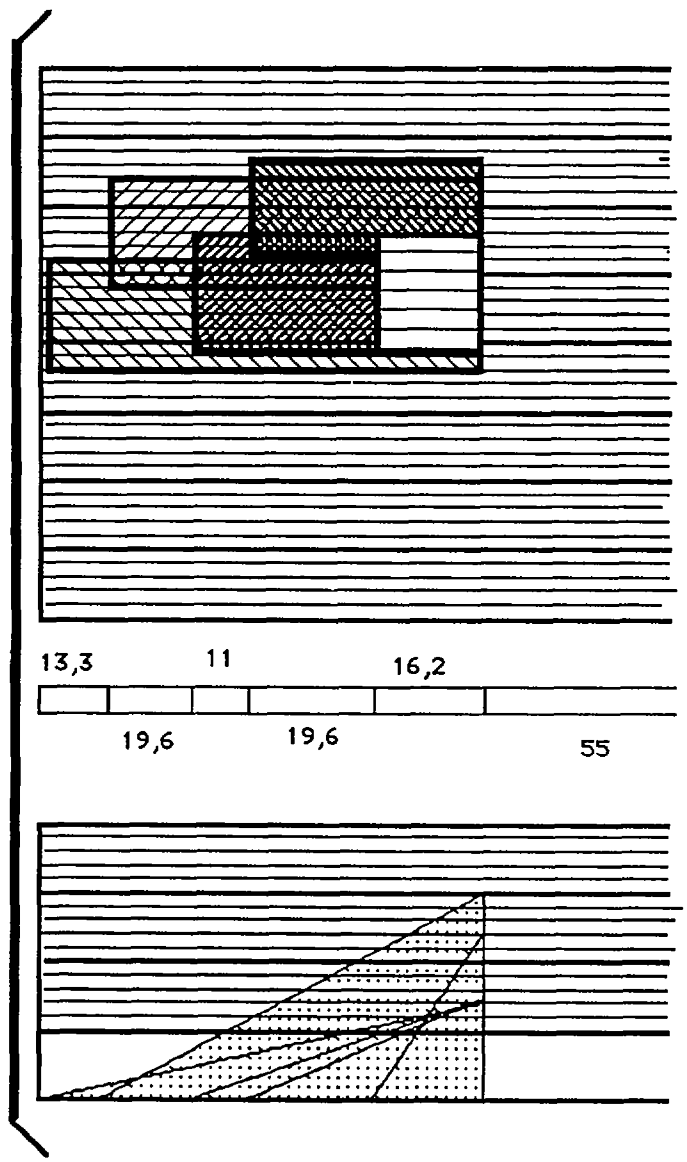


Figure 2: the elementary music object transformation process.

In a previous research, which has deeply inluenced the present work, we have explored how to describe music by means of homological operators [De Stefano/Haus, 1980] [De Stefano et al., 1981].



a)

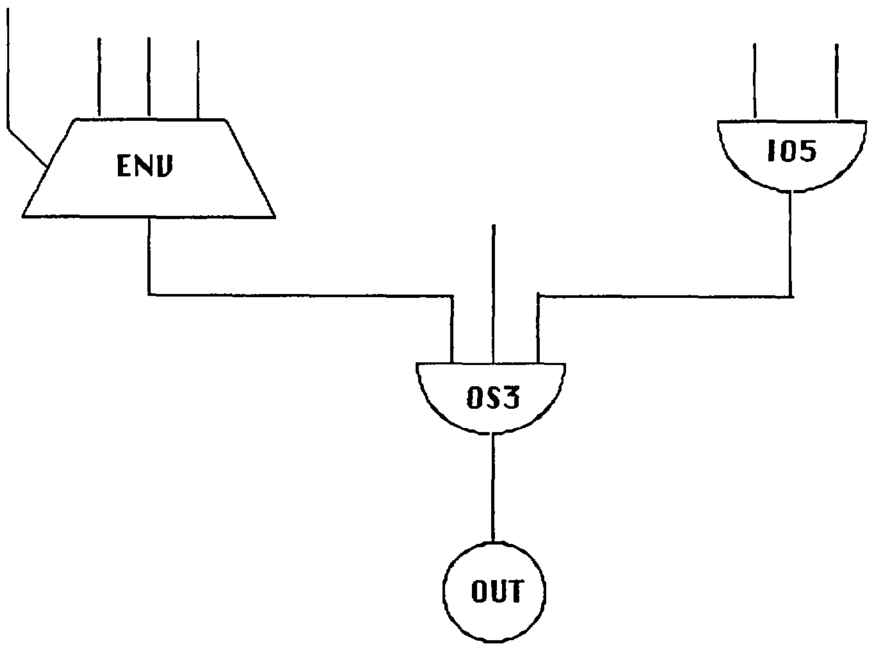


c)

Figure 1a & 1c: music objects of the structural level (a) and electronic symbolic level (c)

b)

Instrument = INS 1
Mod. Envelope = ENV P5 dB fa b5 ATOK
(P2,P8,P9,P9)
Mod. Linear Osc. = 1 .o 5
Mod. Osc. = PSC3 b5 p5 Hz b6 b5 f1
Mod. OUT = OUT b5 b1
END



d)

Figure 1b & 1d: music objects of the traditional symbolic level (a) and timbre level (c).

2.4. New trends for computer music live performances

The music concert by the actual traditional meaning is based on some number of "actors" (musical interpreters and performers) who produce sound processes using musical instruments (acoustical or electroacoustical or, particular case, human voice) directed to the audience; therefore, information which is produced and received during the concert depends on:
a) musical interpretation;
b) performance and interpretation on the instruments;
c) spatial disposition of performers and instruments on the stage;
d) morphologic features of the concert-hall;
e) executive pragmatics in the scenic sense (visual).

Evolution of this informational context has already passed across a great number of experiences which, with a variety of different ways, allowed to test new form of spectacular fruition; we cite only someone of the most significant:

* in advanced music (especially electronic), the magnetic tape concert: sound information depends only on loudspeaker position, visual information is almost unmeaningful, there are no human "actors";

* in live electronic music concert, particularly with computer aid, sound spatialization: even in traditional concert, sound is distributed in space, but according to a static scheme, while with electronic experiences the control of sound spatial distribution is generalized by means of models allowing live dynamic variation;

* in computer music concert, the possibility of changing timbre during the performance: performer's pragmatics change [Waisvisz, 1985], instruments (which act here on spectral content of sound rather than on sequences of timbrically preconstituted sounds) change [Loy, 1985], musical information (in which its more physical aspects are enriched) changes;

* many other kinds of performances in which cards of traditional concept are shuffled as to information content and channels by which information passes from the transmitter to the receiver [Haus, 1990].

Looking at the new scenario of music performance we think that may be interesting for performers to have at their disposal tools which allow to perform at a more abstract level than that of the traditional performance one for two main reasons:
a) the new computer music instruments are able to work with music objects which are more abstract than notes (see, for example, [Zicarelli, 1987]);
b) the new computer music instruments make possible to finely adjust timbre model during performance, so that performers need more time to control timbre.

In other words, we think that may be a future trend that music performance will have a greater emphasis at the structural, timbre and operative levels vs. symbolic level actions.

Our research has as its main aim to give the possibility to the performer of acting on a keyboard at the structural level, so that his actions have more power and he can have more time to act at timbre and operative levels on specific controls and devices.

3. Performance features

Due to the motivations we have spoken above, the availability of a music instrument, which can act at the structural level and engrosses a few actions by the human performer, makes a crucial point both the definition and the choice of music objects for the performance. Two are the most relevant constraints conditioning the choosing process: the characteristics of transforming functions of the FP and the music statements desired. In fact, the kind of the choosen music materials (i.e. predefined music objects) is more relevant with respect to the gestural behaviour, the FP characteristics and the timbral patches.

On the other hand, having more time free, the musician can design his performance in order to:
a) apply transforming actions to timbral patches (i.e. the "orchestra") during the execution;
b) control by himself the mixing process;
c) control by himself the spatialization of audio processes;
d) control further devices for multimedia performance (by example, computer graphics in real time, etc.).

3.1. Planning a performance: pre-definition of music objects

As we show in § 4. speaking about the FP system, the horizon of possible transformations actually concerns pitch and duration domains; then, music objects really are melodic fragments (sequences of notes or chords). Anyway, in spite of actual limitations, we can work with higher formalizing and quicker abilities both in selection and synthesis processing of music texts.

It seems useful to make a distinction about the organization characteristics of thematic materials (melodic fragments' files):
a) fragments which are fit for sequential performance (antecedent -> consequent) or denote causal relationships;
b) fragments which are tending away from sequential and causal logics and lead to a more advanced use of the implemented algorithms for music objects' transforming.

In fact, fragment files can acquire new functionalities if they are put in or called from a context of rules which is tending to not respect their initial semantic characteristics.

3.2. Performance as improvisation: real-time definition of music objects

Real time definition of new music objects is now possible, so the musician can modify his thematic environment during performance, by example basing changes on stimuli coming from the performance environment, both when music objects are ex novo defined and when they are obtained composing and decomposing the original ones.

In that case, as in the case of real time changes of dynamics and timbres (see § 4.4.), there are computational problems, the solving of which represents one of the research topic currently going on at L.I.M.

3.3. Real-time processing of music objects

The real time processing of music objects, that is one of the main features to make possible a functional performance, involves the solving of some computing problems concerned with processes' concurrency and optimizing resources' management. Both of them are crucial factors for low cost computing systems and then require major efforts from the point of view of the design and implementation of software packages, to make up for computing power bounds. On the other hand, the problem is mitigated due to the need of music texts computing vs. audio signal processing, by reconfiguring the problem as a function of complexity and needs which were stated in the design phase of the system.

3.4. Musician/computer interface requirements

It is necessary to provide the computer music instrument with a suitable user interface to allow a kind of real time performance satisfying the above stated requirements. The most relevant characteristics of such an interface have to be:
a) easiness and immediateness of use; during performance there is a few time: needed acts have to be few and simple;
b) highest quality and lowest quantità of information; the performer must know about global flows of information and is little interested in details that, anyway, can optionally control; this approach is suitable to make easier the understanding of control data (preferably expressed as graphics) about performance.

A hypothesis of solution we have adopted concerns the use of the ASCII alphanumeric keyboard to immediately activate the transforming functions, that are associated to the keys, and the use of the mouse device to act onto a graphic representation of data and music objects' flows either to make selections or to get global control operations or as an alternative method to activate transforming functions.

4. The Functional Performer system

A methodology of research for transforming and synthesizing music texts, based on *homological operators* [De Stefano/Haus, 1980] [De Stefano et al., 1981], was outlined with the implementation of the Functional Performer (FP); when we speak of homological operators we mean operators that apply homological transformations to music objects (homologies are a particular kind of geometric transformations whose natural environment is an n-dimensional space).

The FP system is distinguished from other music performance systems mainly for its real time processing feature which acts at the higher level of music representation, that is the *structural level* [Haus, 1984], allowing, on the other hand, essential and limited gestural intervention i.e. the musician presses ASCII keyboard keys. In other words, we have a revaluation of gesture with respect to the pragmatics of traditional performance: now gesture acquires a particular equilibrium: it is no more a virtuoso act of the performer which acts on traditional instruments (where a single sonic event corresponds to each act), but it is not even the insensitive act of the finger that presses a button for activating either a prerecorded sound process or a predefined automatic performance. Instead it is an act to either control the execution of a music object or start a generative process of a new music object (see Fig. 2) by means of the transformation of a predefined music object. Therefore, the human performer becomes free from the constraints of a punctual execution of the music text (i.e. the score), acquiring major freedom to control other performance aspects (timbre patches, spatialization, etc.) and careful control on transformation processes of music texts.

4.1. System architecture

The FP system may be defined as a system made up of a "slow" general purpose computer (for music text computing and synthesis) connected with some MIDI devices (for sound computing and synthesis).

In general, the FP has innovative aspects with respect to the upgraded power for controlling *concurrent processes* , which unfolds by means of *acts* (by the ASCII keyboard) devoted to the *processing of music primitives* , that can be represented as *melodic fragments* defined as events of the pitch-duration kind; pitches are related to the twelve-tone tempered scale.

For every group of user defined primitives characterized by homogeneity or etherogeneity criteria we speak of a *file* (i.e. a library of music objects), whose dimensions (one or more fragments) and the criteria for material selection (intervals, scales, patterns, modes, series) can be newly defined as it is suitable with respect to the amount of transformations expected.

The use of polyphonic and polytimbral MIDI devices allows to imagine a considerable range of *timbral solutions*. Then it is possible to define strategies for improving the organization of information flows toward peripherals in the most efficient way; furthermore, a feedback feature to assure the control of timbres' choice and primitives' modelling is very useful.

4.2. The performance language

The operative environment we have spoken of allows the real time execution of *operative scores* represented as sequences of algorithms. It is also possible that the *functional performance* be free; in other words, that the performance be based on the ability of the musician to improvise variations (or, better, transformations) by means of the ASCII keyboard according with the file of predefined music primitives.

The various experiences the composer and the performer have by the FP system may be unified as an only kind of experience by a new pragmatics made up of production, experimentation, growing, reflection, means' improvement, deeper definition of aims [Stiglitz/Tanzi, 1989].

4.3. Implementations

The FP system was conceived by Goffredo Haus and realized in the earlier version on an MSX computer by Alberto Stiglitz at the L.I.M. - Laboratorio di Informatica Musicale of the Computer Science Dept., State Univ. of Milan; a further version, currently under development, was then designed by Marco Benvestito for the Macintosh.

4.3.1. The MSX version

The MSX version of the FP system was developed between 1987 and 1988; it is based on an MSX2 (µp Z80A) microcomputer equipped with 128 KB RAM, 128 KB VideoRAM and floppy disc drive. The computer is connected to a Yamaha SFG-05 FM sound synthesis module with MIDI interface for communicating with other MIDI equipments. The software environment is made up of the MSX Disc Basic and the Yamaha ROM FM Music Macro II including the MSX Disc Basic extension for SFG-05 module controlling.

The system has the following functionalities:

a) creation of melodic fragments' files with related functions to modify, store, loading and printing;
b) real time execution/transformation of melodic fragments;
c) deterministic and pseudo-random functions for executing and transforming;
d) 4 voices canon imitation (polytimbral);
e) Change Program MIDI functions;
f) operative scores' employment;
g) direct control of the SFG-05 module, employing it as a synthesis module.

The module for the editing of melodic fragments is separated from the performance one due to the lack of RAM.

The real time transformation operators available are the following:

- pitch specular inversion
- durations specular inversion
- intervals dilatation
- intervals shrinkage
- transposition up

- transposition down
- performance acceleration
- performance deceleration
- pitch retrogradation
- durations retrogradation
- total retrogradation
- data flow control (MIDI channel redirection and/or MIDI program changes, melodic fragments selection, etc.)

Almost all the operators are available in two distinct versions: QUICK and RANDOM; the QUICK version allows to directly transform the original music object and the new one is immediately executed, while the RANDOM version produces a sequence of intermediate steps between the original music object and the new one. The number of intermediate steps can be set by the user; they are synthesized by means of a pseudorandom algorithm that substitutes elements of the original music object with new ones until the complete new transformed music object is obtained.

Due to the heavy limitations of the computer, particularly with respect to RAM, we have chosen to renounce to a complete graphic user interface, while graphics features are used to enhance informations that are useful for the system controlling activity of the performer.

4.3.2. The Macintosh version

The Macintosh version of the FP system has many improvements on graphics, ergonomics, efficiency and functionalities with respect to the MSX one and can import/export Standard MIDI File 1.0 scores. The user interface is completely graphic and the transformation functions' set has grown. Figure 3 shows the main window. The score is represented by a music object map made up of 8 strips within the window on which a time scanning bar slides. The time axis can be quantized by either beats and ticks or n-seconds' blocks. The 8 strips are associated to 8 of the 16 MIDI channels; the association table is built by the user.

When we select a fragment, by clicking the mouse into the coloured box associated to the music object we are interested in, that object becomes active and its total duration is computed and a graphic copy of it is drawn below the music object map; then it is possible to apply some operators, selected by the available set of transformations, to the active music object. The following functions are defined:

- pitch specular inversion
- durations specular inversion
- dynamics specular inversion
- intervals dilatation
- intervals shrinkage
- durations dilatation
- durations shrinkage
- dynamics dilatation
- dynamics shrinkage
- transposition up
- transposition down
- performance acceleration
- performance deceleration
- dynamics crescendo
- dynamics diminuendo

- pitch rotation
- durations rotation
- dynamics rotation
- total rotation

- pitch retrogradation
- durations retrogradation
- dynamics retrogradation
- total retrogradation

- subfragments multiplication
- subfragment notes filtering
- subfragment notes cutting
- complementary subfragment notes filtering
- complementary subfragment notes cutting

- fragments merge with left alignment
- fragments merge with right alignment

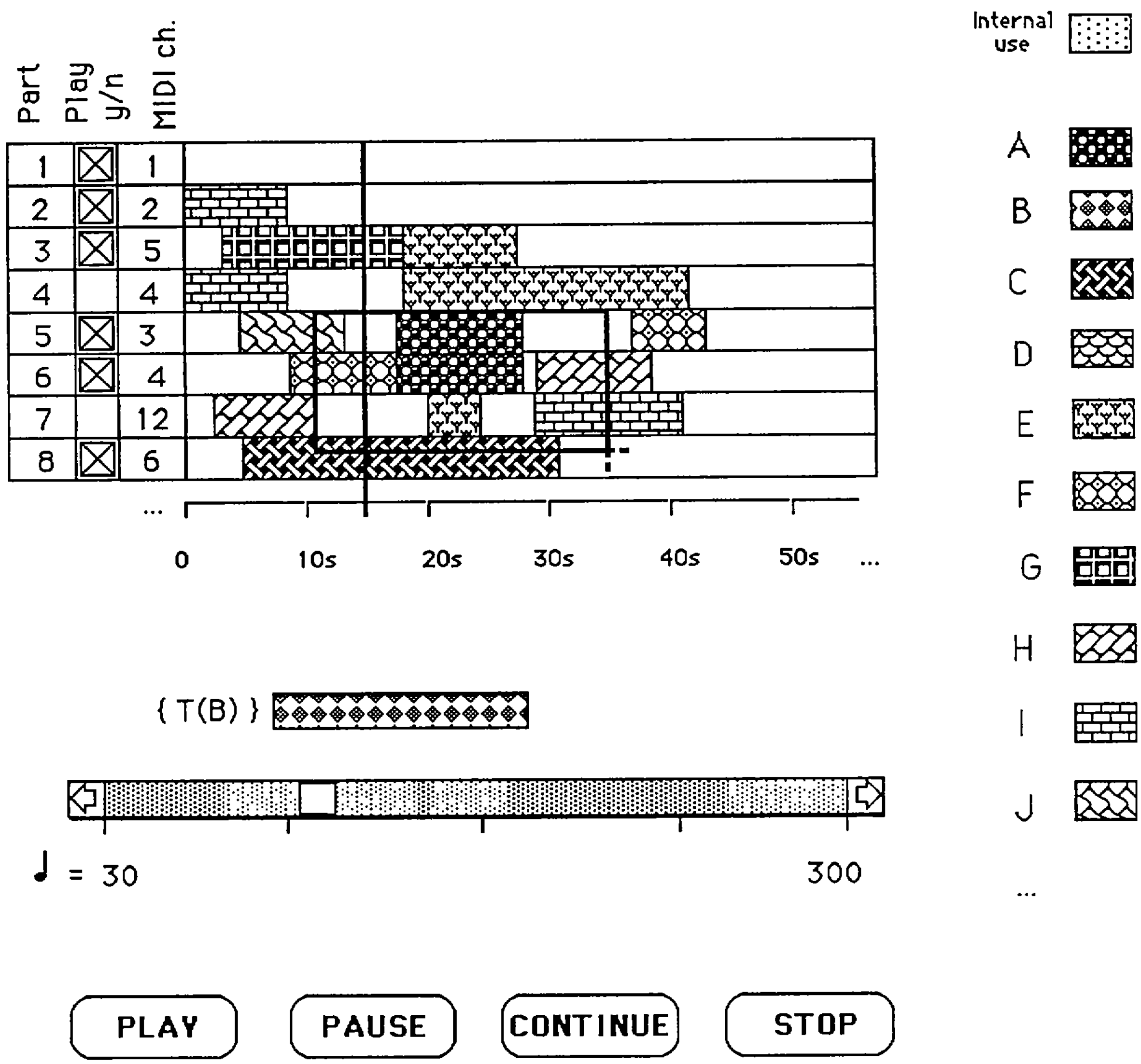


Figure 3: the main window of the FP system (Macintosh version)

- fragments merge with centering
- fragments merge with justification

A fragment or its transformed may be object of further transformation until it is put into the score. This feature allows to apply composite functions (in the algebraic sense).

When we put an object into the score, after the dragging, the mouse button has to be released only when we are upon the desired strip. The fragment aligns itself on the left where it is available the nearest reference point of the temporal grid. The grid density is defined by the user within the set <1, 2, 3, 5>. When the user ask for density changing, the new grid is active starting from the point in which the time scanning bar is.

When we select a graphic music object from the score already synthesized a new graphic pattern (labeled "internal use" in Figure 3) is assigned by default. Starting from that moment the selected music object is treated as a new one and can be put again into the score after some transformations activated by the user.

4.4. Functional Performer and performance orchestration

We have seen that the FP system actually manages only melodic fragments, that is the music objects' transformations affect only one plane (i.e. the melodic one) of the sound space [De Stefano/Haus, 1980]. Then dynamics and timbres are not affected by transformations. In the ideal real time global music performance, the performer would directly control also these two sound components. But before of that we have to solve some problems related to the computing performances of low cost systems and we rely on some powerful and cheap DSP boards to add on FP systems.

At present we adopt some alternative solutions:

a) we delegate the single notes' MIDI parameters to control local dynamics (the performer can set up the values of these parameters at the moment of melodic fragments defining);

b) we delegate the timbral patches' set up of single digital music instruments and the real time mixing operations to control the dynamics of more general levels (i.e. single instruments);

c) as it regards the timbral aspects and the orchestration, we have to program the digital music instruments before the performance, to define a set of timbral patches which will be changed during the performance by MIDI *Program Change* messages sent by performer.

5. Composition and performance experiences with the Functional Performer

Since 1988, we use the FP system for music and multimedia live performances. The work of designing and making performances has allowed to set up a working methodology for the analysis and the check of the performing environments' characteristics [Tanzi, 1990]. The reflections' main topics are:

a) *time-gesture* interaction, which depends on the FP model of generating *the* and interacting *with* music events;

b) *sound-gesture* interaction, which depends on the relations between computers and music devices (these relations are different for every single composition);

c) *image-gesture* interaction, which depends on the characteristics of further devices for multimedia performance;

d) organization of *operative scores*, realized as sequences of algorithms;

e) interaction among a few FP systems and interaction between the FP systems and any set of*acoustic instruments* ;

f) interaction between all electroacoustic ensemble members and the *sound engineering and mixing*.

The FP system offers precious experimentation' opportunities anyone who would making music in a way not purely instinctive. These opportunities can make the process of music ideas' *designing* as an *inquiring* into the cultural matrices which the composer would draw from. Using FP, the composer can study the relations between music objects and the rules which govern, in a little changing universe (i.e. the functional performance), concurrency, the causality relations or even the music events' indetermination.

In conclusion, it's important to point out that in this work, as well as in other L.I.M. works, we propose a substantial mentality change and the refusal of the bad habit of considering acquired a *fixed hierarchy* of relations between the means and the aims, or between the music languages and music events, or between the scores and the processes, or between the symbols and the structures.

We show two examples which represent two important moments of this research:

Ex. 1. Pro. Fumo (Dante Tanzi - 1988)

"PRO.FUMO", for *two FP systems (MSX version)*, has performed the first time at VII Colloquium on Musical Informatics (Rome, 1988).

During the performance, the timbral patches have to change, by *program change* commands, and the polyphony (4+4 real parts), have to increase to a highest number of 16 parts. The music objects for the transformations belong to one melodic fragments' file splitted in two subsets and the two FP systems (FP1 and FP2) follow two distinct operative scores.

In Fig. 4 we show the melodic fragments' file for the part of FP1; in Fig. 5 we show also the respective operative score.

Ex. 2. Louvre (Dante Tanzi - 1989)

"LOUVRE", for *flute, percussions, Functional Performer (MSX version)* and *Mouse Performer* (another program for music live performance developed at L.I.M.), has performed the first time at the Musica del Nostro Tempo L.I.M. concert (Milan, 1989).

"LOUVRE" is the first work made at L.I.M. for real time computer instruments and acoustic instruments' live performers.

In Fig. 6 we show the melodic fragments' file for the part of FP: it's one melodic theme splitted in 11 segments which is the basic reference for the definition of main structures of composition. In Fig. 7 we show also the respective operative score.

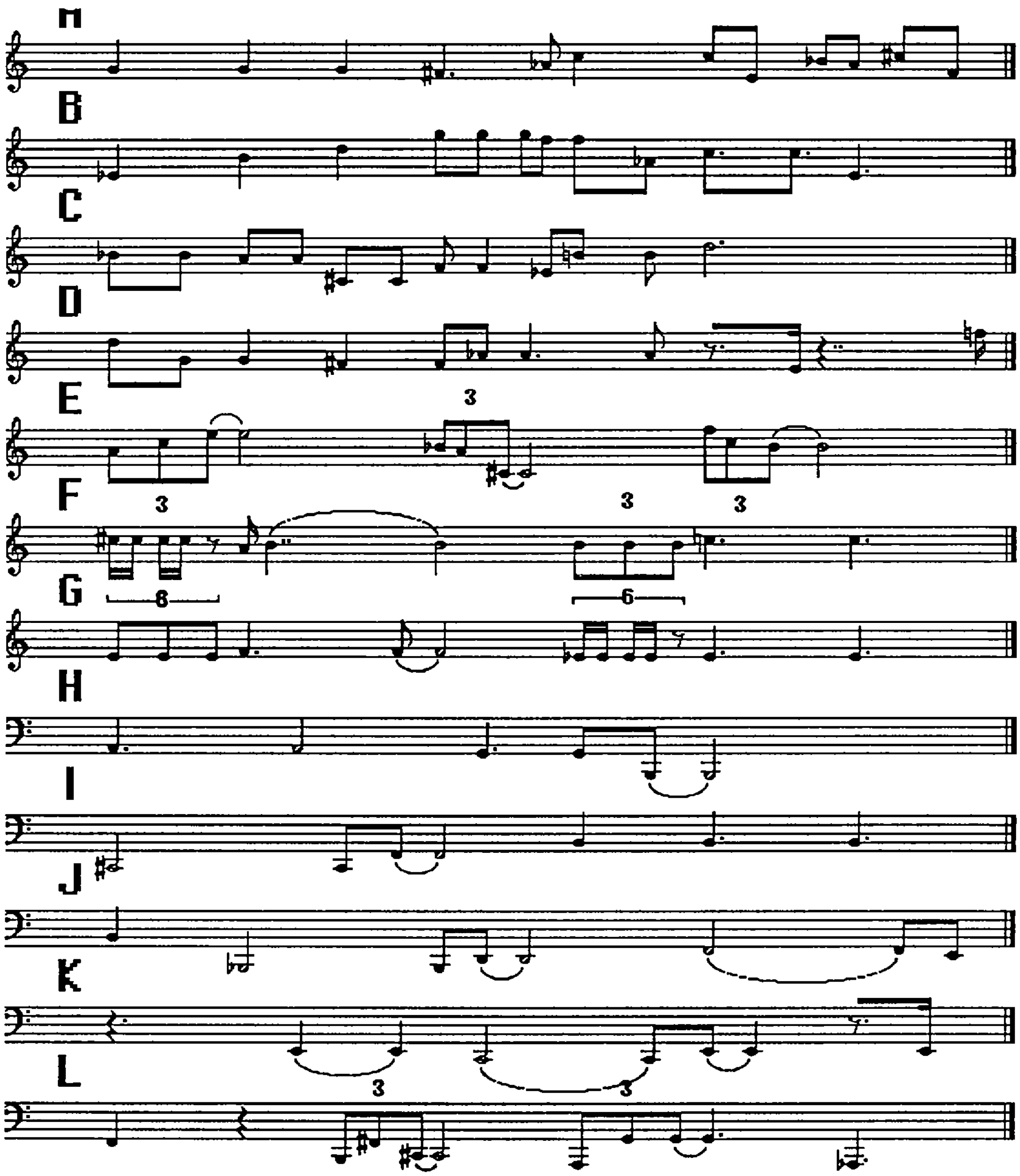


Figure 4: melodic fragments for FP1 in Pro.Fumo (Dante Tanzi - 1988)

step : 4
time : 60

Instruments : MSX Philips
timbres S900 (sampling)
timbres TX802 (FM synthesis)

I

INIT (8)
NEXTQ (I)
NEXTQ (J)

NEXTQ (K)

NEXTQ (L)
NEXTR (E)
RGDR
TR + (D)
RGHTR
INTERV - (A)
INTERV - (A)
CHNGPROG (1) A'
RESTART (8)
NEXTQ (I)
NEXTQ (J)
NEXTQ (K)
NEXTQ (L)
NEXTR (E)
RGDR
TR + (E)
INTERV - (A)
INTERV - (A)
NEXTR (E)

II

CHNGPRG (3)
RESTART (1)
NEXTQ (B)
MN +
NEXTQ (C)
MN +
RGDR
DIL + (C)
TR + (B)
RGHTQ
NEXTQ (D)
DIL - (A)
DIL - (A)
DIL - (A)
DIL - (A)
C CHNGPROG (4)
RESTART (5)
RGDR
NEXTQ (F)
NEXTQ (G)
RESTART (8) <--------------|
RGHTR
NEXTQ (K)
RGHTR
NEXTQ (K)
RGHTR
D CHNGPROG (3) ------------->
or
CHNGPROG (4) ------------->

Figure 5: operative score for FP1 in Pro.Fumo (Dante Tanzi - 1988)

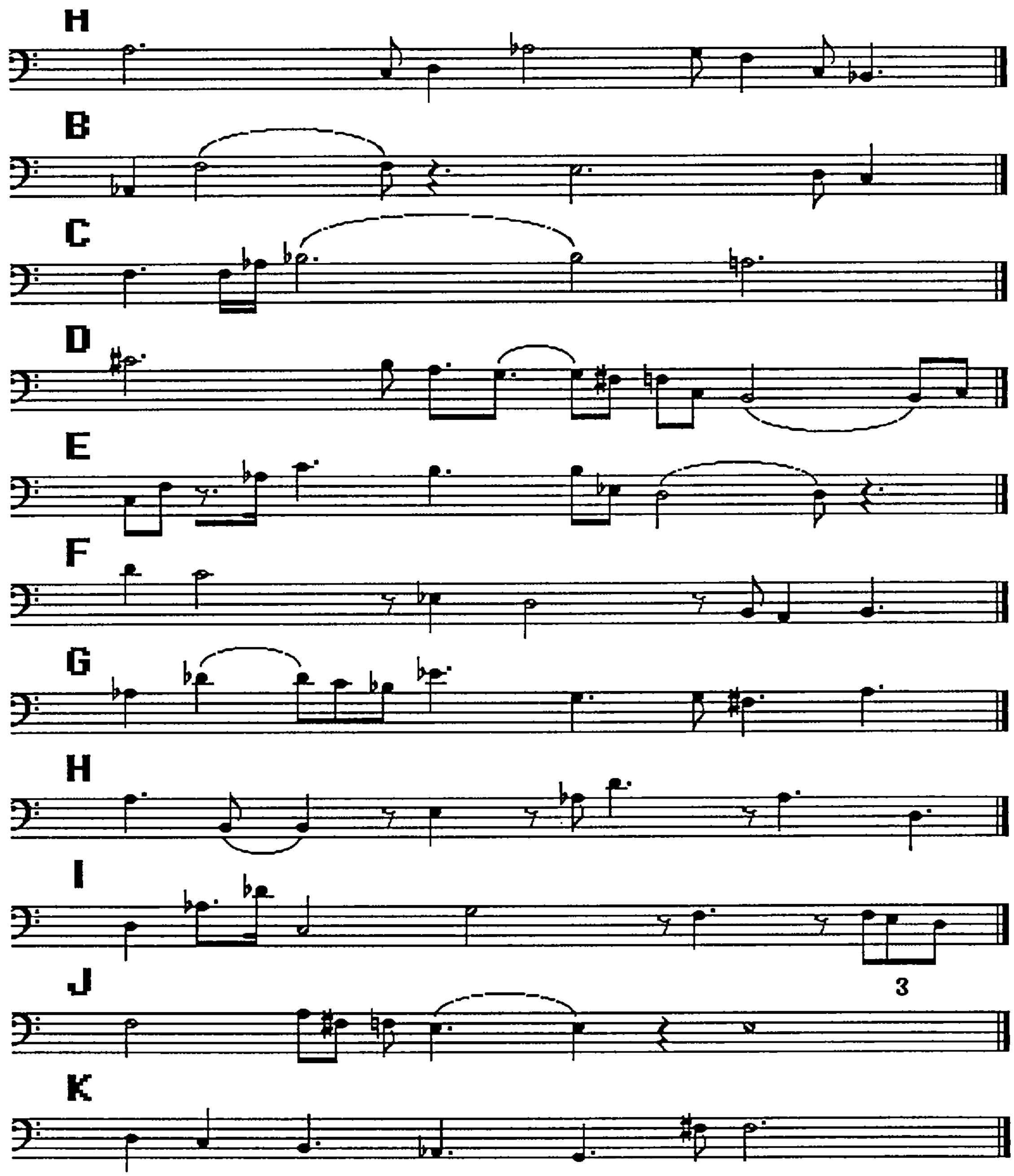


Figure 6: melodic fragments for FP in Louvre (Dante Tanzi - 1989)

step	: 2
time	: 80

timbres S900 (sampling)	:	flatonly-louvre
timbres TX802 (FM synthesis)	:	louvre

0. 50"	INIT	(1) only TX802
1. 00"	NEXT/Q	(K) also S900
1' 20"	TR +	(L)
1'45"	IS + RGD	(A)
2'00"	TR -	(A)
2'12"	NEXT/R	(D)
2'30"	NEXT/R	(G)
2'47"	IS + RGA	(B)
3'45"	AGAIN	only TX802
4'55"	AGAIN	only TX802
6'00"	TR -	(A)
6'12"	TR -	(A)
6'24"	TR -	(A)
6'36"	TR -	(A)
6'48"	TR -	(A)
7'00"	PROX/R	(F)
7'25"	TR +	(A)
7'37"	TR +	(A)
7'49"	TR +	(A)
8'01"	TR +	(A)
8'13"	TR +	(A)
8'25"	TR +	(L)
8'40"	TR +	(L)
8'55"	TR +	(L)
9'10"	TR +	(L)
9'25"	TR +	(L)
	END	

Figure 7: operative score for FP in Louvre (Dante Tanzi - 1989)

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SIMULATION AS ANIMATION

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ABSTRACT

Throughout the history of art, creative advances have paralleled technological advances in media, permitting the artist to illuminate new visual concepts. Such a situation exists today with the computer's assistance in synthesizing knowledge from different disciplines. Physically-based simulation permits such an integration and provides a new animation approach for the artist. This paper outlines a functional foundation for artists to use different simulation systems in the design of computer animation. The functional model seeks to bridge the qualitative - often idiosyncratic - conceptual orientation of the artist with the quantitative orientation of computer simulation.

INTRODUCTION

Computer animation today is still primarily mainly based on the traditional animation approach of specifying each key-frame manually. The computer assists in generating the needed frames "in between" these key-frames. This is not only tedious and complicated, but it is also limiting. It *conditions* the animator to think in terms of creating what a key-frame system can reasonably handle. This mind-set results in a tendency to dwell on 2D visual possibilities and character qualities that mimic traditional methods of generating animation.

As a result computer animation suffers from an absence of intriguing and expressive motion. To a certain extent this stems from the fact that certain phenomena are too visually or temporally complex to be adequately reproduced by the artist's visual skills alone. The temporal problems of creating animation - even within the computer environment - continue to exist: (a) generation of realistic motion is difficult, and (b) animating large collections of objects or figures that appear to interact is very complex and generally avoided. What is needed is a method for generating motion which is analogous to how motion is generated in the real world.

The ***most viable alternative*** is the adaptation of computer "simulation" techniques to an animation system. Computer simulations offer the hope of creating significant complex motion through the incorporation of behaviors of an object as it responds to its environment. Simulation techniques expand the boundaries of the visual process so that the physical limitations of an animator's time or the complexity of the idea does not have an overbearing influence on the creative outcome.

BACKGROUND

Using physical laws to generate animated motion is not a new idea. Traditional animators have long observed mechanical systems to obtain more life-like realism. Today, with the computer, we can generate realistic motion through the use of dynamic laws (Figure 1) or kinematic descriptions. These areas have been

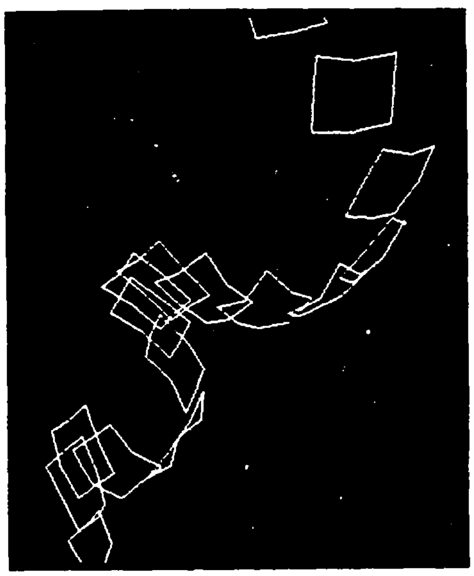

Figure 1, Dynamic simulation of a flexible object by Dave Haumann.

pioneered by scientists such as Haumann[1], Barr[2], Wilhelms[3], Zeltzer[4], Thalmann[5], and Girard[6]. The resultant systems have, in general, been research oriented and have focused on a specific method (i.e. dynamics versus kinematics). The individual limitations of each system, however, indicates a need for a broader outlook, one which can accommodate the changing needs of artists. This paper seeks to propose a functional model that encompasses the implementation of physically-based simulation as an animation option for the artist. The functional model seeks to bridge the qualitative - often idiosyncratic - conceptual orientation of the artist with the quantitative orientation of computer simulation. This in turn will influence the creation of more subtle and realistic animation for sophisticated viewers.

From these new simulation/animation hybrid systems new operands will evolve that tap the unexplored realms of the computer medium.

> The term "simulation", itself, rather than "animation", denotes a shift in control from the animator to the underlying physics of the environment. One would like a system for specifying motion which combines the realism of dynamic simulation without removing control from the animator.[7]

It is hypothesized that the re-creation of motion in the computer has far-reaching ramifications for the animator. In an effort to arrive at a functional mode this paper addresses "How should such a physically-based simulation system be structured for its use in animation?" and "How does the proposed system extend the existing means or create tools for the animator?"

It was determined that to create this functional model from the strictly subjective perspective of artists was not feasible. This would have dictated individual programs every time a new variation needed to be played out. It became obvious that the only way to structure the model was on a systems-oriented approach.[8] The applicability of artistic initiatives differentiates this model from the current computer simulations and their applications.

This functional model is successively organized in concentric layers. Each layer contains abstractions joined through a logical interaction or interdependence. Layering provides a powerful structure from which to create animations governed by physical laws and driven by our imagination. Such a structure permits the artist to transcend various levels of detail.

From this functional model the interrelationships of particular simulation components and the causes of changes in the simulation can be understood. To reproduce the physical interactions of our world it is necessary to view the salient features of this model as a set of ***geometric primitives*** (how structure is represented in the computer), ***mechanical attributes*** (the characteristic qualities of an object's movement), ***functional procedures*** (how geometric primitives and mechanical attributes are interconnected to create higher level motor skills), and ***behaviors*** (interrelationships between objects).

1.1 *Geometric Primitives*

The geometric description level is the foundation upon which each successive level is built. These descriptions comprise the bulk of information used to quantitatively classify a physically-based object. These geometric primitives are viewed as not only separate components, but also as the first level in a layered approach (Figure 2). The geometric descriptions of the functional model can be classified as:

1. One-dimensional point primitives
2. Two-dimensional surface primitives
   (e.g. polygons, patches)
3. Three-dimensional volume primitives
   (rigid or flexible)

One dimensional points and lines would describe natural phenomena that are processes or composed of discrete elements (e.g. clouds, water). Linear elements in our world (e.g. hair, string) can be represented as one-dimensional points linked together.

Two-dimensional primitives would be composed of two-dimensional planar surfaces connected together (e.g. paper, skin). Choices of linkages would determine the characteristic range of movement for an object. Hollow forms could be constructed from surfaces that are connected back on to themselves at their open edges (i.e. a flat surface curled into a cylinder shape).

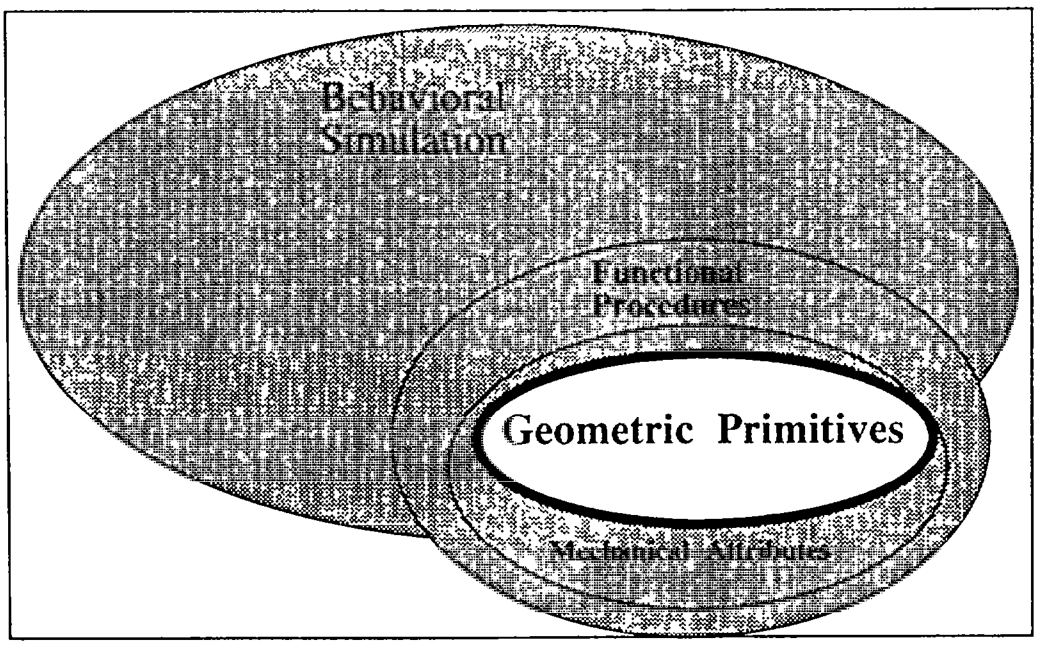

Figure 2, Geometric Primitives.
Structural description of an object or process.

Three-dimensional primitives (rigid or deformable). These would be composed of rigid (e.g. vases, bones, rocks) or deformable (e.g. muscles, jello) three-dimensional forms. The linking of these forms results in articulated structures which could be conceived of as a distinct sub-class within the domain of three-dimensional structures.

Deformable surfaces and structures include realistic forms such as strings (1D), paper (2D), jello (3D), and any subsequent combination. A form like a face can be constructed in layers accounting for the underlying rigid or semi-rigid structures underneath (bone [skull] then mass [fat, muscle] and then surface [skin]). It is from a combination of geometric primitives that articulated structures are composed. Articulated structures consist of rigid segments linked together (e.g. figures, animals, insects, trees).

Objects can be structurally defined not only through these primitives but also from other objects themselves. One object can be "part of" or a "movable part of" another.[9] For example, a piston (i.e. movable-part-of) is part of a motor (i.e. part-of) which is part of a motorcycle. The functional model proposed here is based on the assumption that geometric primitives are defined in a coordinate system, and the coordinate position of the object and its components are known locally or globally. This classification of one-dimensional, two-dimensional, and three-dimensional primitives constitute the foundation upon which mechanical attributes can be bound. Within the computer environment there is no such thing as a flexible object until mechanical attributes are associated with the object.

1.2 *Mechanical Attributes*

The mobile character of an object or agent (i.e. an object that can initiate action) is defined by its ***mechanical*** attributes. It is these mechanical qualities that permit internal and external movement. Mechanical attributes associated with an object includes joint linkages, mass, velocity, acceleration, deformation, force, torque, and surface area as a function of damping and collision detection. An object's characteristic movement is defined by these attributes. It is the combination of geometric primitives and mechanical attributes that permit a self-scripting or automatic simulation to proceed (Figure 3). The animator can affect modifications in the animation by changing mechanical attributes at this local level. A well-defined set of relationships or dynamic attributes will permit the logical assignment of mechanical attributes to the different geometries. These properties can be depicted as separate attributes:

Joint Linkages (connections between primitives) would be constrained to simulate a specified range of movement. Linkages in this model may differ from an artist's subjective concept of linkages. A linkage here determines the characteristic range of movement for the geometric primitives. Realistic joints serve as a reference for linkages. Such a listing would include: ball-and-socket joints, hinge joints, pivot joints, prismatic joints, gliding joints, condyloid, and saddle joints.[10]

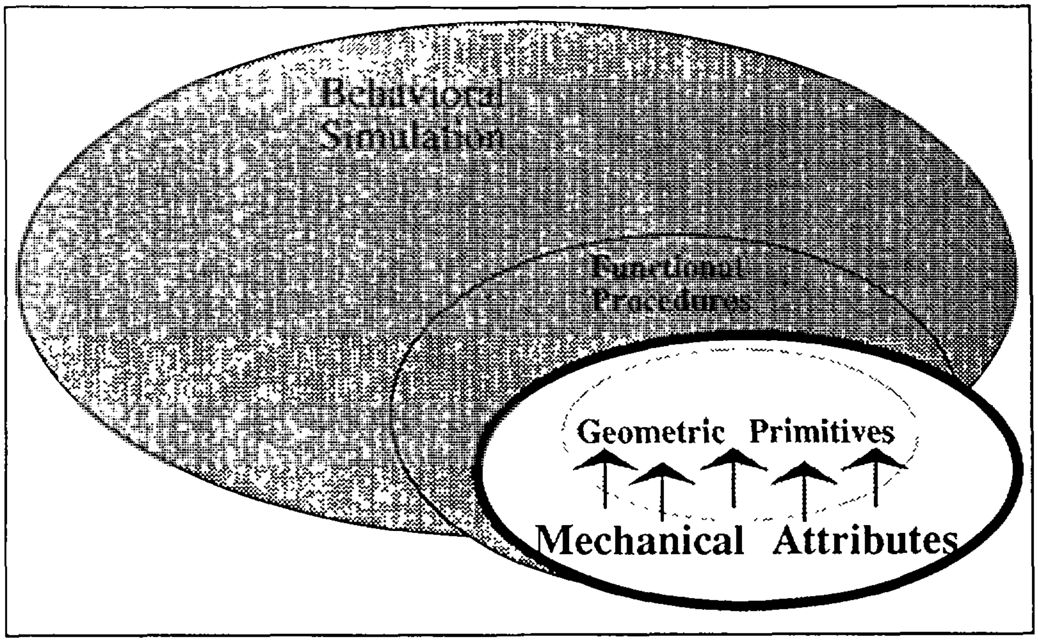

Figure 3, Mechanical Attributes.
The mobile character of an object is defined by these attributes.

Applications of such linkages can be at the micro (i.e. polygons) as well as the macro (i.e. objects) level. Specific linkages would be defined by range and type of constraints assigned to linkages. Under-constrained linkages would lend itself to proximity attachments; this would include rubberband type (i.e muscle to skin) linkages.

Mass attributes represent matter or weight at a point. This is the element that responds to environmental forces. It is responsible for resistance to changes in motion (i.e. inertia). This attribute is the basis upon which most other mechanical attributes interact. This primitive can be set globally for the object or locally at specific vertices on the object.

Velocity attributes contain the initial state of velocity an object has. Velocity is defined as the rate of change from one position to another position. In the real world all objects have a velocity relative to the environment, even if that is a zero velocity. All "states" are important. They represent the initial or current velocity which can be effected by a change in velocity.

Acceleration attributes would be the rate of change in velocity, the change from one velocity (i.e. zero, no movement) to another velocity (i.e. 5 MPH). This primitive would initiate changes in motion as the result of forces and masses interacting. Barr advocates including "impulse" attributes (linear and angular) to account for the initial change when an object begins to overcome inertia.[11] At that point it takes a greater force to get it going than to maintain velocity. The "impulse" attribute would be used to account for that difference.

Deformation attributes define the elasticity or stiffness of an object. This primitive contains information about an object's relative flexibility. This would be in the context of resistance to being pulled apart and/or pushed together. A necessary variable in this attribute would be whether the object kinetically absorbs the external force and changes shape or whether the force is released in the form of a reactive motion. For example, an aluminum can will deform in proportion to the magnitude of a force exerted on it while, on the other hand, a rubber ball will only momentarily deform before kinetically releasing the absorbed force in an observable reaction. The ball retains its original shape after a force, while the aluminum can deforms from its original shape.

Force attributes simulate external forces such as gravity and wind, or as internal forces resulting from muscle exertion. For example, gravity effects a downward force on the mass attributes. These forces are used by the dynamic motion procedures later.

Torque attributes would contain the magnitude of a force being applied in a joint to result in a desired rotation of an appendage at the joint. Again, this would be used by procedures at a higher level for dynamic motion simulation.

Surface-area attributes are a requisite for damping and collision detection. Damping is the motion of an object as the result of contact forces propagated by the surrounding fluid (i.e. wind or water). Damping can be computed through a formula that relates surface-area orientation to velocity vectors. Haumann has employed an effective ad-hoc technique to simulate damping through the use of a hinge joint at the polygonal level.[12]

1.3 *Functional Procedures*

For an object or agent with many links, it is desirable to be able to combine "geometric primitives" and "mechanical attributes" with "motion procedures" (e.g. dynamics, kinematics) into ***functional procedures*** which are necessary to effect a particular set of motions. Functional procedures (Figure 4) illustrate the combining of geometric primitives and mechanical attributes into functional procedures. Functional procedures permit the animator to create motor skills.[13] A prototypical physical object, for example, might obey some subset of the laws of Newtonian mechanics which can be assigned at the functional level. Articulated figures can build a repertoire of behaviors from these functions, such as walking and grasping.[14]

Movements that would be repeated frequently in an animation would be assembled into a reference library of motor skills. For example, the grasping movement of the hand can be factored into a functional procedure. From the known joint-angle rotations and hand movements functional primitive can be assembled

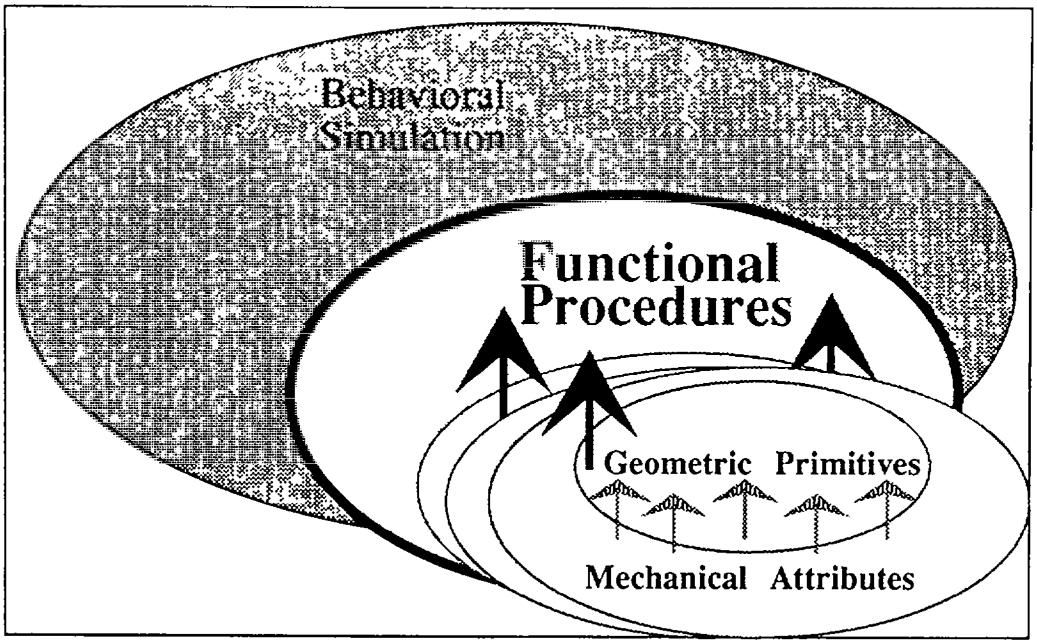

Figure 4, Functional Procedures permit the animator to combine geometric primitives and mechanical attributes to create higher level motor skills.

for "grasping". Once defined, the lower level details do not need to be redefined again later. This permits the animator "to direct" (e.g. target location, fast or slow, hard or soft)[15] the motion.

A functional procedure, like grasping, would be constructed as a kinematic or dynamic motion. It is at this functional level that the actual specification of mechanical attributes to specific geometric primitives would be assigned in conjunction with the desired type of motion (i.e. kinematic, dynamic). How these elements are hooked together directly affects the resultant motion of the objects. Haumann has suggested two useful levels: (a) "a coarse level for external constraints - for example: a complex object is related to the air by drag and to the ground by both gravity and contact," and (b) "a fine level for internal constraints - mass elements interconnected by spring and hinge elements to maintain internal object coherence."[16]

Functions can range from the simple specification of gravity to the complex motion of a scripted sequence (i.e. a dog getting a newspaper). Most important, these functional procedures may be nested together resulting in meta-behaviors.

1.4 *Behavioral Simulation*

The next level is ***behavior*** which is the result of many complex factors and interactions. Though physical motion can be simulated through Newtonian dynamics, *behavior* is more than the numerical solutions output from dynamic equations of motion. The difficulty in creating intelligent behavioral motion is that given some desired behavior (or property of behavior), we must find the forces which will produce it.[17]

The interrelationships between objects contain behavioral elements such as [a] programmable behaviors, [b] properties (mechanical, logical, social), and [c] local memory (event history, current state). The range of behaviors can be defined by a library of functional procedures and their interconnections. Hierarchical motion ***behaviors*** can be conceived of as several functional procedures combined to form a more complex functional procedure. This ***functions within a function*** concept permits the simulation of low-level behavior (Figure 5). Nevertheless, behaviors are also more than nested functions. True behavioral situations require objects to have local or global knowledge of their environments. That is, objects need the capacity to obtain information from their environment and also from other objects. If we wish to utilize goal-directed characters capable of achieving "non-trivial tasks then the character must take into account the geometry and mechanics of physical

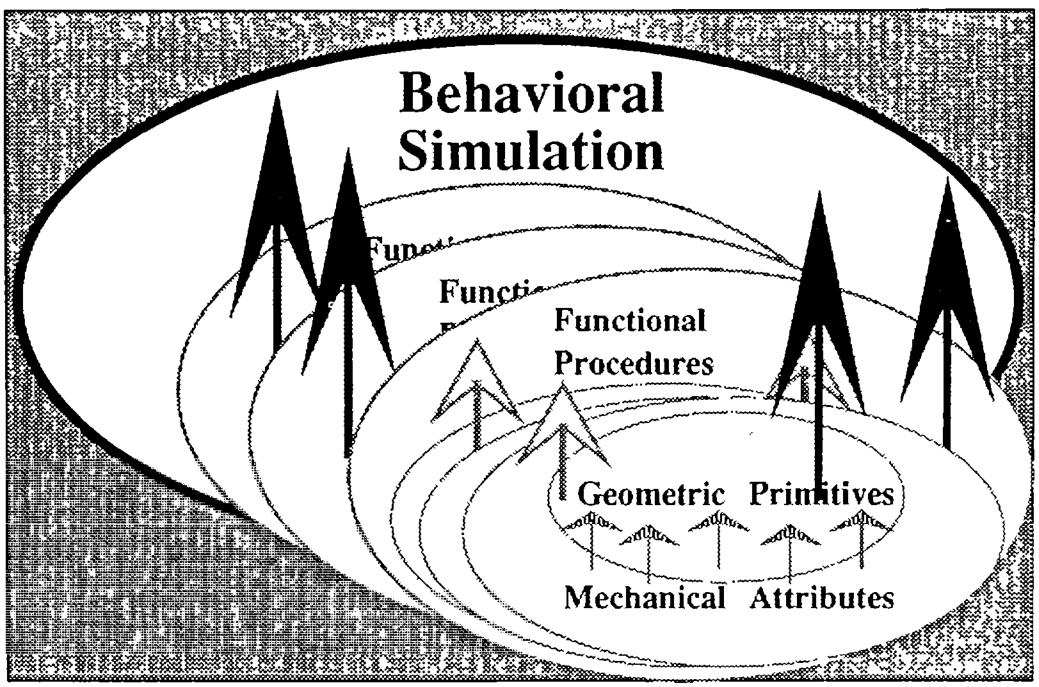

Figure 5, Behavioral Simulation.
The simulation of low-level behavior can be defined by the interconnections of a variety of functions. A *functions within a function* concept.

environments."[18]

Behaviors are not inherently locked to specific structures in this functional model. This ability to arbitrarily interconnect primitives leads to creative associations.

> While humans are in some sense active agents, they also obey the laws of Newtonian mechanics; a person falls just like a rock when pushed off a cliff. On the other hand, an animator may want the chairs and tables to dance around the room when the villain leaves. It should be easy to ascribe such behaviors to otherwise inanimate objects.[19]

Such creative associations will require motor problem solving within the animation system. In order to do simple motor problem solving, it will be necessary to embed common sense "knowledge" in object descriptions. That is, we want to be able to encode such default knowledge as one usually leaves a room by finding and opening the door. From our surrounding environment we have absorbed knowledge of naive physics, common sense, and mechanisms that are built on very non-conscious movements. Not only does this knowledge need to be accessible for use, but it also needs the option of being overridden once implemented so a character can leave by the window. This cognizance of the environment leads to intelligent motion behavior such as navigating through cluttered environments.[20]

Flexibility of the Model

To be able to weave all these primitives into a cohesive operational system will require a responsive interface. Interface issues of usability, flexibility, extensibility, and habitability as each relates to this functional model need to be implemented.[21] Of primary consideration is flexibility for the animator.

The goal of "flexibility" is to have the necessary constraints put on the system, not on the animator. A system should not force a way of working on the animator. Though a system should not impose physical laws on the animator, it should have them available when needed. As Gomez pointed out, "although Wily Coyote falls in a fashion that may be related to $d = \frac{1}{2}at^2$, it usually does not happen until he has been walking on air for a few seconds."[22]

The need to access different control levels stems from the inability of just one control mode (guiding, procedural, task) to provide the animator with complete yet reasonable control. Reynolds believes,

> ...in practice, most real animation is a combination of various techniques--certain characters may be created via behavioral simulation, while others in the same scene might be fully prescripted.[23]

The current prevalent ***guiding***[24] mode provides excellent refinement of explicit details but is too unweildy for controlling complex motion. Heavy reliance on this explicit level results in discontinuities in the motion. It is within this guiding mode that explicit geometric structures and mechanical attributes would be assigned.

The specification of functional procedures is located at the next level within the ***procedural*** mode.

The following four procedural methods of motion control are fundamental: ***forward kinematics, forward dynamics, inverse kinematics,*** and ***inverse dynamics. Forward kinematics*** permits the animator to manipulate an object or articulated figure by transformations in coordinate space. ***Forward dynamics*** also permits explicit placement but by means of forces and torques. ***Inverse kinematics*** and ***inverse dynamics*** permit the input of the position and orientation of a target location. From this transformation information the intermediate positions or torques and forces (necessary to reach the desired position or orientation) are computed. This "inverse" procedure automatically resolves the motion specifications needed. These procedures should be viewed as operating in a pipeline, with different motion procedures interacting with each other (Figure 6, Motion Pipeline and its Modules).

The pipeline organizes motion specification levels as modules. By linking the different modules together through a feedback control loop the artist has access to the different specification levels (guiding, procedural, task) when needed. These different levels permit artists to interject their desires either implicitly, explicitly, or algorithmically.

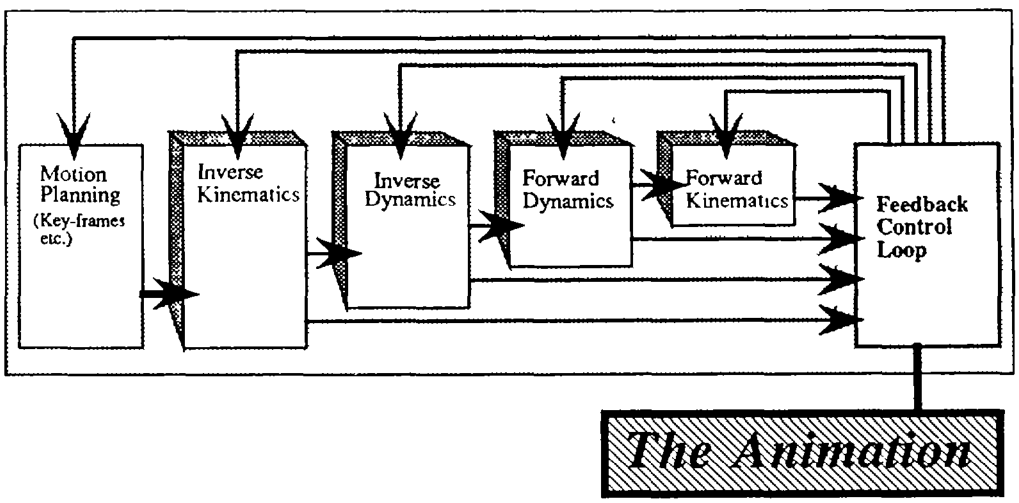

Figure 6, Motion Pipeline and its Modules.
Motion procedures are organized as operating in a pipeline, with different motion procedures interacting with each other.

General motion planning schemes such as gait specification and path-planning will constitute high-level, implicit control. If "directed" or predictable control is desired the animator may choose the appropriate motion control module. For example, the inverse kinematics module permits the intuitive specification of objects by constraints. Kinematic constraints may be assigned in several ways. The most obvious is the pre-specification of position. Constraints may also come into effect when some inequality is satisfied, such as when one object attempts to occupy the same global position already occupied by another object. Constraints also "... may be invoked by a behavior based on current criteria in the system, (e.g., a ball stays in the hand after being caught until thrown)."[25] The inverse dynamic module can take the data from inverse kinematic specifications and determine force magnitudes that result from dynamic analysis. These forces can in turn be supplied to the forward dynamics module, which in turn can output rotational and translational values to the forward kinematic module. The feedback control loop provides a method of linking modules together: whether it be a straight sequence, an individual preference different modules, or repetitive loops of single or mixed modules. This ability to mix different modules can permit a keyframing animation system to be connected within a dynamic system.

The *Feedback Control Loop (Figure 7)* is the mechanism which provides for how these modules can be linked together and controlled. This process determines how closely the results may fulfill the artist's expectations. This control mechanism may be operated in several ways: [a] through explicit manipulation by the artist, [b] by the coupling of modules as procedures, [c] through the implicit goal-oriented direction, or [d] through predefined aesthetic-interpretative conventions in conjunction with evaluative criteria. In the feedback control loop we cannot only implement the explicit guiding control needed for fine tuning but also implement aesthetic controls of a higher order.

The significance of this loop is that animators are not handed one module but a collection of modules and possible connections from which to tailor the motion simulation to their vision. Rather than being confined to the specification of parameter values artists can now construct their own aesthetic algorithm from this model. It is the up to the artist as to select which motion generating modules are to activated and in what order.

It is anticipated that control will be initially focused at the guiding and procedural levels. It is here that the animator will specifically alter individual values or link (e.g. sequentially, intermixed, repeatedly) the different motion modules. The artist in the role of selective agent initiates action, views the results, and either accepts or rejects the outcome with the option to continue the process. The flexibility to interact on different levels with different modules provides a base for the concept of "browsers" as an interactive, procedural *what if?* tool.

The notion of ***browsers*** as implemented in Smalltalk (Tesler, 1981) or Loops (Stefik, 1983) suggests a powerful method for attaching guiding controls to motor skills. Suppose I have on my RGB monitor a shaded display of a human

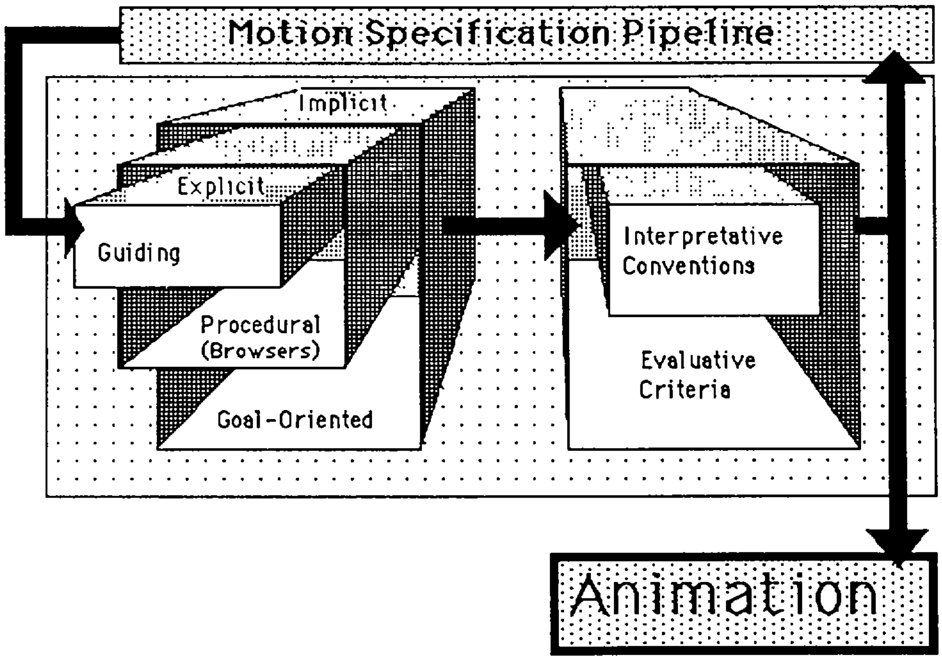

Figure 7, Feedback Control Loop.
This loop determines not only how modules can be linked together but also how closely the results may fulfill the artist's goals.

character. On my terminal screen is a representation of the structure of the character and its skills. Now suppose I trace a curve on the graphics tablet. If I specify that that curve represents a particular joint rotation, - i.e., I point to the node for the little finger on my terminal, I should immediately see on the display the little finger of my character wiggling. Suppose now I point to the node for "grasping with the left hand" - I should see the figure's left hand open and close with the velocity I have specified. Lastly, if I pick the node labeled "walk", the figure should begin to walk across the screen, and this time, the curve I have drawn could determine, say, the speed of the gait.[26]

It is likely that "...the easiest way to specify a motion might be to specify the goal rather than 'how' to achieve the goal."[27] Such a *goal-oriented* mode is appropriate for the rough sketching out of an animation idea, or when only higher level control is needed. This mode gives implicit control over complex motions by trading off explicit command of the details. This goal-oriented mode is composed of the previous two - guiding and procedural.

AESTHETIC CRITERIA

A system derived from the functional model of this paper should not be limited to handling only visual complexities but should also be capable of handling "creative" complexities. That is, to simulate aspects of the creative process about which the artist already has some notion. These aspects address the concern that there is no new art form if the artist only automates the current animation process.

This aesthetic strategy could take the form of interpretative conventions and evaluative criteria.[28] Gips and Stiny have looked at the creative process as one in which external relationships and internal coherence can be codified into aesthetic algorithms.[29] These strategies permit formalized aesthetic viewpoints to be used to select and link motion modules according to predefined criteria. One of the first bodies of aesthetic information likely for this type of integration would be "Principles of Animation" (e.g. squash and stretch, anticipation, etc.)

Animation Principles - Continuity

Continuity in an animation can be achieved through the application of the known successful techniques (e.g. "Principles of Animation" from the book *The Illusion of Life* by Thomas and Johnson). A system implemented from the functional model described in this paper will be successful in direct relation to how its elements are applied. Film is not reality; it's a visual facsimile in need of creative devices to fill in the discontinuities inherent in the medium.

Simulating the *squash-and-stretch* principle of animation in computer animation can be accomplished primarily through techniques of "surface deformation" and secondarily through "motion blur" techniques. Motion blur alleviates the disturbing effects of temporal strobing. Temporal strobing is the disruption of the sequential perception of an image as it moves. Because there is no blurring effect the sequential position of an object becomes spaced far apart. This problem does not exist in live-action film because while the shutter is open the object's motion is recorded as a "smear" across the frame. This smearing contributes to the communication of continuity and in its own way contributes to the perception of *squash-and-stretch.*

Elastic behavior can be built into the deformation of a form as a relationship between the kinematic and dynamic attributes of the object. This can result in *squash-and-stretch, follow-through,* and *overlapping-action,* and *exaggeration* principles being generated automatically .[30] (Figure 8) Chadwick and Parent[31] have suggested that prismatic joints, functioning as springs or shock absorbers can be used to form the foundation for exaggerated squash and stretch where needed.

Figure 8, Still image from the animation "Balloon Guy" by Chris Wedge. This animation utilized dynamic simulation software by Dave Haumann.

The principle of ***anticipation*** can be viewed as the anatomical provision for an action. It is a counter balance to the action impulse; the body stance that permits the action to be launched. The principle of ***follow-through*** and ***overlapping-action*** would be the natural dynamic consequence of an action; as would ***Slow in and slow out*** which deals with the spacing of the in-between drawings between the extreme poses. "Cel animators felt that one of the most objectionable traits of early computer animation motion was its lack of easing."[32] In most 3D key-frame computer animation systems the in-betweening is done automatically using spline interpolation.

Another principle of animation, ***secondary action*** is the reaction that results from an action. Secondary action can be accomplished through a collision detection mechanism or behavioral simulation. As an object collides or interacts with another, a force is transmitted which results in movement being propagated through the scene.

Appeal (the attraction or aesthetic quality of the work) might be considered one of the strongest points of this model. In animation, awkward, inconsistent, jerky, or unnatural motion results in a breakdown of the continuity and a lost of that illusion of reality created by the film medium. The use of simulation techniques results in a more fluid control of the motion continuity.

Whether the animator uses a key-frame method or a simulation approach, it will be necessary to organize the components in some responsive or interactive manner. Lasseter[33] points out that in working with a complex character, creating one complete pose at a time (all characteristics defined together) would make the in-between frames too unpredictable. Unexpected changes would materialize between pose extremes requiring numerous revisions of in-between frames.

In the context of hierarchical modeling there is a much better approach which works "layer by layer" down the hierarchy. Lasseter describes the process:

> Instead of animating one complete pose to another, one transformation is animated at a time, starting with the trunk of the hierarchical tree structure, working transformation by transformation down the branches to the end. Fewer extremes are used. Not all translates, rotates, and scales have extremes on the same frames; some have many extremes and others very few. With fewer extremes, the importance of the in-between frames increases.[34]

Chadwick makes the point that

> In order to effectively fine tune each degree of freedom precisely, each parameter is worked individually for a sequence of motion. Parameters are added and layered to build the desired motion. This effectively allows the user to isolate parameters which require fine-tuned adjustment.[35]

Organizing the parameters (e.g. translation, rotation, dynamics etc.) into a hierarchical system and having the animation proceed "layer by layer" down the hierarchy should prove to be a useful and likely paradigm in computer animation.

An animation system based on this functional model faces the dilemma of how much should be ready-made for the animator and how much should be constructed by the artist in the system itself. The animator is faced with a tradeoff of powerful options against efficiency. Ready-made procedures would contribute greatly to ease of control. However, these ready-made procedures will unintentionally guide an animator to sets of preconceived forms reminiscent of traditional art work. Using a ready-made system would negate the primary artistic use of a medium - to discover, create, and produce original imagery.

If the system relies heavily on the artist to specify a large quantity of parameters, some of which have non-intuitive values, then the motion may be very hard to control. Such a cumbersome situation could easily materialize if too many options are integrated in the system.

Requirements upon the Artist

This model introduces technical levels of complexity generally not found in recognized contemporary artistic methods. This will require a new type of artist, an interdisciplinary artist. Such an artist must be equipped to deal with the technical as well as the aesthetic. Csuri[36] states that it will require "knowledge, skill, perseverance, ingenuity and understanding backed by a sense of order, thought, purpose, and insight" on the part of this new artist. Artists-users who only allow themselves the depth of information that a list of instructions provides will not be "computer artists", just as the possession of a camera does not necessarily make one a photographer.

These new computer artists must be able to traverse the new paths being opened to them with the computer's assistance and to be able to exploit the expressive aspects of this model which emerge from logical processes and choices one makes in that process. In this regard, the medium can only be mastered to the degree that the artist has knowledge of the system. This is exemplified by Miller's[37] definition between "wiggle" and "wobble". These qualitative movements are readily known by artists but describing the difference in quantitative terms to the computer can be difficult - if not impossible - if artists do not understand the difference themselves. This is demonstrated by the following quantitative definitions:

wobble - resonant oscillation in response to external forces.

wiggle - deformation of shape due to internal forces.

The artist must understand the difference if they are to simulate the subtle difference that can exist between movements such as "wiggle" and "wobble".

The implication of this model is that the impact of simulation techniques as animation will be in the release of the animator's energy from the physical act of drawing, and re-focused into designing and directing. As artists aspire to create new original works of art, computer simulation will help them break new ground previously barred by constraints of time and complexity. It is the desire of this researcher that this model will provide artists desiring to explore the medium of computer simulation with a heuristic guide. This model has the potential of providing insights into creative possibilities that have yet to be conceived.

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ORPHICS: COMPUTER GRAPHICS AND THE TEMPORAL DIMENSION OF ELECTRONIC COLOR

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Abstract: This article is a continuation of the ideas presented at the FISEA symposium in 1988 regarding different ways of thinking about the spatial and temporal dimensions of color. In the first part, historical as well as perceptual arguments are presented in discussing certain premises concerning color quality, structure and dimension. In the second part, questions regarding optimal strategies for color dynamics and space articulation are discussed with a focus towards a clear distinction between constructive and descriptive ways of relating color to space and time.

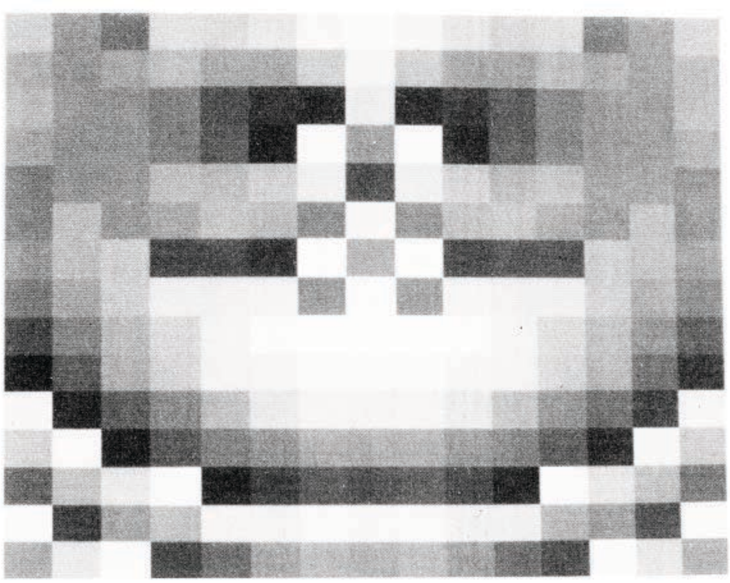

Fig. 2. One frame is shown from an action in which the curve at scale 16x16 is being deformed (frame by frame) in an upward (red) crescendo and a downward (green) decrescendo. The color coding changes, while the underlying grid structure remains fixed.

Introduction

Two years ago at the FISEA Symposium in Utrecht, I presented Orphics [1] as an incipient model for a hypothetical language of light and sound. After some new experiences, I am now able to pose a few more questions and to add a few more details regarding the same model. In the first part basic premises are discussed about the spatial characteristics of color components in relation to color quality, structure and dimension. Historical as well as perceptual arguments are presented in viewing the possibility of composing in actual color space by means of transparent layers of light. On the basis of these premises, the second part focuses on optimal strategies regarding questions such as how to disengage the temporal dimension of color from physical motion, how to provide thematic continuity of change without relying on the rules of perspective, and about what kind of planar articulation will best sustain harmonic color changes in time. Overall, this writing attempts to outline those particular color characteristics which give Orphics a distinct physiognomy in dealing with color in space and time.

BASIC PREMISES

Color and Boundaries

One of the main tenets presented in Orphics is the hypothesis that if color can assume the emotional–expressive prominence that sound has for music, we will have to learn how to shape time in terms of dividual rather than individual forms.

Simply put, an individual form is defined by the mutual proportions of its parts and is frozen within a definite shape, while a dividual form is a variable entity comprised by a multitude of anonymous components and is open to indefinite extension.

The size of the dividual components in a composition was not at issue in the above premise, thus the components could range in size from the micro to the macro. For several reasons, which I will argue below, I now think that there should be a size limit at the lower end of the scale. To make my point, I will stay on familiar grounds and will take a short stroll through western painting rather than venture into the more formal domains of the psychological or physiological theories of vision. If we take a span of time, say, ranging from the Baroque up to Impressionism, and observe the treatment of color in relation to the brush stroke, we will notice that when in an artist's work the accent is on color, the brush stroke is large, when the accent is on volume the brush stroke disappears. As an example, let's take an artist such as Velazquez who is one of the greatest colorists of all time and compare him with his fellow countryman Zurbaran who is more plastic in his treatment of form. We see that Velazquez, particularly in his later works, builds up his forms from a multitude of rather large brush strokes, which from close quarters seem to be arbitrarily strewn on the surface of the canvas, but coalesce into radiant form as soon as we gain the necessary distance. Zurbaran, on the contrary, foregoes the brush stroke completely for the sake of smooth modeling, and the more sculptural effects of lighting.

Such diametrically opposite approaches in the application of paint and in the treatment of color can be found in most periods following the Baroque. But, it is only towards the end of the nineteenth century, with Impressionism, that the brush stroke comes into its own, not only as a full fledged means of expression, but as an indispensable vehicle of color information. The impressionist's quest of capturing the sensation of light on canvas in terms of pure color, was possible only in view of the prominent role given to the brush stroke in their works. When Georges Seurat, a few years later, attempts to anchor the fleeting impressionist sensation onto a more stable formal ground, he turns to Chevreul's color theory of optical mixing, and uses the phenomena of color vibration and the simultaneous contrast of complementaries towards this end. The important fact here is that the size of the brush stroke, and therefore the color quantum, the unit measure at the basis of his compositions, is no longer arbitrary but becomes relative to the size of the canvas.

What does this prove? It is easy to verify, that two colors set side by side will act upon each other not only according to their specific tonalities, by simultaneous contrast, but also, if they are superimposed, according to the size of their respective areas. These contrast phenomena have been given ample attention in classic color theory, and were masterly applied to expressive purposes by Josef Albers but only in terms of the juxtaposition of a few relatively large areas. When a composition is comprised of a large number of similar components, it turns out that the strength of the color sensation depends on boundaries that are large enough to be distinct. It is at boundaries that we are able to make distinctions and grasp the difference in tonality under such circumstances. It is also at boundaries that the color vibration is the strongest not only in quantitative but also in qualitative terms. Thus the smaller the boundary, the weaker the color sensation, until a threshold is reached where the impact of color saturation reaches a relative low, and gives way either to a chromatically shallow texture, if the color components are arbitrarily mixed, or to the illusion of volume if the color components are progressively graduated. An awareness of these phenomena is particularly important in computer graphics where the spatial resolution of the supporting graphics system most often also determines the unit measure for the digital image itself, creating considerable confusion as to the role of resolution in regards to color. A color boundary should not be confused with shape contour. The chief role of contour in art is to separate and distinguish things, whereas the role of color boundaries is to indicate a special modification of light. Thus it seems, that the colorists amongst artists, must have been intuitively aware for centuries of the fact that the quality and radiance of color in a composition, depended, amongst other things, on the size of its constituent components, in this case, on brush strokes that were large enough to be distinct. By the same token, and in confirmation of the need for a lower end size limit, the dividual forms in Orphics, must have components that are clearly distinct, large enough that is, to provide structure for a qualitative color experience.

In my latest work, "Composition in Red and Green" (CRG), I took as a motive a linear entity, a higher order algebraic curve and mapped it onto a square grid in terms of graduated tonalities of reds and greens. Besides providing ample material for thematic transformation the curve also allowed a direct verification of the phenomena described above. When displayed at scale 8 x 8, as shown in Fig. 1a, the colors, even if graduated in intensity, retain a high degree of saturation. The individual components are very large, and take on a chromatic identity of their own at the expense of the motive, of the curve itself which is hard to identify at this scale. The opposite happens when the curve is displayed at scale 512 x 512, Fig. 1b. The curve becomes prominent and is clearly visible, while the color looses most of its brilliance. In the green transparency Fig. 1b, where the tonal order is not progressively graduated we see a rather shallow green texture, while in the red transparency, Fig. 1c, where there is progressive tonal gradation, we see an illusion of rounded, essentially plastic volume, even though the curve itself is linear.

Color and Surface

Besides a rather straightforward illustration of the role of color boundaries in dividual compositions, the above examples also point to another characteristic of the way we perceive color sensations. I am referring to the fact that color, like a liquid, tends to drain from convexities and to disappear into concavities. Painters across the ages were well aware of this dichotomy between the intrinsic flatness of highly saturated color and the intrinsic a–chromaticity of pronounced volume. Speaking in relative terms, one can have one or the other, but not both. To verify this assertion it will be sufficient to take two painters belonging to the same era, one with pronounced color sensibilities and one with pronounced form or plastic sensibilities and to compare the role of color in their work, for instance, Giotto and Duccio, Masaccio and Domenico Veneziano, Michelangelo and Tiziano, Zurbaran and Velazquez, Ingres and Delacroix, Picasso and Matisse. Where color is strong, hues predominate and the shapes tend to merge with the plane, where form is pronounced, values predominate and the shapes stand out. Just as with the brush stroke, we can observe here an intuitive knowledge of perceptual facts on the part of the artist, which has only recently been investigated by some of the newer findings concerning color perception.

It seems that our visual system analyzes information about color and shape according to at least three different subsenses. One that strongly reacts to movement and volumes and is not color sensitive. One that responds to high–resolution shape detail, and one that is strongly sensitive to color nuances, but does not see objects in great detail. If this is true, then on an artistic level, where the role of vision is not directly involved with the amenities of survival, we have been free to choose between at least two modes of expression, one that strongly stresses the subsense of form and one that strongly stresses the subsense of color. If the later is the case, like it is in Orphics, then it should be clear that the aim is not to depict the solidity of objects, but to capture the transient quality of light as it reverberates in the merging of color planes. Thus, in terms of color, flatness, two–dimensionality does not imply an inferior technology or a lack of technical know how, but an esthetic choice which is now also corroborated by the physiology of our visual system. Concerning Orphics, another premise should now be added to the two previously stated. In order to achieve maximum quality in a color experience we must have dividual form, we must have components with boundaries large enough to be distinct, and we must operate with relatively planar components.

Color and Depth

Working with planar components does not mean that we are constrained to act within the confines of an unavoidable flatland. Such a claim might sound implausible if considered from a traditional standpoint which sees color dimensionality irrevocably tied with the depiction of visual reality. Shading, illumination effects and perspective, have been used to depict the solidity of objects and their relations in space since Renaissance times. One of the highest achievements of modern art was to break this tie making possible the disengagement of pictorial space from actual physical space.

After Cezanne, we can think of color depth in purely pictorial terms, as a new way of relating color to volume and space, which has nothing to do with shading and perspective. Depicting the world in Renaissance terms means first of all accentuating the individuality of objects within the surrounding space. Cézanne's overriding concern was just the opposite, he aimed to unite objects and space into a homogeneous whole without individual distinctions. He knew that in order to create an illusion of depth in the traditional way, a surface, as it curved into space, had to be modeled in such a way that it eventually coalesced into a linear contour clearly separating figure from background. This, he observed, was the point where color, for lack of surface, practically disappeared and became spatially irrelevant. The dilemma he faced was exactly one of defining color depth, of formulating new spatial relationships, in terms of color alone. Gradually, he learned how to turn a surface into space, not in terms of line, but by making the shifting of planes correspond to modulations of pure hue. In the process his colors became modular, having independence as constructive elements, and were rendered in layers of transparent hues, while space and the objects within it became dividual, almost grid like. The impossible was accomplished, solid volumetry was translated into harmonic color resonance, and the pictorial aspects of space were unlocked, once and for all, from the purely physical ones.

The layering of transparent, unmixed hues on a pure white ground elicits a deep sense of harmony and immateriality which only music can match. Once the tie with natural appearance was broken it became possible for artists like Robert Delaunay to speak about color as the equivalent of musical tones and to envision an art whose sole subject would be the simultaneous relationships of transparent colors in depth. For Paul Klee, who had a deep feeling and understanding of music, color depth came to embody a more structured approach and opened up the undreamed off possibility of simultaneously harmonizing several independent color themes, like music does with polyphony. His watercolor "Polyphonically enclosed white" [2] is unsurpassed as an embodiment of this vision, of which he wrote "...polyphonic painting is superior to music because its time is more spatial. The idea of simultaneity comes out more richly. The reflection in the side windows of a tram car gives an idea of the background movement I have in mind for music," [3].

Klee's image of "reflection in the side windows of a tram car," offers a powerful suggestion of a form of dynamic color dimensionality, which would have been practically impossible to realize in his time, but has become a possibility today, not only because of the existence of computers, but particularly in view of certain architectural characteristics of our current graphics devices. To avoid technicalities and in analogy to what has been said about color depth, let's imagine a computer graphics device as being a light source, a luminous screen, behind which there is a clear crystal mass made up of many tightly packed layers, and that each crystal layer has been ruled with a very fine square grid. Let's also imagine that it is possible, somehow, to color each tiny cell on any of the grids with a particular hue, to form a different image for each layer. On top of this, it is also possible to individually modulate, single out, mix, or otherwise interrelate the images and to display them on the luminous screen. [4] There is practically no limit to what can be done with such an instrument in visual terms, most striking of all, however, is its layered structure, which seems to have been built for the exact purpose of simultaneously harmonizing transparent color in depth.

We have an instrument now with which it has become possible to think and have others think by means of pure color. In practice, this means having the capability of composing in actual color space by means of transparent layers of light where each layer constitutes an independent plane of color depth, and can be singled out or intermixed at will. Evidently, the definitive decision on how to relate color to space depends on having clarity of intent. If our goal is to portray the physical aspects of space, as it is in 3–D Photorealism, then we will use color as a descriptive element. We will speak of color modeling, and we will work with contrast or continuity of value in quantitative terms. If our goal is to explore the pictorial aspects of space, as it is in Orphics, then we will use color as a constructive element. We will speak of color modulation, and we will work with contrast or continuity of hue in qualitative terms [5].

OPTIMAL STRATEGIES

What has been established so far, mainly outlines some general structural characteristics of Orphics. Nothing has been said about the nature of the dividual components and about compositional rules. In matters of primary constituents and morphology there are hardly any precedents on which to model our choices and decisions. We know in general terms what the spatial and chromatic characteristics of an Orphics composition should be, but we still have to assess what a composition consists off, and how it is formed.

In the preceding chapters we have established some firm grounding regarding the general features of a spatial component in Orphics. It was said that such a component should be dividual, planar and large enough to be distinct. It was also said, that a dividual form is a variable entity comprised by a multitude of anonymous components and is open to indefinite extension. This definition already narrows our choice of spatial configurations considerably. In other words, dividuality in itself already implies a modular organization of the plane. The question is, what kind of planar articulation will best sustain harmonic color changes in time [6]?

Plane Tessellations

The first thing that comes to mind are the regular plane tessellations, which , besides having a strong tradition in the visual fine arts [7], are easy to implement and offer the most neutral, anonymous grounding as compositional devices. Plane tessellations are open to an infinite variety of color interpretations, from free composition to algorithmic articulation. The ray theme in "Chromas" [1], is an example of free composition, while the curve shown in Fig. 1a, is an example of composition by rule, in this instance, a mathematical equation [8]. Fractal geometries and cellular automata offer vast possibilities for chromatically coding plane tessellations, but are too extended in scope to be discussed here.

No matter how planar tessellations are chromatically interpreted, their very nature presents some rather severe limitations. For one, they are structurally rigid. After an initial configuration has been set, only one and the same planar articulation is possible, regardless of the changes in color coding, Fig. 3. Another restriction, which is even more limiting, is that plane tessellations are constant networks, meaning that within such a structure, components can not independently subdivide and therefore develop by generating new structure.

Formal Grammars

Music has a solid theoretical basis concerning the development of structures in time, but provides no clues of how to approach development in space. Much more useful are map representations of natural mechanisms of cell division and enlargement. Map L–Systems, a class of formal grammars [9,10], named after the Belgian biologist Aristid Lindenmayer, aim to unravel and formalize the secrets of cell division and growth in biological tissue. This is a rather complex subject, but a brief introduction, will suffice for further discussion. Lindenmayer defines a map as being "A two–dimensional network of line segments composed in such a way that they entirely enclose a certain number (at least one) of distinct areal units and no line segments are left over." As for the objective of map L–Systems, he says, "We are interested in those maps which can be generated from simpler ones by binary cell divisions, i.e.: by the insertion of a new line segment into an already existing cell, so that two new cells originate.

Two–dimensional cellular patterns that originate in just such a way are observed frequently in epidermal and epithelial cell layers as well as in tissue cultures. Some of these real cell patterns are modeled by our examples. Also, map generating algorithms have their own importance since they further our understanding of possible developmental mechanisms responsible for these patterns. In this investigation of cellular maps we are concerned both with the neighborhood relations among the cells (the cell topology) and to some extent with their analytic geometric structures." [11]

What is not immediately obvious in the above description is that Lyndenmayer considers the neighborhood structure and the geometrical structure of cellular patterns as separate problems. The neighborhood structure establishes the invariant, topological relations between cells (the map). Additional rules are then needed to actually draw these structures, to give them a geometric representations. This means that each map can be interpreted by many different geometries.

In terms of Orphics, it becomes immediately apparent how important such an additional level of control could be in sustaining thematic continuity. To have two ways of looking at one and the same thing of which one is additionally eminently modifiable means having a significant relations already built into the system. It is easy to imagine a complex of juxtaposed color layers where all the layers are thematically aligned on one and the same topology, but vary in geometry, or vice versa, one and the same geometry is the thematic constant for layers with different topologies [12]. The ability to control development or growth on the plane is another important compositional gain which offers a valid alternative to the rigid confinement of grid structure. Components can independently subdivide and generate new structure while their shape and size are no longer constant. Most important, though, is the added flexibility which provides a structuring link for thematically relating space changes with color changes.

Will L–Systems allow the kind of planar articulation that will best sustain harmonic color changes in time? The question obviously remains open. Alongside the gains there are also some drawbacks. There are the added levels of abstraction and complexity which put further distance between doing and experiencing, and there is, at least for now, the problem of realization,i.e.: L–Systems are computationally intensive. By this, I mean that it is hard to envision through limited implementation what the actual dynamics, the visual potential of using L–Systems could be. No extensive work has been done as yet, but the initial work done on the Connection Machine by two of my graduate students, Gil Fuchs and Gregor Lakner, already confirms the control potential and structuring flexibility of such systems, particularly on a parallel platform, and is important for having provided some first glympses into the truly parallel nature of Orphics [13,14]

Color Flow

No clear cut distinction was made up to now between the spatial component and the color it contains. What we know about color was mainly specified in terms of opposites i.e.: hues rather than values, transparent rather than opaque, and in associative terms modulation rather than modeling. We don't know if a color theory or a fundamental color tuning, comparable to the harmonic theory and tempered scale in music are possible [15]. But even without a preferred color model, the above chromatic characteristics are binding enough to allow a discussion of some possible color articulations.

We established that a clear distinction can be made between a descriptive and a constructive way of relating color to space. Can the same distinction be made in relating color and time? To be sure, as with space, we also have a traditional way of dealing with color and time, which sees color intimately tied with physical movement and illumination effects, while perspective provides coherence and continuity of change. The question here is actually twofold, how to disengage the temporal dimension of color from physical motion, and how to provide continuity of change without perspective. In more general terms, this means asking if there is an optimal strategy that would establish a biunivocal correspondence between the ordering of the planar units and the ordering of color in space and time [16,17].

The first part of the answer is already given by reconsidering the spatial characteristics of Orphics. It has been established that in order for color to have quality we will work with dividual forms. That in order for color to have structure, the dividual forms in Orphics will have relatively planar components that are large enough to be distinct, and that in order for color to have dimension, we will modulate transparent layers of unmixed hues in depth. The independence of the dividual components in such a framework not only allows an implicit disengagement from physical motion, but also hints at an alternative temporal flow, based on autonomous color relations and on thematic rather than figurative continuity.

What remains to be answered is the problem of finding an order that will provide coherence and continuity of change within a multidimensional complex of simultaneous color changes. It helps to know that the nature of this order will be thematic and not figurative, which means that we will use color not as a symbol representing information, but as the information itself. In this sense the key element here will be color flow, the continuity, discontinuity and segmentation of chromatic change at boundaries, between the juxtaposed layers in depth, and between one image and the next. Continuity implies establishing successive relationships of hue in terms of sequence and gradation. Discontinuity implies establishing simultaneous relationships in terms of distinction and contrast, and segmentation implies establishing correspondence of chromatic features in the unfolding of events.

Thematic Transformation

The structuring coordinates of gradation, contrast and segmentation chart the flow dynamics of color in general terms, but tell nothing of an order that will provide coherence and continuity in a complex of simultaneous color changes. We have outlined certain spatial features and certain color features as being characteristic of Orphics, but we have no clues of how they will work in unison, which means that we have to establish some kind of relation tying each planar unit with a particular hue, and most important, we must also determine how these relations will change in time. The best way to envision one such possible order is by presenting an example. In CRG, I based the whole action on thematic transformation, a principle by which a whole composition is derived from one central unifying idea, in this case an algebraic curve.. A color theme, for instance, is made up from the same dividual forms as the smallest component and is articulated in time and space in such a way that this kinship is immediately visible closely relating the parts to the larger whole.

To show how thematic continuity is achieved in CRG, I will describe the part dealing with color depth relations, where one color transparency dissolves into another by means of a number of intermediary steps that have some relation to both transparencies. The thematic character of the dissolve comes to light through the action of the underlying transparency weaving itself into the upper transparency's action. The first transparency demands that the second be adjusted to suit it in color and design, and vice versa. Within this framework it is then possible to intertwine and unify different interlocking areas that reveal hidden patterns as well as unexpected color harmonies that are not part of either transparency but surface only for the duration of a thematic dissolve (Fig. 1d). Furthermore, the transition from one transparency to another involves structural changes that closely interrelate motive development with color modulation providing continuity, according to the principle of thematic transformation.

Thematic dissolves are transitional movements, allowing smooth and continuous structural changes and interrelations within a multidimensional color complex and represent just one element of a hypothetical order of harmonic color composition.

We cannot speak of optimal strategies as yet, but we can say that in relating color to time it is possible to clearly distinguish between two alternatives, one that sees color as tied to physical motion in the ambit of narrative and figurative continuity, as is the case in 3–D photo realistic animation, and one that sees color as a harmonic orchestration of light in the ambit of thematic and associative continuity, as is the case in Orphics.

Conclusion

We have seen that the decision of how to relate color to space and time is not completely dependent on personal whim, but that some general criteria can be established to serve as limits either to adhere to or to depart from. It was my intent that these limits should be as general as possible, based on art historical precedent as well as on perceptual and physiological factors. At present these limits are not binding enough to delineate a theory of harmonic color composition, but provide enough structure to reveal a clearly distinct constructive alternative to the well established descriptive ways of thinking about color in space and time.

References and Notes

1. E. Zajec, "Orphics: Computer Graphics and the Shaping of Time with Color", Leonardo Supplemental issue "Electronic Art" (1988) pp. 11–16.
2. P. Klee, "Polyphonically Enclosed White", "Paul Klee" Exhibition Catalogue, C. Lanchner, Ed., (New York: The Museum of Modern Art, 1987) p. 242.
3. P. Klee, "The Thinking Eye", J. Spiller, Ed. (New York: Wittenborn, 1964), p. 520. Even if it may seem almost as fantastic as Borges's "Aleph", this description is actually a fairly faithful analogy of the structure of a current high

level graphics computer with high intensity resolution (the crystal layers i.e.: bit planes), high spatial resolution (the grids), massive amounts of memory and processing power (performance features), and appropriate software (control features).

5. Scientific visualization seems to be one of the areas where a meaningful and direct interchange can take place between art and science. But even within this interdisciplinary domain, the orthodoxy to the 3–D model still seems to hold sway. Having several clearly distinct models by which to relate color to space and time would undoubtedly widen our ability to see things from more than one perspective.

6. H. Clauser, "Towards a Dynamic Generative Computer Art", Leonardo 21, No. 2, 115–122 (1988).

7. The Swiss artist Richard Lohse choose the square grid as a compositional device and the white light spectrum sectioned into a finite set of hues as a color model. His work is of fundamental importance for having established a coherent method for comunicating with pure color, by which a composition becomes the visual embodiment of its underlying structuring principles.

8. H. Franke, "Mathematics as an Artistic–generative Principle", Leonardo supplemental issue "Computer Art in Context" (1989) pp. 27–30.

9. J. and R. Kirsh, "Storing Art Images in Intelligent Computers", Leonardo supplemental issue "Electronic Art" (1988) pp. 47–54.

10. R. Lauzzana and L. Pocock–Williams, "A rule System for Analysis in the Visual Arts", Leonardo 21, no. 4, 445–452 (1988).

11. F. Siero, G. Rozenberg, A. Lindenmayer, "Cell Division Patterns: Syntactical Description and Implementation", Computer Graphics and Image Processing 18, (1982) p. 329.

12. It is also possible to have several thematically related sets of rules shaping one

and the same composition. Table L–Systems (TL–Systems) operate with more than one set of compositional rules (Tables), and allow different but related developments in a composition.

13. G. Fuchs, G. Lakner, "An Experiment in Visual Music: Deterministic Binary Propagating Map 0–L Systems", Term Paper, Art Media Studies Department, Syracuse University, Fall 1989.

14. G. Lakner, "The Digital Computer as a Visual Instrument", M.F.A. Thesis, Art Media Studies Department, Syracuse University, Spring 1990.

15. B. Evans, "Establishing a Tonic Space with Digital Color", Leonardo Supplemental issue "Electronic Art" (1988) pp. 27–30.

16. Ideally, such an optimal strategy would imply compositions in which the logic of the color structure would be indistinguishable from the logic of the space structure. I described an elementary version of such a system in [16], where a particular color sequence establishes at once the theme and the forming principle for the whole composition.

17. E. Zajec, "Computer Imaging and the Musicality of Dimensional Upgrades on the 2D Plane", Proceedings of the 6th International Conference on Computers and Humanities (1983) pp. 763–771.

Computer Simulation of Calligraphic Pens and Brushes

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ABSTRACT:

A computer graphic method is described for simulation of calligraphic pens and brushes. Unlike a paint system which uses a mouse, here the artist uses a force-transducing pen to create realistic pen or brush strokes in real time. The system has been used for the production of western-style calligraphy and for writing with brush-based alphabets such as kanji.

Successive values of x, y, and pen-tablet force are measured, and others are derived--such as velocity, accumulated stroke length, and stationary dwell time. These are all used to define the momentary geometric footprint of pen or brush; the incremental geometry of the stroke depends in turn on rules for connecting successive such footprints. Additional rules may apply at the beginning or end of the stroke.

Crucial to the real-time aspects of the method are a very fast means for computing the momentary footprint, and for defining and filling the area connecting the current footprint with the previous one. This high-speed processing permits regular, uninterrupted acquisition of input data (thus avoiding improper polygonal faceting of curved strokes) and it produces a screen display without noticeable delay.

Later, hard copy output mat be produced at higher resolution by recomputing from the same data.

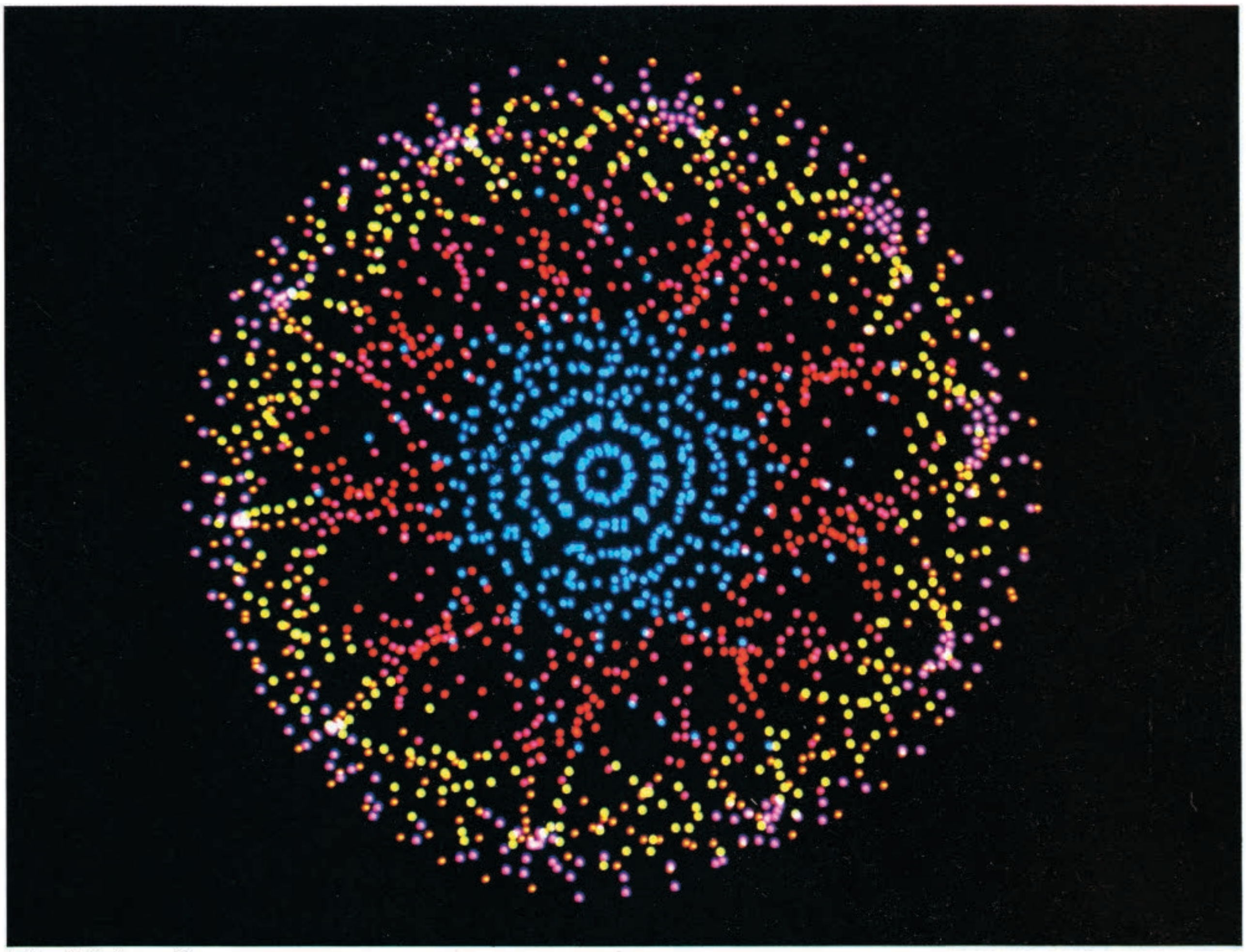
Early History of the Project:

This project arose as a result of talks regarding force sensitive annotation capability within the Freestyle* annotation environment, and the desire to be able to vary stroke width and shape dynamically as a function of force. Initially, a force sensitive pen was implemented as a rigid broad-edged Western style calligraphy pen. The underlying software used for this pen was then built upon to model the Asian style brushpen described in the following paper.

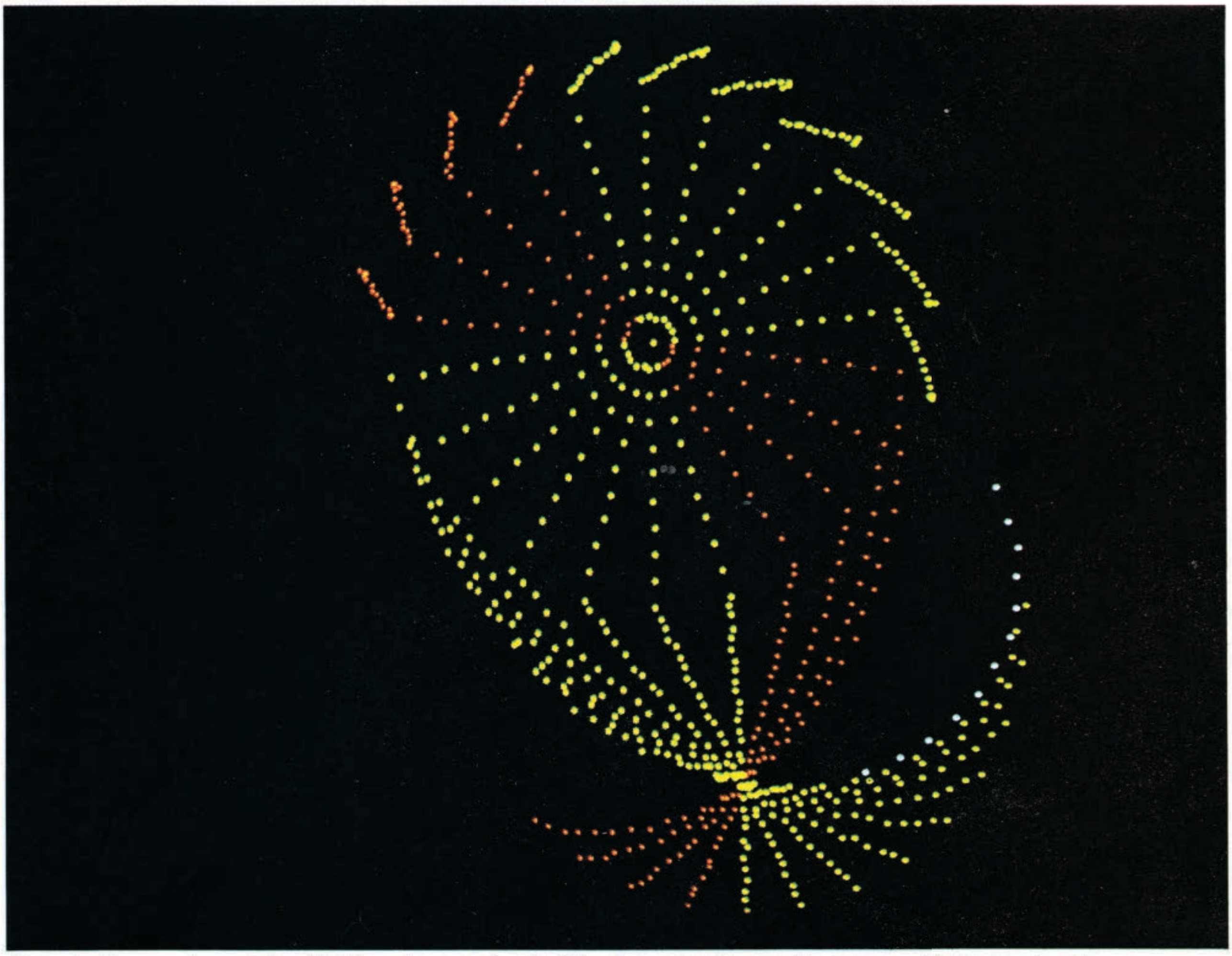
Reasons for Doing This Project:

A computer model of an Asian brush pen is described, using the Freestyle force sensitive pen and tablet as input devices. Though the underlying software can be used to model any type of brush, we have chosen at this time to model a brush pen that one might use to do Chinese or Japanese calligraphy (kanji). This type of Asian brush writing is a good model to simulate, as it consists of strictly defined stroke forms, and strictly defined techniques for stroke creation. This type of computer model is useful as an alternative method of annotation in a document processing system, particularly in the Far East, where stroke weight (i.e. - line width and shape) are important to the aesthetics of the writing style as well as to human readability. In addition, it is a useful method of graphically-based input for systems used in cultural areas where the

***Freestyle** is a registered of Wang Laboratories, Inc.

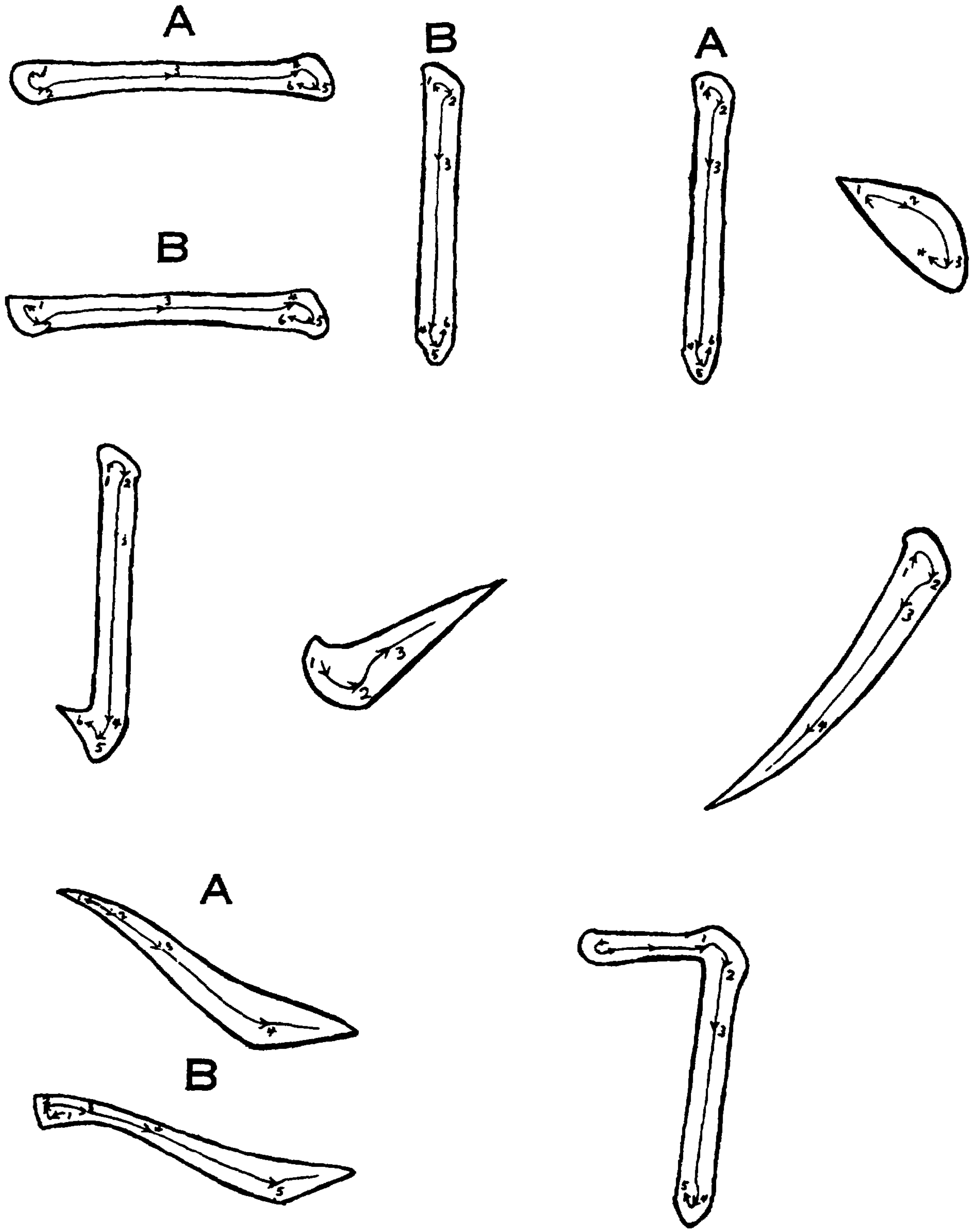


John Whitney Sr

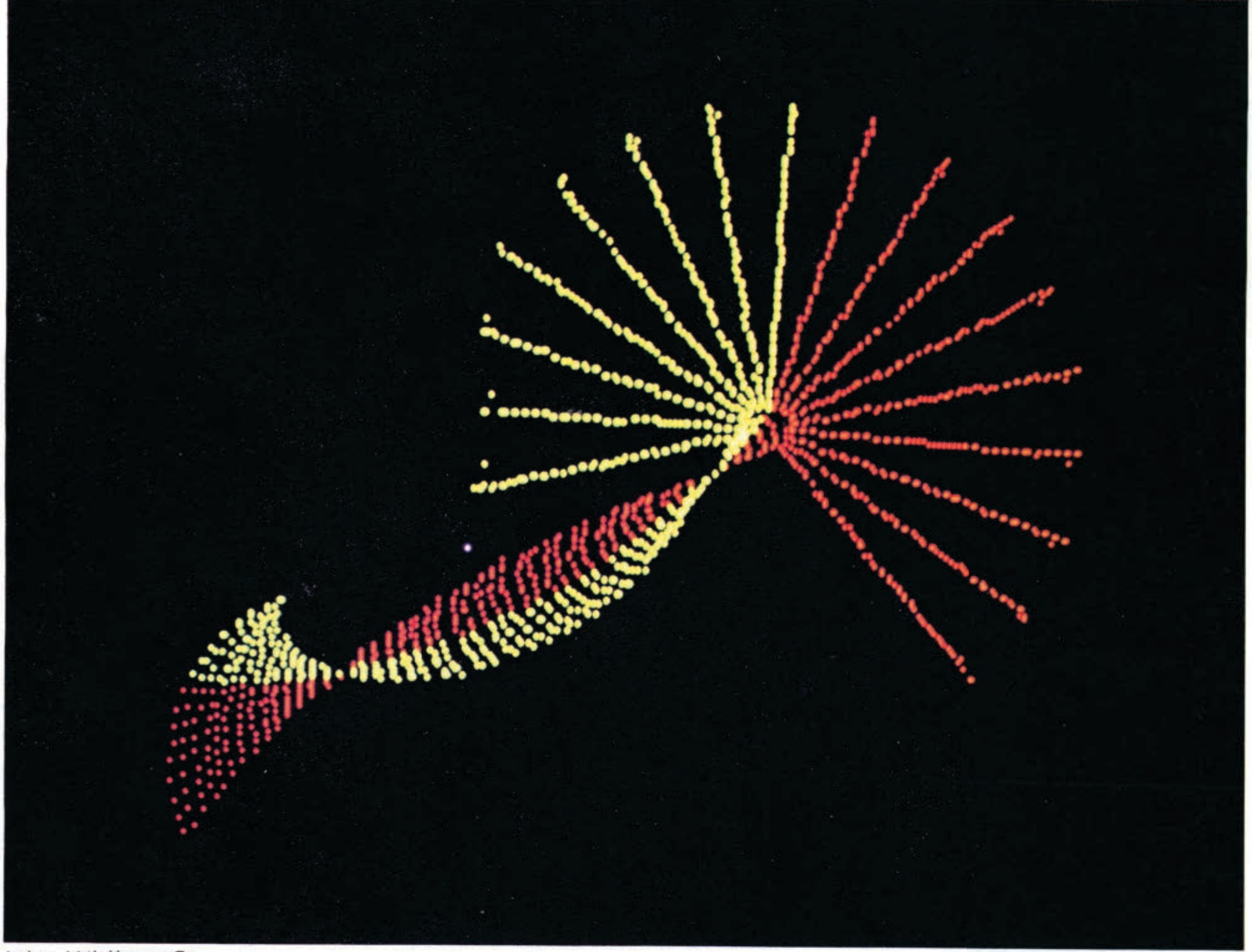


Sample frames from John Whitney's recent set of twelve music-graphic compositions inspired by early native American pottery, textiles, pictographs and artifacts.

Karen Donoghue & Ken Knowlton
fig 1- The 3 basic kanji stroke styles, from left to right, linear lift, lift at 135 degree angle and lift with a backward sweep.



Karen Donoghue & Ken Knowlton
fig 2- The set of all basic kanji strokes.



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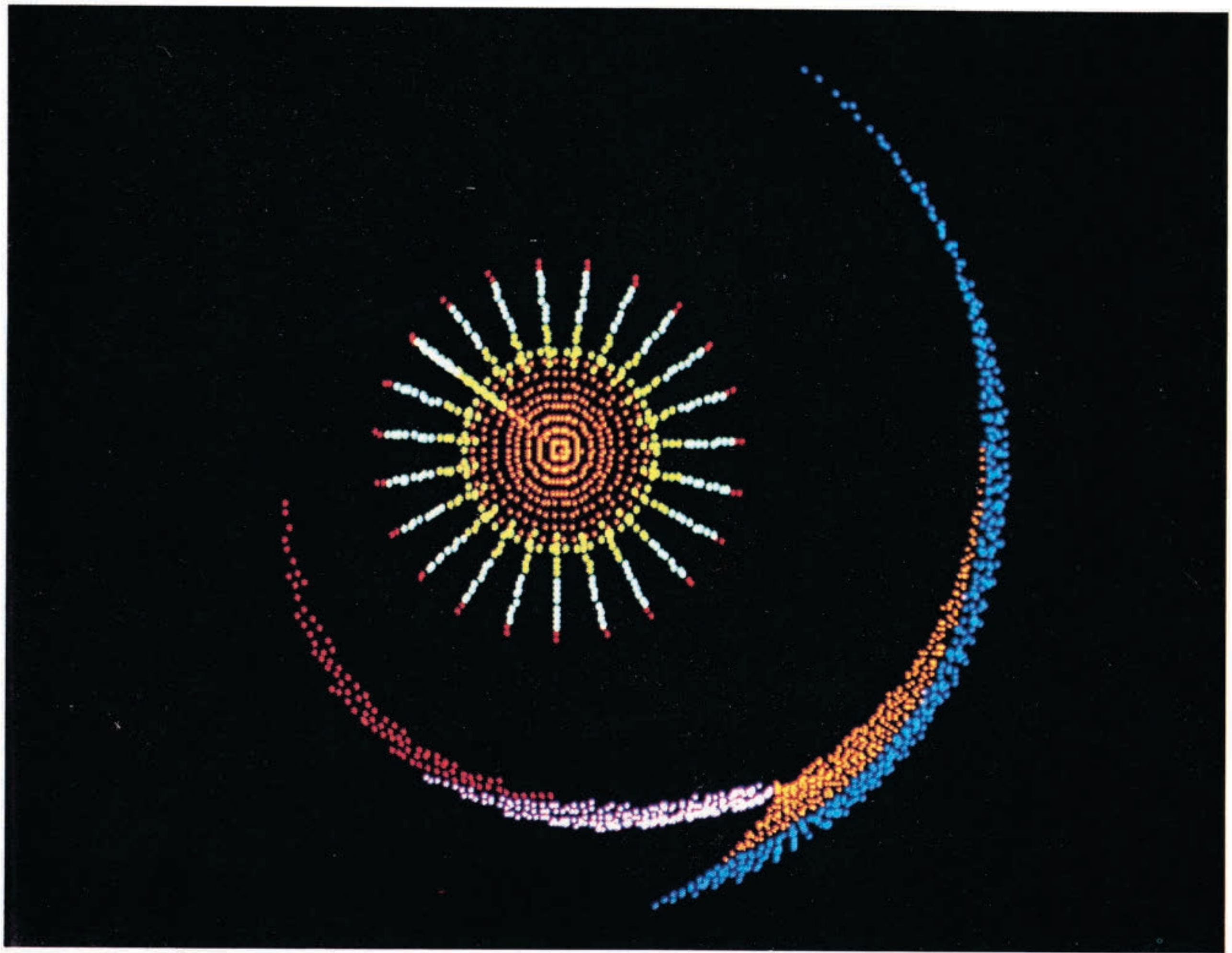

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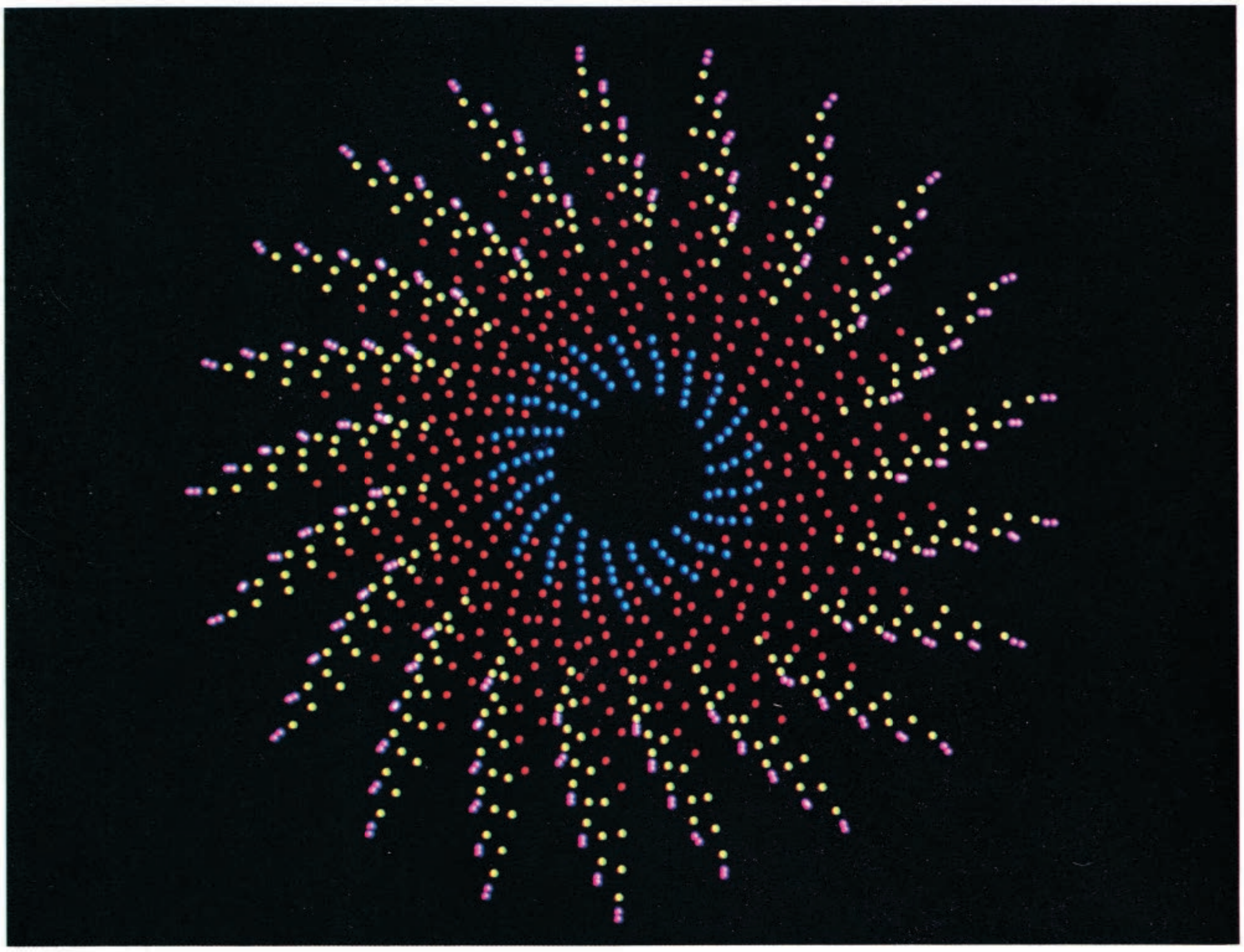

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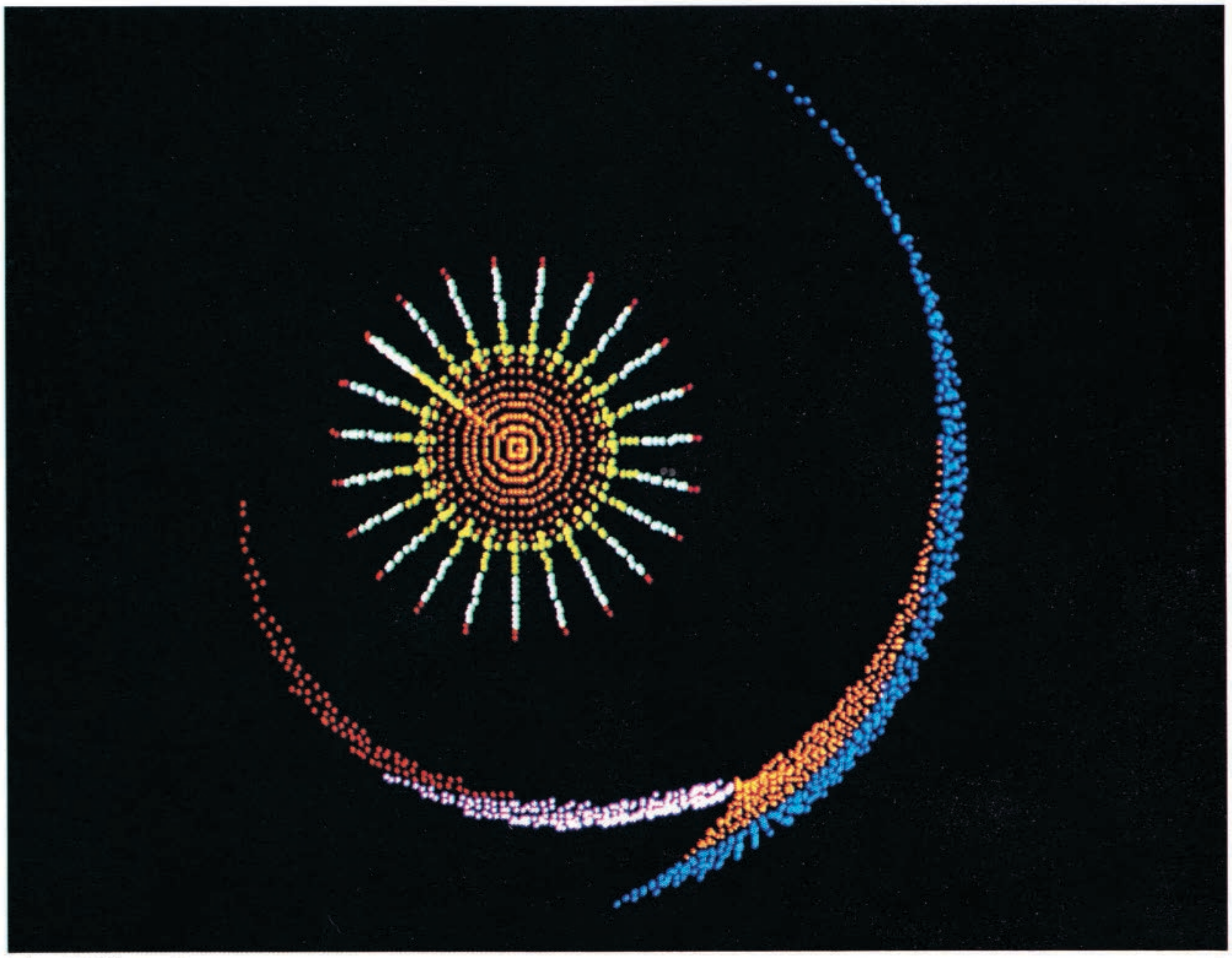

John Whitney Sr

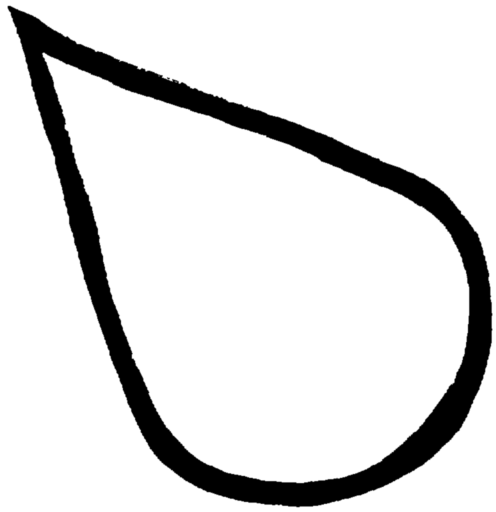

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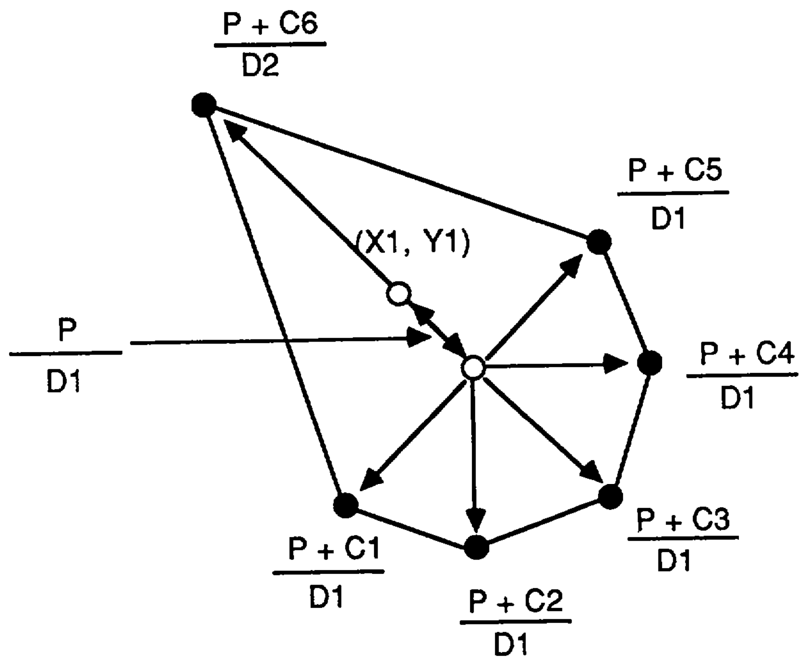
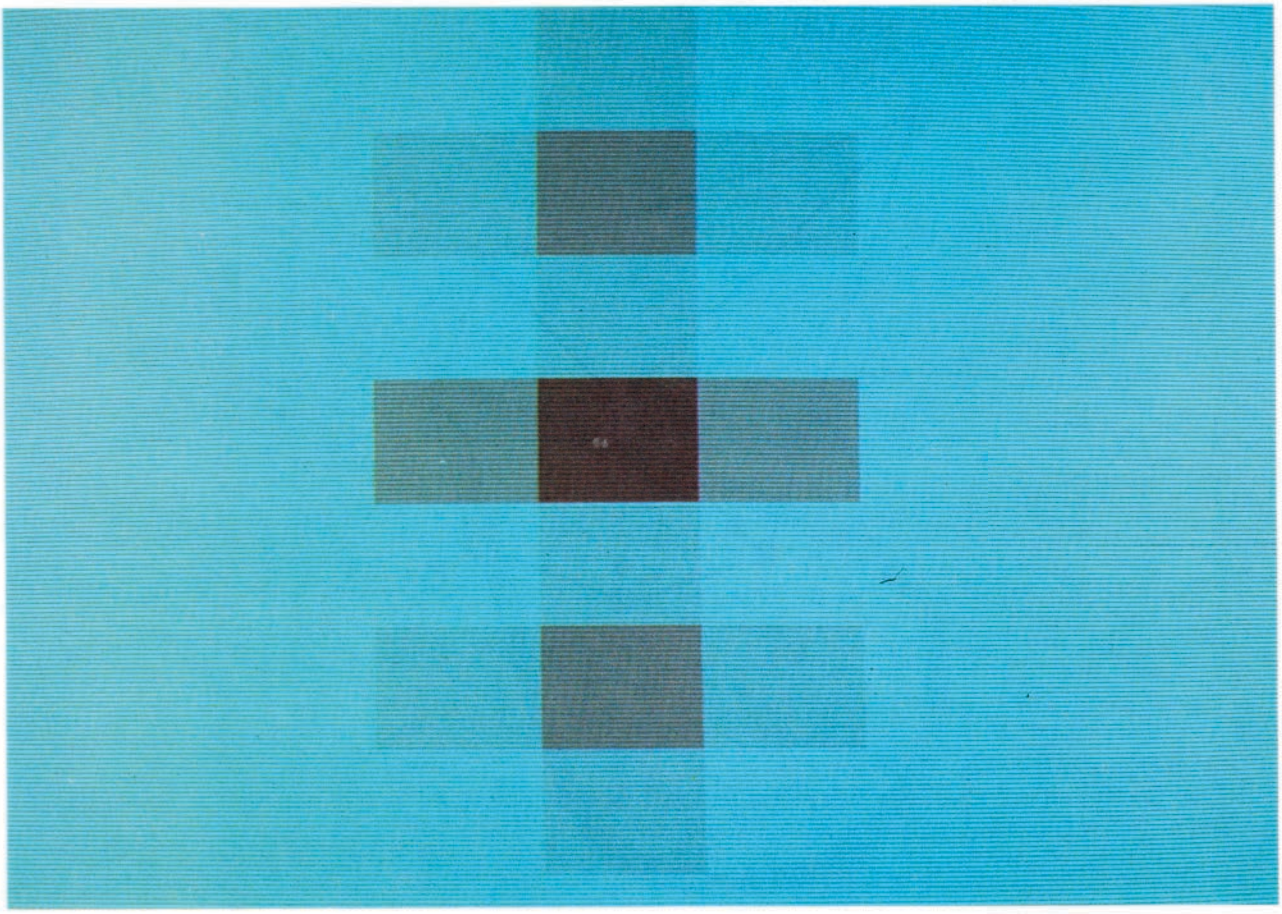
fig 3- The idealized Brush Pen teardrop primitive.

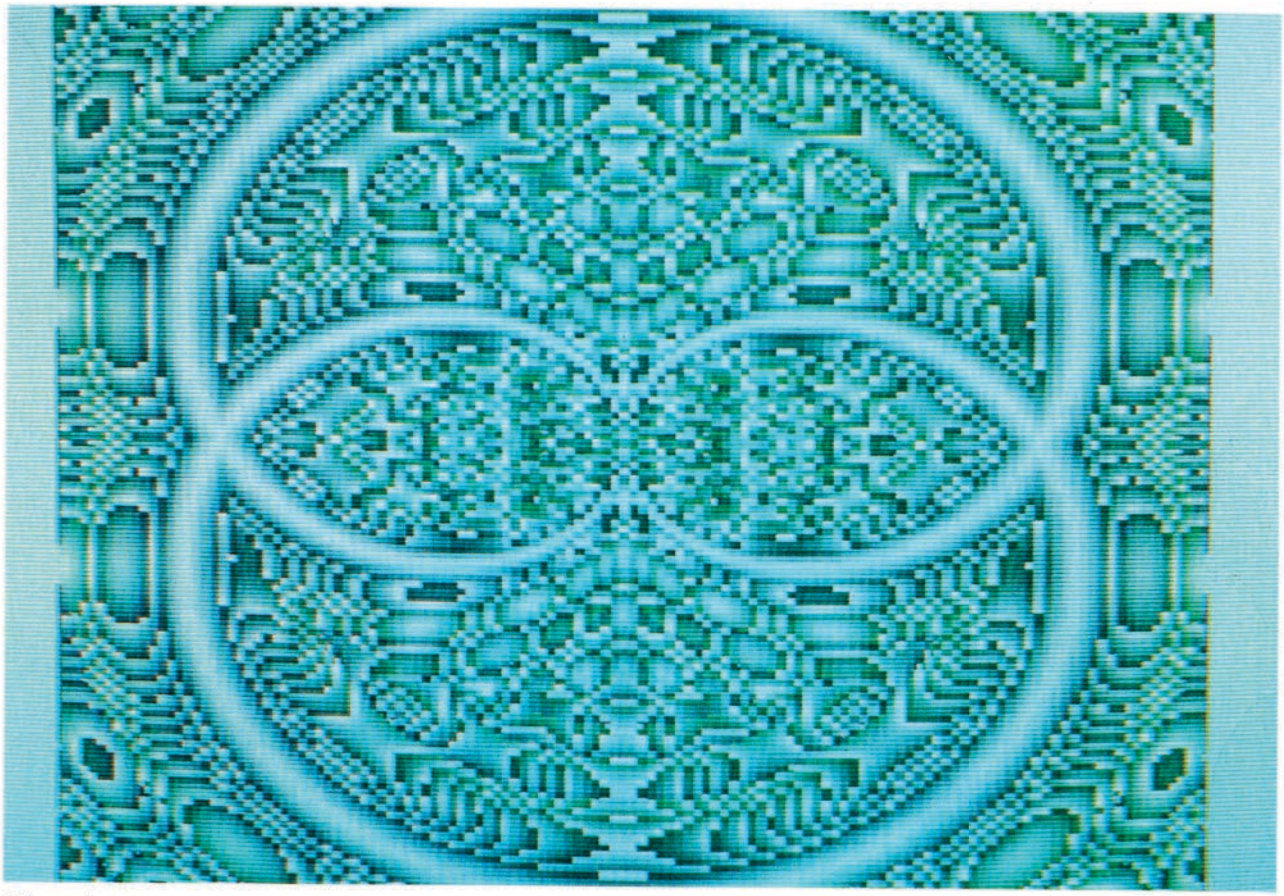


Karen Donoghue & Ken Knowlton
fig 4- Brush Pen primitive with weighting factors based on pressure P and constants Cn, Dn. Note that each Cn is distinct, and D1 is a multiple of D2.

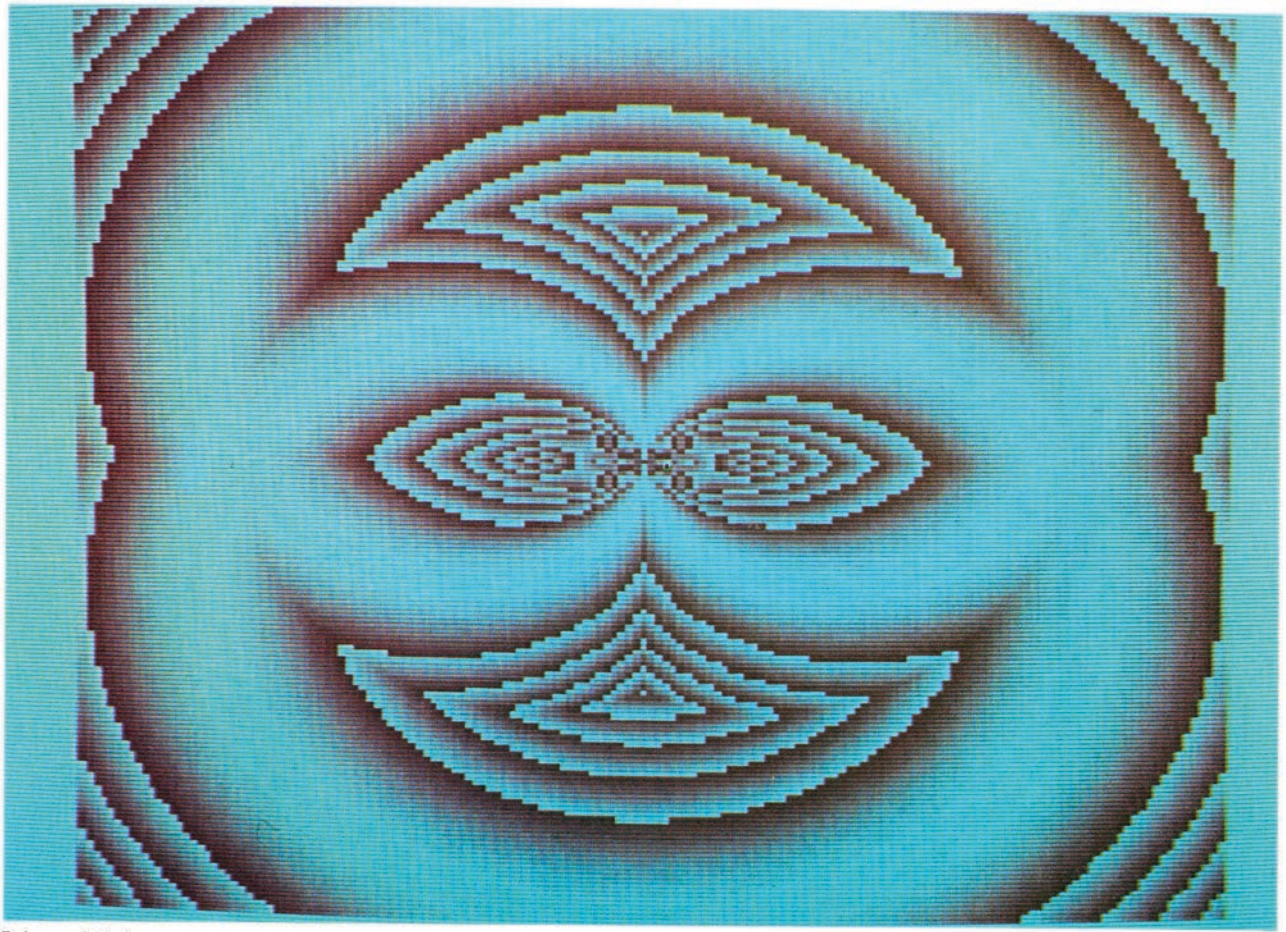


Edward Zajec
fig 1a The curve at scale 8x8 the components are large, colour retains a high degree of saturation

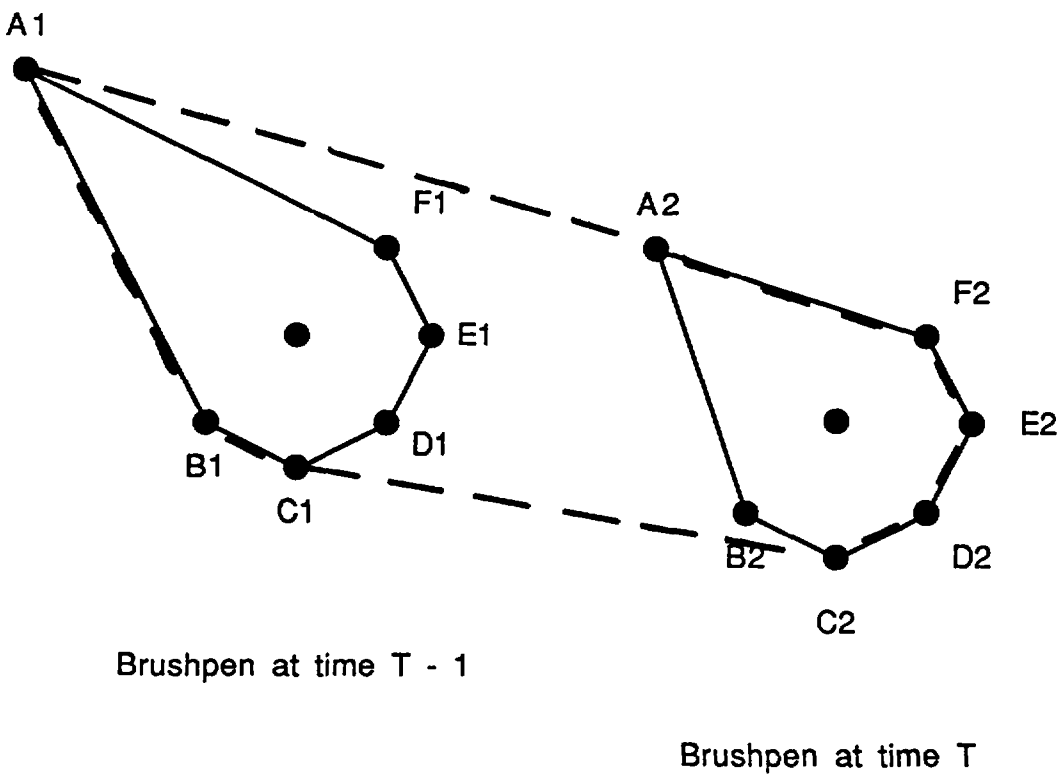
Edward Zajec
fig 1b The curve at scale 512x512. The tonal order is not progressively graded showing a rather shallow green texture.



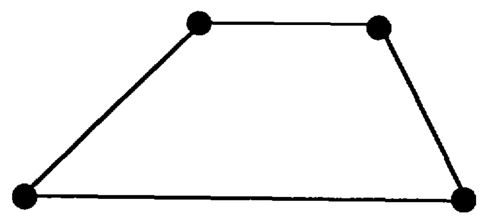
Edward Zajec
fig 1c The curve at scale 512x512. The progressive tonal gradation gives an illusion of volume, even though the curve itself is linear.



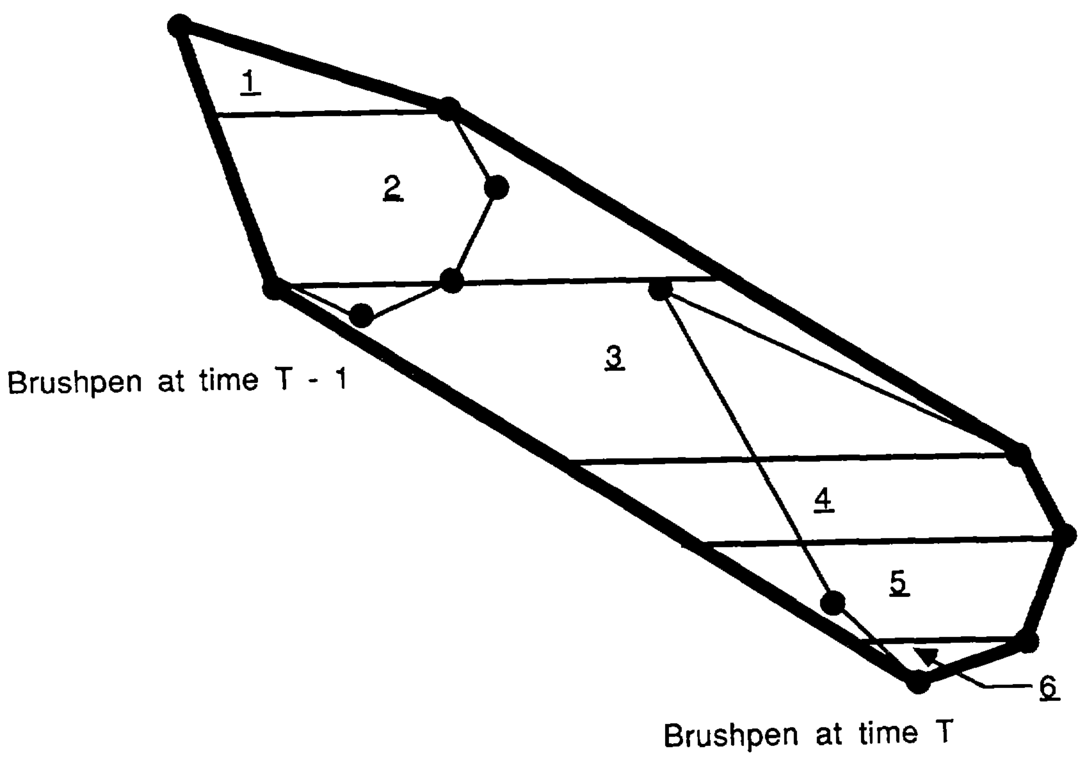
Edward Zajec
fig 1d An overlay of two transparancies (scale 4x4 and 128x128), simultaneously evidences thematic continuity as given by the curve at different scales, and colour depth in the modulation from green to red.



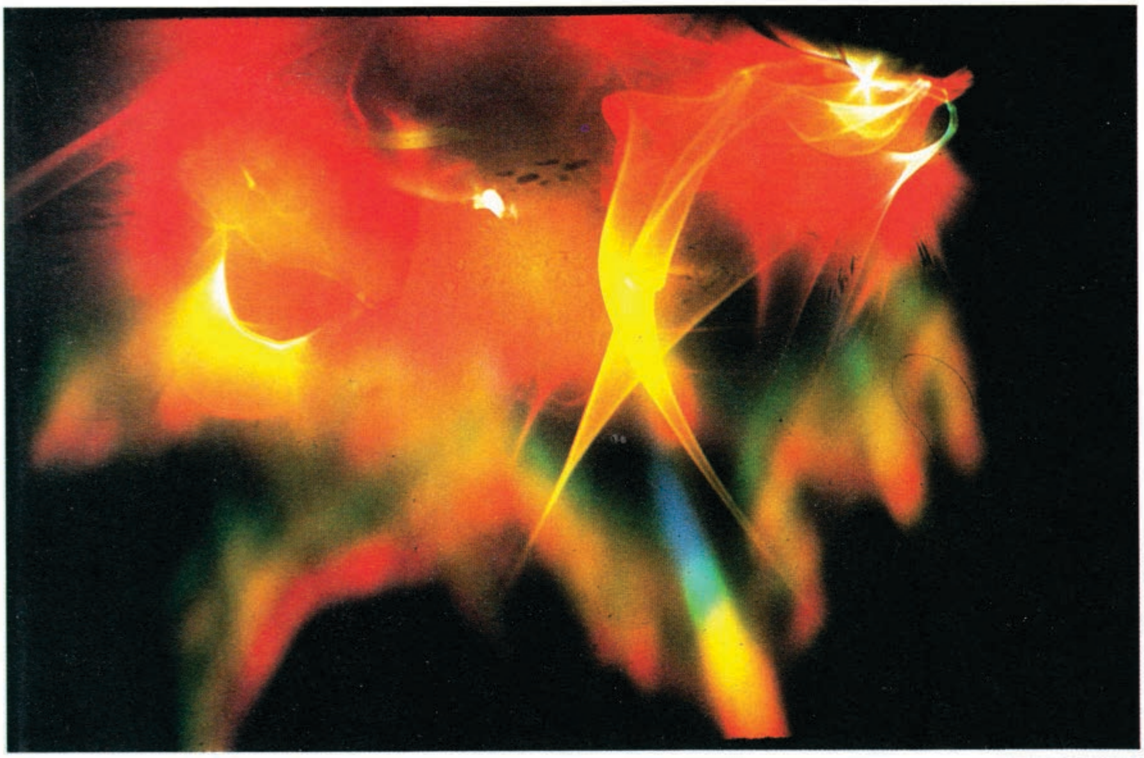
Karen Donoghue & Ken Knowlton
fig 5- The dotted line depicts the convex hull formed by Brush Pen primitives at time (T-1) and time T.



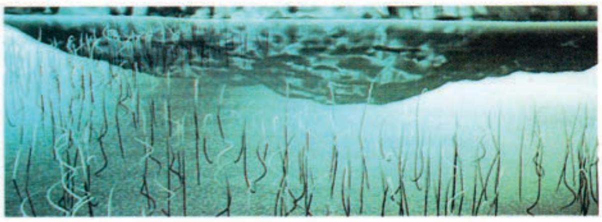
Karen Donoghue & Ken Knowlton
fig 6a- A typical trapezoid consisting of two X values at each of two Y levels.



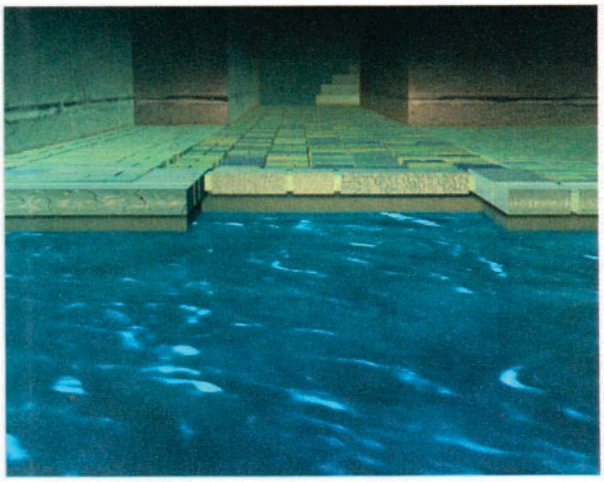
Karen Donoghue & Ken Knowlton
fig 6b- Brush Pen primitives at time (T-1) and time T, showing convex hull and corresponding decomposition to trapezoids, numbered here in order of filling.



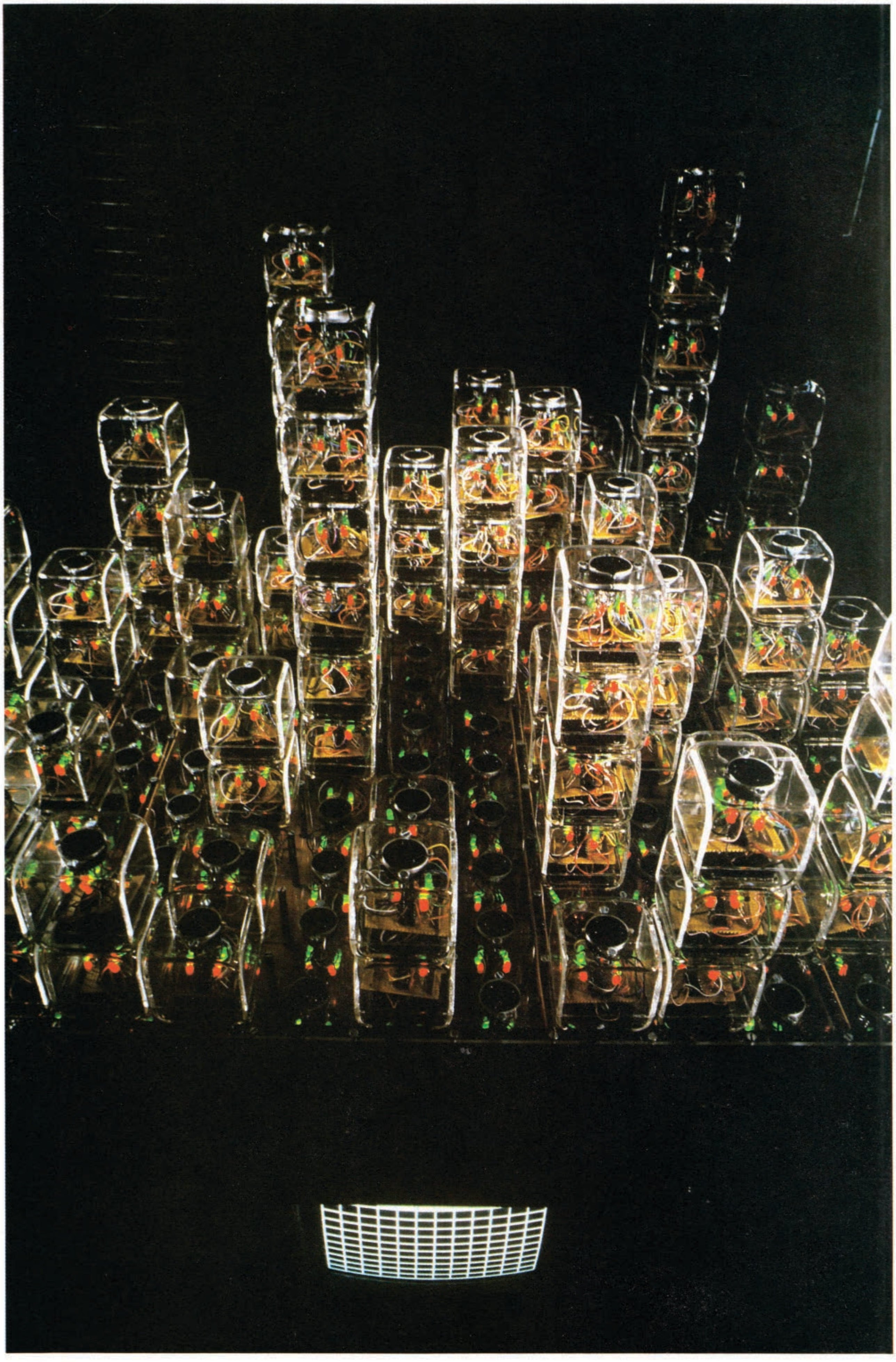
P K Hoenich
fig 1



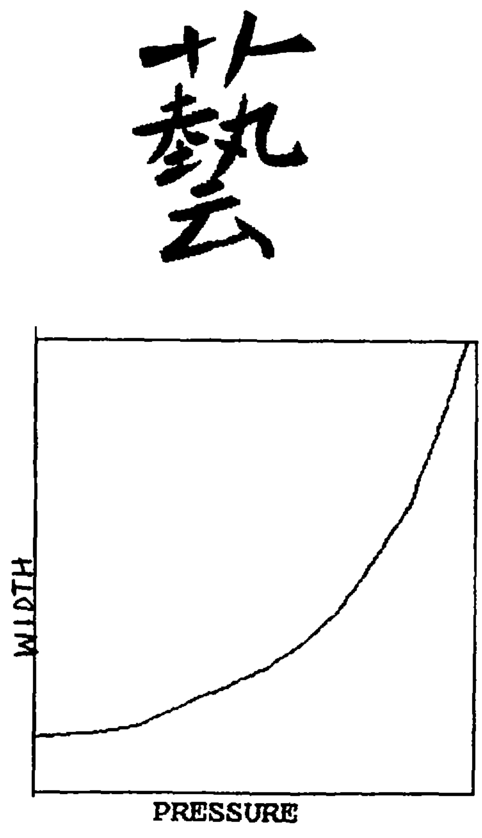
Delle Maxwell
Sketches of Venice



Delle Maxwell
Reflection



J H Frazer
UNIVERSAL CONSTRUCTOR photograph by Geoff Beekman, Building Design



Karen Donoghue & Ken Knowlton
fig 7-Example of screen showing user interface with pop-up window for redifining Brush Pen pressure transfer function.

Karen Donoghue & Ken Knowlton
fig 8- Example of Brush Pen hardcopy, printed on a 300 dots per inch laser printer.

Karen Donoghue & Ken Knowlton
fig 9- Examples of 300 dots per inch output from computer model of a rigid broad-edged pen common Western calligraphy.

Sally Pryor
"Thinking of Myself as a Computer"

character set cannot be easily and quickly entered through a keyboard.

A.) Introduction and Background:

Nowadays in China and Japan, writing for practical purposes is done using pencil or pen, though brush and ink calligraphy is still widely practiced as a separate art. Until modern times, the brush was the main writing implement for writing the Chinese language, which consists of pictographic and ideographic characters written in succession downwards in vertical lines arranged right to left. It is from Chinese that the Japanese imported their written language, and have added phonetic symbols called *kana* used in conjunction with the basic Chinese characters. The first Chinese characters were primitive pictographs (called *shokei moji*), though now several types of characters exist. One such character type is that of combined-meaning characters (*kai-i moji*), consisting of several sub-characters consolidated into one form. Another type is the form-and-sound character (*keisei moji*), comprised of two parts, one denoting pronunciation, the other denoting meaning. *Kashaku* characters are borrowed from the words they represent, and *tenchu* , which are characters that differ from the original ideas that they represented due to an extension of their meaning. These six principles of construction constitute the structure on which the Chinese (and the Japanese) style of calligraphy referred to as *kanji*. A *kanji* is comprised of three elements: form, sound, and meaning. Form is the most important element to us, as we try to model the graphical behavior of a brush pen using the Freestyle environment.

B.) Rules and Characteristics of Kanji:

Each kanji character is comprised of a number of strokes, where the ordering of the strokes and their form is strictly defined by the type of script to which the character belongs. Some characters are so complicated that they are comprised of more than 30 strokes. Wang (1) asserted that Chinese characters are artistically elegant and rich in imagery, and therefore possess semantic meaning that is directly depicted by appearance or syntax. Proper visual feedback is then important in creating kanji characters, as both aesthetic and semantic information is contained in the strokes of the character.

To create a kanji characters, the brush pen is usually held perpendicular to the paper, with the writing hand sometimes placed atop the other hand for support and to keep the writing hand from smudging the ink. There is no specific type of brush used for a particular style of kanji, hence the brush used for kaisho (a popular block script dating from the 4th century A.D) can also be used to create characters in the gyosho (or semi-cursive) script. Instructional books on *kanji* (2) recommend that the calligrapher keep vertical strokes absolutely vertical, and that all horizontal strokes be kept at the same slope during the creation of a single character. At the beginning of a stroke, more force applied to the brushpen's bristles should result in their forming an angle of 135 degrees from the right hand horizontal in a Cartesian coordinate system (3). During lift, three basic techniques exist. These are a.) linear lift, b.) lift at 135 degree angle, and c.) lift and sweep backwards. These stroke styles are depicted in Figure 1. Each stroke is created using slow and deliberate motion, holding the pen rigidly at the same angle throughout the creation of the stroke. There is no turning or twisting of the brushpen between the fingers, as it common in Western calligraphy as a technique used to vary stroke width. In kanji, stroke width is a function of stroke direction and force, where an increase in force may result in more bristles coming in contact with the paper, or a spreading of the bristles so that they cover a larger area of the paper at a given moment. Direction can also be used to vary stroke width, as the angle of 135 degrees made by the bristles means that diagonals downwards to the right (and closely related strokes) are somewhat thinner than strokes in other directions. The set of basic strokes used to create all possible kanji characters is small, as depicted in Figure 2. However, these are consolidated together to create thousands of possible characters.

One of the problems of data processing in Asian cultures is the difficulty in entering data through the keyboard. A single character is broken down into its constituent strokes, and each stroke corresponds to a keystroke on a typical keyboard. Depending on the complexity of the character, there can be few or many keystrokes needed to enter a single character. Multiplying the complexity of an average kanji character by the thousands of characters in the language makes inputting data for a form, for example, an extremely difficult task for someone who is not an expert kanji typist. Kanji characters made with a ball point pen (or non force-sensitive writing implement) lack proper visual feedback. Leedham and Downton (4) showed that this affects writing dynamics and changes writing style, as well as the process of stroke creation. Using a ball point pen to create a syntactically correct, force-sensitive kanji stroke would require the writer to scribble over the same line to make it more distinct. Of course, force is not enough to provide perfectly realistic visual feedback, but helps in providing visual feedback closer to what the writer expects. Therefore, writing dynamics should be less distorted.

C.) The Computer Model:

1.) The Brushpen "Footprint":

Because the set of all possible kanji strokes is so small, it is fairly simple to characterize a kanji stroke based on three parameters: initial contact of the brushpen with the paper at the beginning of the stroke, stroke body, and stroke termination. We studied the technique of real (human) brushpen calligraphers to collect data on stroke creation and calligraphy technique. We determined the shape of the area formed by the brush bristles touching the paper to be a teardrop shape leaning diagonally to the left, symmetric about an axis that is 135 degrees from the right hand horizontal. Hence, we decided to use the teardrop shape as our basic drawing primitive, or brushpen "footprint". This footprint shape allows for the creation of all basic stroke forms, both narrow and wide (See Figure 3). The footprint size is related to the amount of force exerted on the pen, and allows the user to create pressure-determined variable width strokes. The Freestyle system is especially useful for modeling the creation of kanji, since the stylus is force sensitive so that the strokes constituting a kanji character can be rendered using stroke width as a function of force.

The angle at which the brushpen handle is held is always constant, perpendicular to the paper, hence there is no need to sense any angle data in the computer model. The Freestyle stylus is physically the same basic shape and size as a typical brushpen, so strokes created using the computer model are created just as they are in the real world - using the same hand motions and muscles, and using force to vary the width of the strokes.

2.) Stroke Creation:

Most brushes in computer-based paint systems use a single, static drawing primitive repeatedly drawn as a function of the movement of the input device. In some systems such as FullPaint (from Ann Arbor Softworks, Inc.) and SuperPaint (copyright 1986, Bill Snyder) available for the Macintosh (registered trademark of Apple Computer, Inc.) as the input device (a mouse) moves along from point P1 to P2, the entire path joining the two points is filled with paint. The user cannot dynamically change path

stroke easily during the creation of a stroke, except by going to the menu and choosing a sub-menu for brush shape and/or size. In other systems, the single primitive itself is drawn at each sample point, giving a non-continuous series of dots or filled circles, or whatever the shape of the drawing primitive happens to be. Paint systems that use a 2D mouse as their input device are not capable of expressing stroke as a function of force. MacCalligraphy (copyright 1986-87, Enzan-Hoshigumi Co., Ltd.) allows the user to create kanji brush strokes using a mouse, however thickness of stroke is a function not of force but of the length of time that the mouse button is depressed. Realistic computer modeling of an application like kanji requires an input device which realistically refelects the dynamics of the hand motions of the artist - with variations in force and speed resulting in realistic feedback. Strassman (5)
modeled a non real-time brush as a compound object composed of bristles, keeping track of the physical state of the brush and remaining amount of ink over the course of the stroke. Strassman's "stroke" is described as a path whose constituting control points each have a force value associated with them. The force value for each control point is input by the user through the keyboard. Ware and Baxter (6) described a paint program
using a 6 degree of freedom "flying mouse" input device measuring x, y, z, and three variables of twist, allowing the artist to control form and color by moving the mouse in 3D space.

We chose to create a brushpen that combines some ideas of the above mentioned methods into a real-time brush whose resulting stroke is sensitive to dynamic force changes made by the user. As the stylus moves, the path traversed by the stylus determines the placement of the stroke on the screen, and the force exerted on the stylus determines the stroke shape and width.

For current use of the system as a brush pen to do Asian calligraphy, our method is good enough to create very realistic kanji strokes, according to our expert kanji calligraphers. One of our users, an expert painter, has also commented that the visual feedback from the system is excellent, and could easily be extended to model any type of paint brush, including brushes of different shapes and used with paper of different textures. This is an area for future research.

We have developed a fast method for creating a real-time kanji stroke using the Freestyle stylus. We approximate the convex hull of the teardrop drawing primitive using six control points. Six was determined, based on user feedback, to be the minimum number of points for an acceptable approximation for the teardrop shape. The arrangement of the six points is determined by adding a user-definable constant "C" to the raw force data "P" of the current stylus position at time T-1. Pressure data is in the range from 0 to 500 grams of force. After adding the constant "C" to the current force "P", the resulting value is divided by a non-zero user-definable constant "D". This result is then used as a "weighting factor" used to calculate the coordinates of each of the six control points in relation ot the current position of the pen at (X,Y). This (X,Y) data is obtained from the current tablet data packet. The points of the convex hull are calculated using (X,Y) at the very center of the brushpen footprint, to allow an even weight change in the stroke as force is changed linearly. Each control point has its own distince "C" value independent of all the other "C"s used in calculating the other control points. Each "C" is distinct so that, with slowly increasing force, the radial spokes of Figure 4, when pixel-quantized, do not increment simultaneously. (See Figure 4). Unlike the charcoal sketch program by Bleser et al (7), which uses pressure as an index into an array of predefined brush shapes, our method allows the convex hull of the drawing primitive to increase and decrease dynamically in a staggered manner, allowing for smooth gradations as force changes.

After the convex hull of the current drawing primitive is determined, the points are sorted in increasing Y, duplicates are thrown out, and points with the same Y value are culled - of these we keep only the leftmost and, if it is distinct, the rightmost. The remaining points are then fed to an N point Polygon fill routine, which fills the current primitive with paint (or ink). As the user moves the stylus to a new position at time T, the new tablet data packet is determined, and the new brushpen primitive is derived using the current force value and the series of "C' and "D" constants as stated above. The convex hull formed by both brushpen primitives at times T-1 and T is determined. These points for T-1 and T are each sorted in the manner stated above, and the remaining sorted points from both primitives are then merge sorted and fed to an N point Polygon fill routine. As the stylus moves, the last brushpen primitive for position (X,Y) at time T is saved and used in conjunction with the current brushpen primitive (based on most recently received tablet data) to determine the current stroke. (See Figure 5)

The filling of a stroke section between data packets happens within 5 milliseconds (running on a WANG 286), which is the time between tablet points at the fastest data rate possible. Because kanji is done at a somewhat slower pace than normal handwriting, and because of the importance placed on stroke quality, 5 milliseconds is enough time to fill the current stroke path with ink. This level of temporal resolution (200 points per second) gives very realistic kanji stroke feedback and is within the acceptable level for handwriting at normal speeds as described by Phillips (8). The current software allows the user to slow the tablet data rate as desired via the keyboard, and this may come in handy later when larger or more complicated shapes are used as footprints.

We developed a fast polygon fill algorithm for filling the convex hull of an N point polygon, which breaks convex hull of a stroke into its constituent trapezoids, each having horizontal top and bottom. (A trapezoid consists of 1 or 2 points on 1 or 2 possible Y levels. See Figure 6.) Each of these trapezoids is then fed to a trapezoid fill routine, which fills the trapezoid with horizontal lines, using Bresenham's line algorithm to determine the successive line endpoints. Figure 6B shows the convex hull of a brush stroke broken down into its constituent trapezoids.

The speed of the algorithm enables real-time strokes to be created with no jaggies, except when the pen is moved in a curve at very high speed. The code is currently implemented in Microsoft C running under Freestylus 1.0 on a high resolution (100 dpi) monitor. The only current colors avaiable are black and white. Data from the tablet is in 1000dpi format, so when data is mapped onto the monitor's screen at 100dpi, there is some quantization, though it is not objectionable. Non-real-time hard copy output from the same data can have higher resolution and even smoother edges.

3.) User Definable Parameters:

In addition to allowing the user to define the "C" and "D" constants that determine the relationship between raw force data and stroke width, our software allows the user to interactively define a force transfer function. This resulting value is substituted into the force-to-line-width equation as the raw force. These curves can be altered to create brushpens of different types, such as a brushpen whose stroke width decreases as more force is applied, and vice versa. (See Figure 7)

Most of the users like to experiment with their own force mapping curves, though variations on the exponential curve seem to be the most favored. Some people prefer more force sensitivity at low force levels, which others want as thick a stroke as possible over the entire range of force.

4.) Output:

Output for the brushpen system is now obtained either by saving a 100dpi screen image, or by converting the stroke data to a Postscript readable file. Both methods are currently used with a WANG LCS15. The second, higher quality method, is obtained by taking the 1000dpi tablet data, running our postprocessing software with the data, and converting it to a Postscript file for printing at 300dpi. Samples of output are shown in Figure 8.

D.) Additional Applications:

Since the polygon fill can handle any number of points, we can vary the drawing primitive shape to be any convex polygon, such as a hexagon, or a square. It can even be the degenerate case of a straight line, thus simulating a rigid broad-edged pen common in Western calligraphy, whose nib components spread further apart as more force is applied to the pen, resulting in a wider stroke (See Figure 9). We can thus model many brushes of different types, including ones that do not even exist in the real world. This code could be integrated into a paint system which would allow the user to create his or her own brush, specifying its shape, size, and force sensitivity. The addition of color into the system would provide a palette for different paint colors, type, and textures.

The polygon fill code and its supporting sort routines are currently implemented in C, but to operate more quickly, they will eventually be converted to assembly language. This will allow larger strokes to be created quickly, with no aliasing effects.

Currently, we are adding some more features requested by our kanji experts. These include a "smearing" or "bleeding" function to allow the paint or ink to smear on the paper if the brushpen is held in the same position for some length of time (about 3+ seconds), primarily by increasing the size of the footprint as the brush dwells at one place without significant movement.

E.) Ackowledgements:

The authors would like to thank the many calligraphers that helped give constructive comments and suggestions to the project, especially Kenichi Akagi, Horace Tsiang, Steven Teng, and John Cataldo. Also thanks to Steve Levine, Jonathan Reduker, Maria Witt, and Jean Renard Ward.

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QUASICRYSTAL ARCHITECTURE

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The big news in patterns is that there exists a wholly different class of patterns --Quasicrystals. Two dimensional quasicrystals, often called Penrose Tessellation after Roger Penrose who discovered them in the mid 1970's, are made up on only two shapes or "tiles" -a fat and a skinny rhombus. Three dimensional quasicrystals --made up of a fat and a skinny rhombohedra--are only a few years old. What is new about them, what has escaped 30,000 years of previous pattern making, is that they are non-repeating patterns. Quasicrystal patterns have astounding visual and structural properties that make them ideally suited for applications to architecture.

Imagine a car's tire track in the snow. Perhaps it is a few rows of "w's all nested and interlocking. If the snow was fresh and there was gas in the car, one could make a 500 mile track of millions of little 'w's. Three hundred mile down the track one could find exactly the same sequence as in the beginning; 492 mile down the track the same sequence, because the entire track is made by the same wheel going around, again and again. This is the very essence of what we mean by patterns; one or just a very few elements repeated in a regular way. If there is a pattern then there must be repetition, and if there is no repeat there can only be randomness. No doubt E. Gombrich and R. Ornstein are right about patterns, and the eye and right brain work together in an especially efficient, non-verbal way to precisely confirm these regular intervals. True, one could imagine a completely random tiling: a crazy-quilt of irregular shapes with no regular intervals add up to no line-of-sight structures. But such a crazy-quilt is not a pattern; it is not captivating or satisfying and is only charming as a frustration of our natural inclination to see regular patterns.

A non repeating pattern, then, is an apparent paradox. The perfect stacking of just two quasicrystal elements over and over again looks and feels like a pattern. Recognizable parts of a quasicrystal do repeat, but not in a regular way. It is even possible when given the position of some elements to predict the location of others, but like an irrational number there is not the regular repeat of sequence that we are so conditioned to seeing. There are also many line-of -sight concurrences. There are even rotations which leave the pattern essentially unchanged, in that unit cells are still oriented in one or another of just a few directions. And yet, the patterns are not exactly the same after rotation, only essentially the same. Although quasicrystals frustrate our common pattern recognition systems, we intuit that there is some kind of structure and pattern really there. Even when first encountered, they quickly become endlessly fascinating. As a geometry of flux, rich ambiguity and subtle order they seem elegantly to express our modern experience of space.

The history of quasicrystals is the development of more and more powerful mathematical techniques to generate them, techniques that allow more and more of their subtle symmetry to emerge. Nicholas deBruijn's genius was to discover a global (long range) structure in quasicrystals at the time when every one else though of them as having a purely local, and quite random, structure. A global structure implies a computational algorithm to generate perfect quasicrystals, without trial and error, that can be mechanized to be a computer program. Once quasicrystals became computer generated, rapid progress is being made in using them.

Quite by accident D. Shectman and his collaborators discovered in a rapidly cooled sample of an aluminum-manganese alloy properties of both metallic crystal structure and glassy random structure. These samples had the fivefold (pentagonal) symmetry that had been disallowed for patterns until the discovery of quasicrystals, and P. Steinhardt suggested that they may be serendipitious quasicrystals. Initially there was debate on the part of scientists as to whether these small, early samples might have only the illusion of five-fold symmetry or whether they had only a few atoms in such an arrangement and could not be expanded into whole crystal lattices. Now that large, flawless samples have been made, and it is clear to all but a few researchers that they are truly quasicrystals. Research can now focus on their electrical and chemical properties, possibly with quite startling results.

There is still a major philosophical debate about what it means that these quasicrystals can be formed. If Steinhardt is correct that he has found a new set of matching rules -step by step local operations -that is foolproof, then it is possible to imagine some physical implementation of these rules. Quasicrystals would form when atoms connect to one another according to the local forces described by these rules. If Penrose is right then no such foolproof set of matching rules exists, and perfect large scale quasicrystals can only form by reference to a global and algorithmic system. But what do little atoms know about the big picture? For Penrose that is precisely the point, they do know about the big picture just as quantum theory suggests particles "know" about other places and other times. Thus quasicrystals are macroscopic quantum effects and as such are a model of everything. Penrose's theory, discussed in his book "The Emperor's New Mind", is a breathtaking leap into speculation. No one thinks so highly of quasicrystals: they are the model of the working of the human mind; they will be the basis of new quantum effect computers. While all this may yet turn out to be true, I think Steinhardt is right and a foolproof step by step system exists for making quasicrystals so that it is not necessary to see them as macro quantum effects.

With Steinhardt's help and using de Bruijn's powerful dual method, I have written computer programs which generate, rotate, slice 3d quasicrystals, and which demonstrate the visual behavior of these structures as seen from different angles. Sometimes they seem to have fivefold symmetry and are pentagons and star pentagons. Other times they appear to have three fold symmetry, and appear to be made up of triangles, hexagons, and 60 degree parallelograms. Still other rotations reveal them to have the two-fold symmetry of squares and diamonds. This icosahedral symmetry is a characteristic of all quasicrystals. It is thrilling to see this structure transmute before your eyes, in real time, becoming one thing and then another, dissolving cells at one place and re creating them elsewhere, becoming one moment a dense thicket and the next a transparent lacework-- and all the while knowing that the structure is not really changing, that only a rotation of a fixed, rigid, structure is being observed. IT is a though three different structures were hidden in the same structure.

I am convinced, based on these programs and the large scale models I have made, that quasicrystals will be a major contributions to architectural structures. Imagine the delight of seeing a structure that transforms as you walk around the outside of a dome, or underneath a quasicrystal ceiling, or even by just turning your head. Quasicrystals are exquisitely and magically responsive to both changes in light and the viewer's movement. Buildings could become effervescent, and seeming alive.

I am also convinced that quasicrystals have novel structural properties, and that these building would be interesting for their engineering, alone. Because they are non-repeating patterns, quasicrystals are structurally deferent from anything yet built. Forces are not translated directly as with other structures; rather loads are instantly diffused in all directions. Yet these resilient and flexible structures can be stiffened by tensile membranes, by new materials, or by open plates.

It is well known from before the time of the Eiffel tower, that truss structures can be made that are stiff by assembling triangles. It is not difficult or novel to introduce rigidity into these structures; what is hard to accomplish and necessary to do on many occasions is to introduce flexibility without loosing strength. Quasicrystals were originally thought of by Steinhardt as a model for an idealized fluid, and pressing on one part of a quasicrystal structure dislocates many other parts of the structure in directions that are greatly different from the original force. It is like pressing on a balloon filled with water- the force in not translated trough the balloon to come out of the structure on the opposite side basically unaltered, as would be the case in a truss. Rather the force is diffused in all direction and absorbed by the structure as a whole. The structure, like the balloon of water, is only as weak as the stress skin resists tearing.

When maximum flexibility is required, in earthquake prone area for example, even large scale quasicrystal structures can be built using new spring concrete that can flex. When build with rods and nodes, quasicrystal structures can be thought of an complicated three-dimensional springs that "spring" in many directions at once. Quasicrystal architecture can also be build with open plates which still maintain all the visual properties mentioned. Plates have many practical advantages: any three plates meeting at a corner form a rigid unit, the edges of the plates carry the load and the nodes are structurally unimportant, only two plates make every quasicrystal structure, units can be prefabricated on the ground and hoisted into place, and the partially completed roof has more structural integrity than with other structures.

If we adopt the Gombrich-Ornstein pattern thesis (that pattern matching is the work our right brains do, is the basis of our unconscious creativity, and is the source of our mystical connection to nature) then the discovery of quasicrystals is a tremendous challenge to and opportunity for consciousness. Non-repeating patterns are extraordinarily hard to visualize- they do not match a template already in the right brain storage racks. But if we can learn to work with them, to think in them, who knows? Maybe magical and magically constructed building are just the beginning.

The author wishes to tank Paul J. Steinhardt for his many kind consultations on the mathematics and computer programing of quasicrystals.

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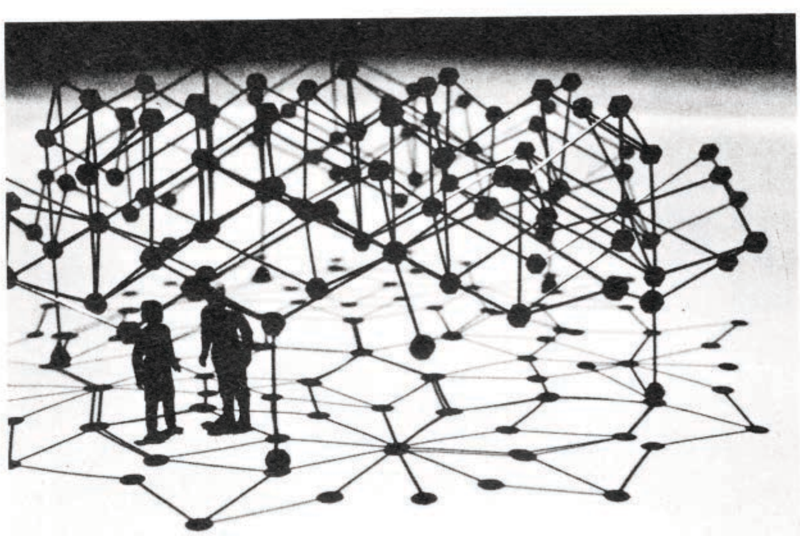

A Quasicrystal Spaceframe casting a shadow of a Penrose Tesselation, Model in BRASS, 30" diameter.

Art-Related Virtual Reality Applications at the University of North Carolina at Chapel Hill

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Abstract

"Virtual Reality" is a field that has attracted much interest from people of many different disciplines. This is not surprising, since there are so many applications for virtual reality, from architectural building walk-throughs, medical applications and scientific visualization, to performance art.

The emphasis at the University of North Carolina at Chapel Hill (USA) is on improving virtual reality technology and using it to solve real problems. Some of the current applications of virtual reality at UNC are: architectural building walk-through, radiation treatment planning, molecular docking, and medical "X-Ray vision."

This paper gives an overview of virtual reality techniques and highlights work in progress and recent developments at Chapel Hill and discusses this work's relevance to art.

Introduction

For me to discuss how virtual reality relates to art is a little like a toolmaker who makes better chisels talking to sculptors about how to do statues. I will give my impressions of how virtual reality relates to art at the end of this paper, but for the most part I will stick to the explanation of how virtual reality is accomplished and of the many applications for which we are using it at the University of North Carolina at Chapel Hill, and leave the vivid imaginations of thousands of artists to decide how best to use it, and where it might go from here.

I. Overview of Virtual Reality Ideal

A. The Promise of Virtual Reality

The promise of virtual reality (VR) is that it offers us the ability to enter a "parallel universe" or "virtual world" in which all things are possible. This universe contains whatever we want or need it to at the moment- we can choose how it will act in order to satisfy our current need. If we are architects, this universe may consist of the building we are designing and the surrounding landscape; if we are radiologists, it may consist of a model of the current patient's anatomy, so that we can properly place a radiation beam to destroy a tumor; if we are biochemists, this universe may consist of a huge protein molecule, whose structure we come to understand by flying through it on a "magic carpet" and by manipulating its twistable bonds. In the parallel universe, we are not bound by physical laws which are not useful- what is imaginable is possible.

That's the *promise* of virtual reality; but what is the *reality* of VR?

The reality is that we do our best to *simulate* the parallel universe described above: we don headgear, handgear, and body suits; we walk on treadmills and "fly" by pointing a three-dimensional mouse and pressing a switch. The more convincing this simulation is, the closer we come to the promise of virtual reality.

B. Simulating Another World

In order to simulate reality, we need an understanding of the ways we sense and interact in the real world. Here in the real world, we use our *senses* to perceive the reality around us: there are sensory receptors scattered throughout our bodies which sense external stimuli and report to our brain. In order to simulate another world, we need to feed in different stimuli to at least some of these receptors. In addition, we need a way of detecting actions taken by the user so that we can reflect these actions in the virtual world in order to maintain the illusion over time.

One way to characterize this complex interaction is by imagining an interface between the user and the world (real or virtual), and categorizing sensory stimuli as his *inputs*, and anything that the user might do that must be reflected in the virtual world as his *outputs*.

Sensory inputs are described well by the literature of sensory-perceptual psychology; the list that follows is one possible categorization (of many) of the components of this interface. I have listed the outputs with the inputs, since every output can be associated with some input.

Type [1]	Input / Output
visual	what the user sees / his appearance
auditory	sound / voice, user-generated sounds
haptic [2]	touch, contact forces experienced / forces exerted
proprioceptic [3]	current body configuration
vestibular [4]	acceleration, orientation
olfactory	smell
gustatory	taste

With this model then, we associate inputs with real sensory receptors; the outputs are defined to be those actions that could serve as a stimulus to some other (real or virtual) user. For example, the auditory input is any sound that the user hears; his auditory output is any sound that he makes that another user in that virtual world could hear. The user's visual input is anything that he sees; his visual output is his appearance in the virtual world. Finally, the position and orientation of the user's body parts is his proprioceptic input *and* output: he can sense where his limbs, etc, are, and the system must also detect where they are in order to properly display his appearance.

In summary, in order to fool the user into believing that he's in another world, we must present alternative stimuli (sights, sounds, forces, etc), or "inputs" to his sensory systems. In order to keep the illusion up to date, we must detect any user "outputs": changes in his position or orientation, sounds generated, etc.

[1] This list contains only the most relevant to this field, and is a subset of those found in the psychology literature (see [5], [10]); I have omitted some categories for brevity and simplicity.

[2] haptics- "pertaining to sensations such as touch, temperature, pressure, etc. mediated by skin, muscle, tendon, or joint." [14]

[3] proprioception is "the sense of movement and bodily position," [5] and is one of the haptic senses.

[4] the vestibular system of the inner ear provides information about the linear and angular accelerations of the head. [10]

II. Virtual Reality Equipment at UNC Chapel Hill

To implement the model above, we need devices for providing the stimuli to the user, as well as sensing devices to detect user output. The VR equipment currently in use at UNC does not cover every category in the model above- there is simply too much to simulate and detect. What follows is a list of VR equipment now in use for our current applications.

A. Input Devices

1. Displays

Displays are arguably the most important feature of a VR system, since the visual system has such an impact on our perception (Christman [10] characterizes the human eye as "an extension of the brain."). The visual input in a VR system is usually computer-generated, and displayed on some type of screen (cathode ray tube (CRT), liquid crystal display (LCD), etc). Although the *head-mounted display* (HMD) is often used in VR systems, it is by no means the only way to give the user visual input. At UNC, we currently use four types of display:

a. *Regular CRT's:* due to their availability, these displays enjoy wide use, especially for the Walkthrough and molecular studies applications.

b. *Large, rear-projection screen:* This is a Sony Super Data® 12700 projection display, projected onto a 4' x 5' 4" rear-projection screen. It gives a wide-field-of-view color image, and is used often for the Walkthrough and molecular studies applications.

c. *Opaque Head-Mounted Displays:* We use both a commercially available VPL Eyephone® and a bicycle-helmet-mounted display, developed at the Air Force Institute of Technology in collaboration with UNC; these two are used for all applications except X-Ray Vision.

d. *See-Through Head-Mounted Displays:* We have two units (only one of which is currently operational) that were developed at UNC that use half-silvered mirrors to superimpose virtual objects on the real world [6] [9]; these are currently used only for X-Ray Vision. A new, more robust, high resolution model is under development.

The first two display types above can be fitted with stereo viewing plates (we use Tektronix alternating polarization plates) so that a stereo image is displayed when viewed with polarized glasses; the Eyephone® and see-through HMD's normally display in stereo; the AFIT is currently used in non-stereo mode.

2. Sound Equipment

Audio input is usually computer-controlled and may be recorded or computer-generated. Currently, most of our sound generation is done by an Apple Macintosh®IIcx, and uses computer-generated and recorded sounds. Any sound can be recorded and played back under application control through the built-in speaker in the Macintosh®. Examples of sound in the featured applications are:

a) In a simple molecular application for the force feedback arm, collisions between two atoms is marked by a "knock" sound played by the Macintosh® (this is not yet feasible for more complicated molecules and so is not currently done).

b) In the Adventure Game application, a similar "knock" sound is generated when the user bumps into a virtual wall; a "whoosh" sound is played when the user fires the application's "vortex gun".

c) The Virtual Piano application's notes are generated by the Macintosh® as well.

d) The force feedback arm (described below) uses a simple bell sound to give user feedback when the arm is out of range.

3. Force Feedback / Motion Simulators

Haptic input can be given in all sorts of ways, since there are receptors all over the body for this type of input.

The most prominent haptic input device in use at UNC is the ARM (Argonne Remote Manipulator, a donation from Argonne National Laboratories), a six degree-of-freedom (3 forces, 3 torques) force feedback device. The ARM is currently used primarily for molecular docking research.

Another type of haptic input is given by the treadmill, which is used for the Walkthrough application. Although this form of feedback is not as direct as the ARM's forces, the treadmill nonetheless provides haptic input by giving the user the feeling that he is walking on a real surface.

B. Output Devices

1. Trackers

One of the most critical user outputs is the position and orientation of his body: head, torso, extremities, etc. If the user moves his head, we need to update his view of the world as shown on the display (assuming we are doing head tracking) to reflect his new viewpoint. In order to detect user motion, we have three types of tracking systems at our disposal:

a) *Polhemus Trackers:* We currently have three Polhemus Navigational Sciences 3Space® trackers. These trackers use a low-frequency magnetic field generated by one or two *sources* , and report the positions and orientations of (depending on the model) from one to four *sensors* at once. The working range of these trackers is a hemisphere less than five feet in radius, with an update rate equal to 60 Hz divided by the number of source-sensor pairs that are in use. The two main problems with the Polhemus are its *lag* (the time between a user's movement and the appearance of data reflecting that movement) and its limited working volume.

The Polhemus is currently used for all head-mounted display applications; one sensor is attached to each of the HMD's for head tracking, and another sensor has been placed inside of a hollowed out billiard ball, which serves as a 3-D mouse for hand tracking. Alternatively, we sometimes use the hand sensor on a guitar finger pick equipped with a microswitch.

b) *Optical Tracker:* An optical tracker is currently under development at UNC that should solve the problems we are having with the Polhemus. Its goal is to allow room-size working volumes with update rates in the neighborhood of 200 Hz. It is at present a working, limited-volume bench prototype [11] [12] [13].

c) *The ARM:* In addition to being a haptic input device, the ARM is also an effective hand tracking device, since the ARM's handgrip position can always be calculated from its joint angles.

In addition to these more general-purpose trackers, we also have a VPL DataGlove® for tracking the fingers of the user's hand (the DataGlove™ uses the Polhemus tracker for the hand position and orientation).

2. Audio Output

One of the most natural ways of communicating for humans is via voice; thus, devices for detecting auditory output in the form of speech are a natural part of a virtual reality system. We have recently acquired a DragonWriter® speech recognition system for our lab. This system is speaker-dependent, and thus has to be trained for each user. The system has not been used yet, but is promising for applications where the user will spend enough time with the system to justify the training time.

3. Motion Devices

If the user actually walks very far in the room where his VR equipment is connected, he may run into a wall that is not part of his virtual world, but is part of the real building, or he may run out of cable. For applications (such as Walkthrough) where the user will need to "walk through" a building or building-sized model, the user's translation output is detected by a specially modified treadmill, which is equipped with bicycle handle bars for steering and electronics for reporting changes in its virtual position and orientation.

For greater distances, a similarly modified bicycle has been used.

4. Other "Input Devices"

There is also a host of other devices that can be used in virtual reality systems which are traditionally called "input devices", since they provide input to a computer. We use them to detect user output in the form of button presses, knob twists, etc. Examples from the featured applications:

a) *Joysticks and Sliders:* The user's vertical position in the building model in Walkthrough is controlled by a slider. Also, when the user is not using the treadmill for moving through the floor plan, his movements can be controlled by a joystick; another joystick can be used for the head's orientation when the head-mounted display is not used.

b) *3-D Mouse Buttons:* The 3-D mouse mentioned in the Tracker section also has two microswitches for detecting user output. In several of the applications, a button press on the 3-D mouse allows the user to "grab" a virtual object, which stays attached to the user's hand for as long as the button is pressed. In the adventure game application, the user picks up the "vortex gun" with one sequence of button presses, and "fires" it with another. Flying through the virtual world is also initiated with a button press.

c) *ARM Dials and Switches:* There are dials on the ARM for controlling the level of force output and for general use, as well as a safety switch that enables any output forces at all.

5. Haptic Output

With the ARM system, the user outputs real forces in response to those produced by the ARM; these may move the ARM to a new position, which it must detect and act accordingly. In the other systems where the user grabs virtual object, the forces are virtual, but still may be classified as haptic output.

III. Virtual Reality Applications at the University of North Carolina at Chapel Hill

The department of Computer Science at the University of North Carolina at Chapel Hill has been active in virtual reality research for over two decades. The emphasis at UNC is on improving virtual reality technology by tackling real-world problems and letting these problems drive the research.

Descriptions of some of the most relevant projects follow. The projects are grouped into *research projects*, which are collaborative efforts which may take years, and *personal projects*, which are usually done by one or two people for exploring various aspects of virtual reality, or for class projects. The more mature projects are listed first.

(The majority of the VR research projects have been supported by the DARPA project "Advanced Technology for Portable Personal Visualization", Frederick P. Brooks, Jr. and Henry Fuchs, principal investigators (contract #DAEA18-90-C-0044), and by NIH Grant #5-R24-RR 02170-07, ONR Grant # N00014-86-K-0680, and NSF Grant # CCR-8609588.)

A. Research Projects

1. Molecular Studies

Tool-building for biochemists doing research on protein molecules has been going on at UNC for over twenty years, dating back to the GROPE I project in 1967 [4].

More recently, the GROPE III project has been used to show that force feedback improves performance in a molecular "docking" task (finding a minimum energy position and orientation for a drug molecule in the active site of a protein molecule) [4]. The user holds the handgrip of the ARM (described in II) with a virtual drug molecule attached to it. As he moves it around the large protein molecule, he experiences a simulation of the forces that would be exerted on a real drug molecule in that configuration by the protein molecule.

Viewing can be done either with the head-mounted display or with a PS-330 color vector display with a Tektronix alternating polarization plate and polarized glasses (the latter display is preferred for large models).

A newer molecular application is the "fly-through" of a molecule. The user can load in a protein molecule modeled as a cluster of spheres, put on the head-mounted display, and enter a world where angstroms are as long as meters, and atoms are as big as beach balls. The user can scale the model up and down, and fly through it by pointing the three-dimensional mouse and pressing a button. As long as the user presses the button, he will "fly" in the direction he's pointing. When he stops, he will be suspended in space at that point, free to walk around in that area and explore any interesting local structure.

Credits: ARM: Ming Ouh-Young, James J. Batter, P. Jerome Kilpatrick, William V. Wright, Russ Taylor, and Frederick P. Brooks, Jr. (P.I.)

Flythrough: Warren Robinett, Jim Chung, Bill Brown, David C. Richardson

Grants: ARM: NIH Grant #5-R24-RR 02170-07

Flythrough: DARPA #DAEA18-90-C-0044, NIH Grant #5-R24-RR 02170-07 and ONR Grant # N00014-86-K-0680

2. The Walkthrough Project

The Walkthrough project started in 1985 with the basic goal of "a virtual building environment, a system which simulates human experience with a building, without physically constructing the building." [1] Using this system, the user can "walk through" in real time a building that may not yet exist. As the user moves through the three-dimensional building model (by whichever means), perspective views are generated that make it seem as if the user is really inside the building.

Viewing can be done with a regular CRT, the large rear-projection screen, or a head-mounted display. With the HMD, the user's viewpoint is controlled naturally through his head movement: if he wants to see off to the left, he simply turns his head to the left. If the other displays are used, the head orientation and position are controlled by joysticks or the three-dimensional mouse.

Movement through the building can be controlled by walking on a treadmill, by the 3-D mouse or by another joystick. If the treadmill is used, the steps taken on it are translated one-to-one to steps in the virtual building. Turning while walking is accomplished by turning bicycle handlebars that are attached to the front of the treadmill.

When the joysticks are used for moving through the model, a technique called *adaptive refinement* [2] is applied to the image whenever the user stops (this can't be done with the HMD because there are always small head movements). This technique takes advantage of the reduced demand for interactivity and uses the compute time to improve the image realism and anti-aliasing.

This system was used to walk through the UNC computer science building before it was built and was actually used to make some design modifications before the construction began.

Credits: John Airey, John Rohlf, Randy Brown, Curtis Hill, John Alspaugh, and Amitabh Varshney, and Frederick P. Brooks, Jr (P.I.)
Grants: NSF Grant # CCR-8609588 and ONR Grant # N00014-86-K-0680.

3. Radiation Treatment Beam Placement

James Chung, a graduate student at UNC, is working on a CAD tool using a head-mounted display for designing radiotherapy treatment beam configurations in the hopes that it will aid radiotherapists in making better treatment plans [7].

In this VR system, a model of the patient's anatomy is explored by a doctor who is preparing a radiation therapy treatment plan in order to deliver a lethal dose of radiation to a tumor, while minimizing the exposure of healthy tissue to the radiation. The doctor puts on a head-mounted display and enters a virtual world containing a model of the patient's anatomy (as obtained by standard computed tomography (CT) methods and rendered as a set of polygons) and some number of polygonally defined radiation beams. While in this virtual world, the doctor experiments with different beam placements by moving the virtual beams by "grabbing" them with the 3-D mouse in order to find the optimal placement of the beams as described above.

The problem that this system addresses is that currently, radiation treatment planners have to look at the patient's anatomy on a two-dimensional screen, which makes it difficult to understand views other than the "cardinal" (orthogonal) views, so treatment geometries involving odd angles are not often used, even though they might result in a better overall treatment. The projected advantage of this system is that in the virtual world, the doctor is free to examine all angles of beam placement in a very natural manner, and should thus allow better treatment plans in less time.

Credits: James Chung, Julian Rosenman, Henry Fuchs and Stephen Pizer
Grants: DARPA #DAEA18-90-C-0044, NIH Grant #5-R24-RR-02170 and
ONR Grant # N00014-86-K-0680

4. X-Ray Vision

The X-Ray Vision project is a planned head-mounted display application where, instead of blocking out the view of the real world in favor of the computer-generated world, the computer-generated world is superimposed on the real world, using the aforementioned see-through head-mounted display.

There is no limit on what type of image can be superimposed, but I have chosen to focus on the problem of cranio-facial reconstruction (CFR) planning as my driving problem. In this application, computer-generated images of a patient's bony tissue (and possibly soft tissue) would be superimposed *on the real patient*. This would allow the surgeon planning reconstructive surgery to see the real soft tissue, yet have a three-dimensional image of the underlying bone at the same time. According to Davis [8], there is often a need in CFR planning to superimpose CT images of bony tissue onto CT images of soft tissue, and a tool that accomplished this in 3-D would be quite useful for planning.

In addition to the passive visualization, the system would have a marking capability, so that the surgeon could mark points in the computer image that were important in the planning process while with the patient.

Credits: Richard Holloway, Jefferson Davis
Grants: DARPA #DAEA18-90-C-0044, NIH Grant #5-R24-RR 02170-07 and
ONR Grant # N00014-86-K-0680

B. Personal Projects

1. Adventure Game

Another application developed at UNC to investigate navigation and action in virtual reality is an adventure game created by Warren Robinett.

This world consists of a network of rooms connected by portals. The spatial relationship between rooms is not necessarily one that is possible in normal three-space: ie., the room that you access through a portal to your right may also be accessible by going through the portal on the left and then up one level.

Movement in this world is accomplished by flying, as in the molecule fly-through described previously.

Each room has its own "thrills and chills": one room has an elevator that will take you up or down when you fly into it. Another room contains a mirror, which mimics your every movement. Still another contains a giant, hungry bird that chases you around the room and tries to eat you; however, if you're quick enough, you can "pick up" (again, with the 3-D mouse) a "vortex gun" and blast the bird with a swirling polygonal vortex.

This virtual world comes complete with sound effects: if the user bumps into a wall while trying to fly through a portal, a "thump" sound is generated by the Macintosh®. When the vortex gun is fired, it makes a "whoosh" sound, and if you hit the bird with the vortex, a buzzing sound confirms the hit.

2. A Sampling of Student Projects

Other personal projects have been done by students, both on their own and for class projects. The "Exploring Virtual Worlds" class at UNC has spawned many interesting virtual worlds. A few interesting examples of independent and class projects follow.

a) Virtual Piano

Bill Brown created a virtual piano, consisting of a model of a virtual eleven-key keyboard floating in the middle of the room. When the user puts on the VPL Eyephone® and the VPL DataGlove®, a large, animated white glove comes to life, and shadows his real hand. As he presses on a virtual key with his virtual hand, the key descends and a note comes floating up from the Macintosh®, corresponding to the key that was pressed.

b) Fly-through of a city

Ron Azuma and Ulrich Neumann created a virtual world with a city, tunnels, and a lake. The user can fly through the virtual world, experiencing visual, audio and force feedback. In the city, the user flies between buildings that range from small to skyscraper size through targets that give directions on where to go next. Collisions are detected between the user and objects in the city, and audio and force feedback (if the ARM is used for flying) make the user aware of the collision. In the lake, the user swims with fish that are animated in such a way that they avoid collisions with each other and objects in the lake.

c) Virtual Golf

Virtual miniature golf is the objective of Curtis Hill's virtual world. Here, the user is armed with a special putter (whose movements are tracked by the system) in order to sink a virtual golf ball into a virtual cup. When the user hits the golf ball with the putter, a putting sound is emitted to give audio confirmation of the hit. When the ball stops rolling, the user is transported to the point where the ball is so that he can continue play. When the user sinks the putt, the flag sticking out of the hole turns red and the sound of a ball falling into a cup is produced by the Macintosh.

d) Virtual Mountain Bike

Ryutarou Ohbuchi created a virtual mountain bike system which featured kinetic feedback of changing terrain through computer-generated resistance on the pedals, as well as real-time visual feedback. The large, rear-projection screen displays terrain data while the user pedals through the scene, while a kinetic resistance device changes the load on the pedals to reflect the slope of the path. Collision detection with virtual trees is also detected.

IV. Relevance To Art

While many of the aforementioned applications are scientific, their relationship to art does not require too great a leap of imagination. If this medium is ever to be useful for artists, then surely some advances made in the technology in pursuit of scientific goals will also benefit the artistic uses of it. For example, advances made in image generation facilitate better, faster images; improvements in tracking make the system more responsive and more usable; better auditory and haptic systems also increase the realism and the possibilities for interaction.

Also, when you look at it, the very nature of virtual reality is artistic: before we start, there is no virtual world- someone has to *create* it. The very nature of the medium is therefore creative, and, I assert, *artistic*. Much of the work in creating a VR application is in modeling the virtual world: choosing the colors, shapes and sizes of the objects in the virtual world, which seems to me to be an inherently artistic task. Moreover, since the creator is unbound by physical laws, his choices are freer (and thus harder!) than ever.

Finally, a note of realism. As great as the *promise* of virtual reality technology is, the reality is that it is an immature field and that many VR systems are still quite hard to use and prohibitively expensive. Except for the top-of-the-line flight simulators, most VR systems fall far short of actually fooling the user into believing he's in a virtual world. Of course, some will not be daunted by these failings and will use VR technology as is; but with continued hard work VR systems should continue to improve and be usable by more and more artists.

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Searching Pictorial Databases by Means of Depictions

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""computer scientist

This paper argues that, in general, information technology systems are capable of storing at low cost large volumes of pictorial data and hence we should anticipate an increased reliance on pictorial databases. However, pictorial databases will only be useful to the extent to which that allow flexible and rapid search. A distinction between depictive and descriptive representations is made and it is argued that visual depictions, such as drawings, are useful for representing visual-spatial properties of pictures. Earlier methods for accessing pictorial databases make no provision for depictive search. In this paper, a system that provides methods that include search by depiction is described. Essentially the user creates a "sketch" of the target picture from which the system extracts descriptions that are matched to descriptions of the pictures in the database.

INTRODUCTION

The range of domains in which computers are applied has increased quite significantly during the last decade. This is partly due to increased availability as a result of low cost miniaturisation. At least as important, however, in the spread of computers is the increased range of information representation formats that can be supported. In the early days information had to be represented using numerical codes, later words, and more recently pictures. Today even personal computers can handle the creation, manipulation, presentation and storage of pictures, making the use of computers in art and design a commonplace occurrence. This increased use of computers by people who routinely generate and use pictures has led to the need for pictorial databases that store large quantities of pictures. Clearly there is a role for pictorial databases in many domains. However, in this article we only consider issues relating to databases of paintings, although we hope to show that the ideas discussed here are of more general interest.

Chang [1] defines a pictorial database as an integrated collection of shareable pictorial data encoded in various formats to provide easy access by a large number of users. With large volumes of pictorial data "easy access" becomes a crucial matter. In such cases it is usually not practical to scan all pictures in order to locate the one or more pictures desired. Instead, to make search practicable and timely the pictorial database is organised so that various selection strategies can be employed by the user to locate a smaller set of pictures for viewing. The goal of a database designer is to provide a search strategy that produces a picture set containing only pictures, and omitting none, that match the user's target picture (set), or is empty in the event of there being no matches in the database. We shall argue here that "easy access" has a lot to do with the 'language' available to the user for communicating the target picture, or picture set, definition to the computer.

SEARCHING ON VISUAL-SPATIAL PICTURE PROPERTIES

The two-dimensional visual-spatial properties of the picture surface are important to artists and art historians. Indeed in the development of twentieth century painting notions of picture surface have played a crucial role. In 1890 the painter-aesthetician Maurice Denis wrote, " Remember that before being a war-horse, a nude or some story or other, a picture is essentially a flat surface covered with coloured pigments arranged in a certain order [2]. In this statement Denis defined the essential principle of modern painting. "The moderns discarded any dependence on subject or nature and made it their business to create 'pure painting'. Even when they wanted to translate some definite emotion, it was the form itself that had to be expressive, and not the evocation of some touching theme" [2]. However, this preoccupation with the structure and organisation of the picture surface is not restricted to twentieth century painting. Throughout the history of painting the organisation of represented objects and scenes has been partly constrained by the need to comply with a required surface order. It is not unreasonable to postulate that a user of a database of paintings might wish to search for pictures having particular two-dimensional visual-spatial properties. To what extent, then, is visual-spatial search supported in existing pictorial database techniques?

Early pictorial databases consisted of both textual information and images. However, they were constructed by storing textual information separately from pictorial data, linked only by textual registrations of the images. Examples include medical databases storing X-ray images linked by textual registrations of patient name and patient number [3]. In such systems the user can only get to the picture by providing queries that match simple descriptions of the picture content.

Gradually systems using computerised digital analysis techniques were introduced in an attempt to automatically analyse the actual images within pictorial databases. These systems have been further developed by the inclusion of textual picture query languages such as GRAIN [4] and IMAID [5] which enable users to construct their own queries about the information depicted within the images. IMAID for example is an integrated relational database system interfaced with an image analysis system. By using pattern recognition and image processing manipulation functions, symbolic descriptions of depicted structures can be extracted from images and stored in relational form. User queries about pictures can be manipulated through the relational database and pictures matching these queries displayed. In this way the need to process vast amounts of imagery data at query time is eliminated. If a user's requirements can be expressed in terms of the extracted descriptions, then there is no need to retrieve and process the actual pictures. If on the other hand the stored information is not sufficient, all pictures satisfying selection criteria can be retrieved and processed until the required precision is obtained. Systems, which integrate conventional and picture query languages [5], are flexible tools for analysing the contents of a pictorial database. However, such systems suffer from a number of limitations. The processes for extracting descriptions are highly application specific. For example, we would not expect the process that extracts the descriptor "highway" from a satellite picture to be very successful when presented with a picture of a highway taken from a land vehicle. Also, there is difficulty in extracting information about spatial arrangement in the picture.

The relational model used within such systems has been amongst the most popular techniques by which to analyse information within images. However, the use of relational calculus for manipulating location data has been shown to have severe limitations [6]. The basic set of operations of union, intersection and containment hold in a spatial sense, but this approach is derived purely from traditional mathematical concepts, and there is no ability to handle inexact, context-dependent relationships, set-oriented or otherwise, or of defining higher-order relationships on the basis of simpler in-built operators.

Meier and Ilg [7] have demonstrated that an extended relational database management system approach in which spatial relationships within a picture are directly encoded within a textual database is also severely limited. Such systems use a set of primitive textual relationships when storing spatial data [6]. Here the designer views the spatial description of an entity as another attribute within the database. Various lists of "primitive" spatial relationships have been derived. These include spatial relationships such as "below", "left-of", "right-of", "above" etc. However, the difficulty of describing spatial relationships between entities in this way makes the use of such systems problematic.

In current approaches to pictorial databases, then, there is a failure to handle effectively the problem of searching for a picture in terms of its visual-spatial structure. Where facilities are provided for querying on visual spatial properties these are restricted to simple linguistic terms. The user has to describe the things of interest, and these descriptions are matched to descriptions derived from the pictures. The problem is that humans' find it difficult to use natural descriptive systems (such as language) to adequately describe the visual-spatial structure of a picture. To provide "easy access" of a visual-spatial kind to a pictorial database we need to consider ways, other than language, for representing the target picture.

DESCRIPTIVE AND DEPICTIVE VISUAL REPRESENTATIONS

In recent literature dealing with the nature of representations there has been much discussion of the difference between description and depiction [8,9,10]. Fish and Scrivener [11] summarise some of the suggested differences between descriptive and depictive representations. Descriptive representations involve signs systems , such as language, which have arbitrary learned rules of interpretation linking the sign system to the represented objects or concepts. Descriptions are useful for representing classes and properties of things. In addition, descriptive representations allow us to separate important from unimportant information. For example, specifying the relationship "on" without specifying position, or specifying the type of object without specifying its size or colour, say. The information in a description is extrinsic, meaning that it only exists by being associated with externally defined rules of interpretation. As we have seen, pictorial database techniques rely heavily on the use of descriptive representations (eg. textual queries).

In contrast, a depictive representation, sometimes termed analog, is not dependent on externally defined rules of interpretation because it causes visual experience which is similar to that associated with the object, or scene, or event represented. The colour of a cat may be described by the word "black" or depicted by spatially extended paint generating a similar colour sensation to the represented cat. Visual depictions represent spatial structure in a two or three dimensional spatial medium in which there are correspondences between spatial position in the medium and spatial position in the thing represented. Much of the information in a depiction is intrinsic, meaning it is not represented explicitly but can be extracted by inspection. Depictions are commonly associated with specific modes of perception. Apart from being necessary to represent detailed concrete spatial information, visual depictions facilitate the search for information not easily represented descriptively, or not easy to find because it is not represented explicitly.

REPRESENTING VISUAL-SPATIAL STRUCTURE

For centuries artists have used drawing as a way of depicting the visual world. More recently, in design, drawings have been used extensively to represent imaginary worlds. Drawings are depictive in the sense that they promote visual experience resembling that associated with the objects or scene depicted. For example, there will be visual correspondences between drawn contours of a copy of a picture and reflectance contours of the original picture in terms of curvatures, relative lengths and distances. In general, these properties of the picture are not represented explicitly in the drawing. Instead they are implicit in the sense that they are reflected amongst the array of structures constructed by visual perception when presented with the drawing. For this reason drawing looses some of the precision of a descriptive representation, since each viewer may take different accidental visual structures as representational. On the positive side drawing gains in the sheer volume of available visual-spatial structure in apparently immediate percepts that can be used to represent.

A simple task for the reader will perhaps illustrate this point. Take a sheet of paper and draw the outline of a circle on it. Now draw a second circle to the right of the first, and finally a third circle between and above the two already drawn. Immediately we see more in the drawing than is explicitly stated in the above instructions. We see a triangular arrangement of circular shapes located in particular relation to the limits of the paper, in a particular orientation, and having a particular shape. If one only wanted to represent the information explicitly stated in the instructions the depiction might be misleading as other perceived properties, such as those cited above, may not be properties of the represented world. Also the properties that come to the attention of one reader when viewing his drawing might be quite different to those noticed by another in his, even if their respective drawings were exactly the same. In contrast, the incompleteness of the above instructions as a representation of the visual-spatial structure of a picture can now be seen by comparing the drawing produced from this description to the picture described (Fig. 1). It would be interesting to collate all readers' drawings in order to compare the difference in appearance between them. One assumes that there would be considerable variation between them. To reduce this variation and to produce closer copies many more instructions would be required for even this simple picture, hence increasing the effort required in constructing the description. However, it is not difficult to see that constructing a drawing of it (Fig. 1) would be a more straightforward task for the communicator, even one with little drawing skill, and more likely to replicate its visual-spatial appearance. Hence we posit that depiction, in the form of drawing, should be considered as an alternative means of representing the visual-spatial structure of a target picture, or pictures, required by the user of a pictorial database. Put another way, we propose that the user queries the pictorial database by constructing a drawing of the target picture, or pictures. However, what evidence is there to suggest that humans would be able to envision such depictions?

DRAWING FROM IMAGINATION AND THE SKETCH

Imagine a user about to search a pictorial database. In front of him or her is a photograph of a picture the user hopes to find in the database. Here envisioning the query should not be too difficult as a version of the target picture is available to perception. However, what if there is no such external copy of the target picture. In this case the user must construct the query from memory. The question arises as to whether mental representations are likely to support the construction of such queries. Most of us can answer this question from experience. Imagine your favourite picture and there is a sense of a picture in the mind; a mental image of the picture. A mental image that whilst less stable and vaguer than the percept of the picture in some sense resembles the picture. There is now considerable evidence [12,13,14] that the type of mental images that resemble percepts are 'quasi-pictorial' spatially depictive maps in which size, shape, and relative distance of a visual element are implicit in the position of a matrix of neural elements. These internal visual depictions seem to share many of the properties of external visual depictions, such as drawings. Given that mental images resemble percepts and that constructing drawings from percepts is a relatively straightforward matter it would seem that the idea of doing the same from mental images is not beyond the bounds of reason. Indeed, we have clear evidence for this human ability in the drawings created by designers to represent imaginary, or non-existent objects.

Typically such drawings are depictive in the sense that we have described. However, they are also descriptive in that often the elements of the drawing only partly resemble the thing represented, for example the window symbol in an architectural sketch. These elements of the representational scheme are partly descriptive and partly depictive, and have explicit rules of interpretation which must be learnt by the interpreter. In addition the drawn parts of the sketch are often supplemented by purely descriptive representations such as written notes. Hence, in general, sketches used to depict imaginary objects are partly depictive and partly descriptive representations. Clearly, we would not wish to suggest that depiction replaces description as a means of searching pictorial databases, rather that depictions can provide a useful adjunct to descriptive methods. The sketch, then, provides an insight into how we might go about providing interfaces to pictorial database systems that allow a user to search for pictures using a query method which is both depictive and descriptive. That is to say, the depictive component of the query might be provided graphically and the descriptive component textually, or by the selection of other descriptive symbols, such as icons.

In the following sections we describe a prototype pictorial database system that provides such a query method for visual-spatial search. The system is implemented on an Apple Macintosh IIx connected to a Philips VP835 laserdisk. Information from the laserdisk is displayed on a 14 inch colour television. The application runs on Hypercard version 1.2 and the relational database (built using ORACLE, version 1.1 for Macintosh) stores descriptions of paintings by the nineteenth century post-impressionist artist Van Gogh, recorded on the laserdisk titled "Vincent Van Gogh (a portrait in two parts)", published by North American Philips Corporation. For reasons of convenience, however, the images used below are not taken from this laserdisk.

QUERY BY DESCRIPTION

We can identify two possible extremes of query. At one extreme a query in terms visual-spatial properties of a picture can be constructed purely descriptively. At the other extreme they can be constructed using depiction only. Between these two extremes lie queries that combine both description and depiction. In the following sections we provide examples of how purely descriptive and descriptive-depictive queries are supported by our system.

Descriptive tables are provided that allow a user to describe target pictures textually. This is achieved by selecting objects and attributes (including visual and spatial) by moving through a textual menu hierarchy. Words describing an object or its attributes can be typed directly into the appropriate field or, alternatively, the user can enter information into a field by selecting words from a mouse controlled pop-up menu. Thus, for example, clicking on the OBJECT name field would show all objects within the database (Fig. 2), and clicking on the word LOOM puts the object name into the object field.

Each textual menu within the hierarchy has several headings. Thus for the object flower; values in these headings might be

OBJECT	**HAS-COMPONENTS**	**IS-PART-OF**	**TYPES**
FLOWER	STALK	FIELD	SUNFLOWERS
	ROOT	BUNCH	IRISIS
			DAISIES

Selecting one of these values moves the user to a different menu until at the lowest level the actual images are located. Therefore the textual menus reflect the logical linking of data allowing a user to navigate through the database.

In practice a user has two initial choices when searching for a picture descriptively :

1) items can be selected directly from the relational database , or
2) objects can be selected by moving through the database structure via direct manipulation.

Using 1), on selecting an appropriate object name and choosing SELECT from the database management system, all records in the relational database which match the query will be displayed. Thus selecting 'fisherman' from the object name field will display all pictures within the database that contain a fisherman. Other attributes can be entered if a more specific query is desired.

Using 2) the user moves through the textual database by directly manipulating the menus in order to locate a specific object after which attributes of that object can be selected. Thus for example moving through the hierarchical menu might involve selecting the following:

PEOPLE------>MAN--------->FISHERMAN

Having identified the object (in this case a fisherman), visual and spatial attributes (currently relative size, orientation, colour, length, width, and position) can be entered into the appropriate relational database query field. Thus at present the text menu structure is designed to assist the selection of an object name, and it is only after this is done that object attributes are entered by typing in values.

QUERY BY DESCRIPTION-DEPICTION

Pure depiction is not supported by our system. Instead depictive-descriptive query is provided by means of graphic objects (Fig. 3a) that can be located and combined (Fig. 3b) in a display area representing the picture surface of the target picture. Visualised shapes of the target picture can be depicted by locating these graphical entities in this display area. As we can see (Fig. 3a), a thin line represents the width of a shape. Used on its own, its middle point represents the position of the shape. In a similar way a thick line represents the length and position of a shape, and in addition its orientation. When the width and length symbols are used together in the specification of a shape their intersection point marks the position of the shape and their product its size. The thick rectangle is used to represent tolerances on the position of a shape in the database that matches the query. Finally, the thin rectangle is used to represent size in the absence of either the width or length symbol. Default tolerances are associated with the length, width, position and size attributes.

Clearly, these symbols are partly descriptive and partly depictive. For example, there is no correspondence between thickness of line (in the representation) and width and length (in the represented world), and the user must learn to associate different thicknesses with the related attributes of length and width. In this sense, line thickness is used descriptively. On the other hand the metric distances defined by the length and width lines do share correspondences with the represented world. A 'width' line in the query having the property of being greater than another 'width' line in the same query depicts a picture in which the perceived width of the shape corresponding to the first line would be greater than that of the shape corresponding to the latter. Similarly, the orientation of the 'length' line depicts the orientation of a corresponding shape. Hence we would expect some perceived correspondence between the orientations of the representational symbol and a matching shape; they should appear perceptually similar.

In order to construct a query, first the user selects a drawing tool representing the attribute required and locates it in an area of the screen representing the picture surface (which can be user defined). Many such symbols can be placed into the picture field and manipulated, thus allowing the user to depict visually complex queries.

The use of these graphical entities is illustrated in a query (Fig.4) constructed with reference to a watercolour painting of Lyme Regis, by Scrivener (Fig. 5). Here, starting from the top left (comparing Fig. 4 with Fig. 5), the position, size, length, width and orientation of the bush is represented by combining the length and width markers, as are these attributes of the cliffs in the middle distance. Only the positions,lengths, and orientations of the buttress at the bottom left and breakwater in the middle right are defined, whereas the window group at the top left is specified in terms of size, and position tolerances. Finally, all of the visual-spatial attributes of a shape (ie length, width, orientation, size and position tolerances) that can the specified using the system are defined for the breakwater at the bottom right of the picture.

If this example (Fig.4) was used to query a pictorial database it would cause pictures consisting of shapes that matched those of the query to be retrieved irrespective of the content of the matching pictures. For example, a still life might be retrieved. In many instances this might be exactly what the user wants. In other instances one can imagine that the user might wish to retrieve pictures that consist of particular objects having particular visual-spatial characteristics. As we have seen above, this can be achieved by first selecting objects using the textual menus and then proceeding to define visual properties. An alternative approach to this is illustrated (Fig. 6) in which icons of objects are selected and located in the query. Essentially these icons are descriptions since they are equivalent to writing 'window' or 'fence'. In this way combined descriptive and depictive queries can be used to identify pictures from a pictorial database.

ENTERING PICTURE DESCRIPTIONS INTO THE DATABASE

So far we have described how the user can query by depiction but we have not explained how the descriptions of the pictures against which queries are matched are entered into the database. For the Van Gogh database this was done manually. All pictures were inspected in order to identify objects, and quantify, by visual judgement, the location and attributes of shapes. Clearly, this was a time consuming process but was adequate for our purposes. In the future we will explore a number of ways of simplifying this activity. As we have already mentioned, a sketch provides a way of representing a picture. It can be used to represent a picture in mind (for search) or a visible picture. Initially, we propose to modify the system so that a picture can be entered into the database by constructing a sketch. In this later case the sketch will be constructed over a displayed image of the picture that is to be acquired.

We will also investigate the use of image analysis techniques [15]. This will allow greater drawing freedom using a painting system. Here a sketch will be painted and the sketch processed automatically to derive shapes and attributes of shapes. Methods for doing this have already been developed [16], what remains to be done is to implement them for the pictorial database application. It is possible to get the descriptions directly from the picture using these techniques, but we foresee difficulties with this and prefer to follow the more practical path described above.

CONCLUSION

We have argued that information technology systems are capable of storing at low cost large volumes of pictorial data and hence we should anticipate an increased reliance on pictorial databases. However, pictorial databases will only be useful to the extent to which that allow flexible and rapid search.

We have drawn a distinction between depictive and descriptive representations and have argued that visual depictions, such as drawings, are useful for representing visual-spatial properties of pictures. Earlier methods for accessing pictorial databases make no provision for depictive search. In this paper, we have described a system that provides methods that include search by depiction. Essentially the user creates a "sketch" of the target picture from which the system extracts descriptions that are matched to descriptions of the pictures in the database.

Currently a shape and its gross attributes, including position, can be specified depictively. As a consequence the system is application independent. In the future we will attempt to maintain this application independence whilst investigating how other properties of a picture might be communicated depictively, including for example shape, and relationships between shapes (eg adjacency), and how to improve the ease with which descriptive-depictive queries can be constructed and manipulated.

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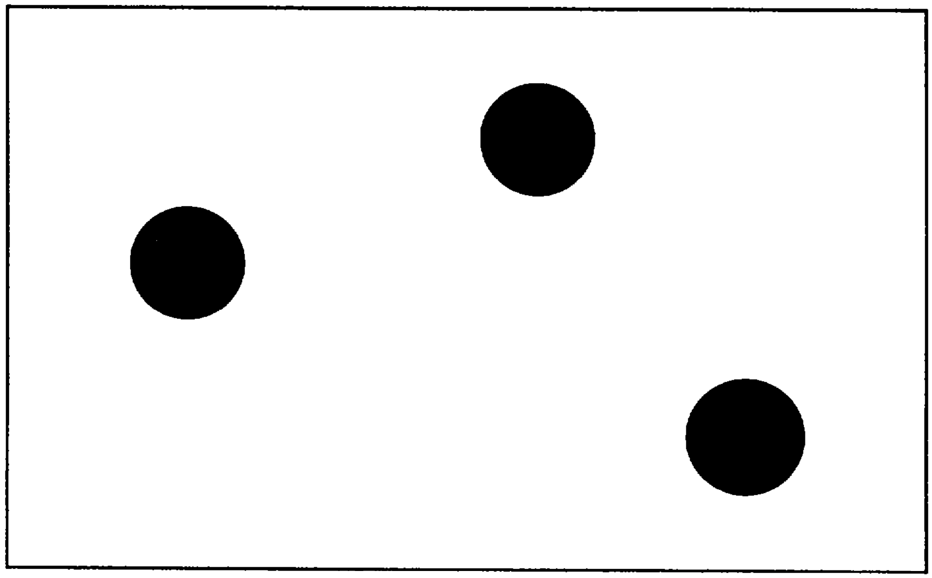
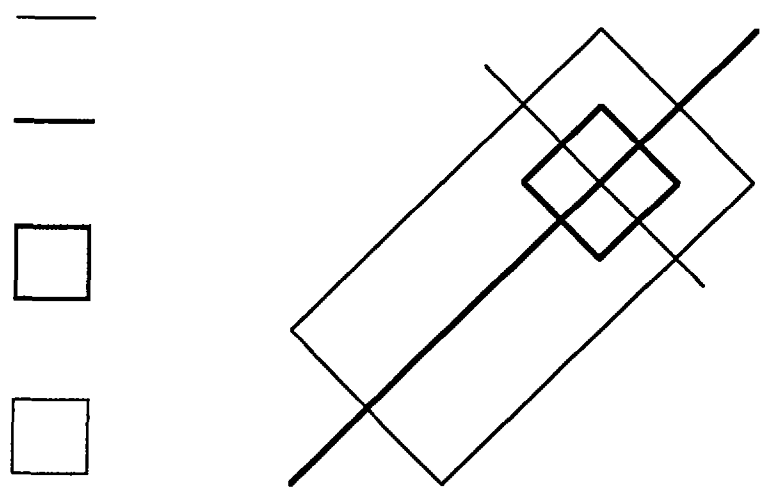


Fig. 1. This picture can be described as "a circle with another circle to the right of it, and a third above and between these two". However, the inadequacy of such a textual description as a representation of the picture's visual-spatial structure can be demonstrated by using it to produce a drawing without sight of the original picture described. A comparison of the drawing and the picture is likely to yield many differences. To reduce these differences many additional descriptive statements are required even for such a simple picture as this. In contrast, it is much easier to construct a representation of the visual-spatial structure in the picture by drawing.

OBJECT	HAS-COMPONENTS	IS-PART-OF	TYPES
MAN-MADE OBJECTS			**JUG LOOM PIANO PICTURE PIPE PLATE**

Fig. 2. Descriptive search. The system allows the user to issue queries by selecting objects via a menu system linked to object type and part-whole heirarchies. Here, having inserted "man-made objects" as the point of interest a listing of the next level down in the hierarchy can be scanned and an object type selected, if desired, for insertion into the 'object' field.



a) b)

Fig. 3. Shape depiction entities and their combination. Starting from the top left of a) a thin line is used to represent shape width and position; a thick line length, position and orientation; a thick edged rectangle shape position tolerances, ie. the centre of gravity of a matching shape in the database can fall anywhere within this rectangle; and a thin edged rectangle the size of a shape. These shape depictors can be used individually or combined as in b).

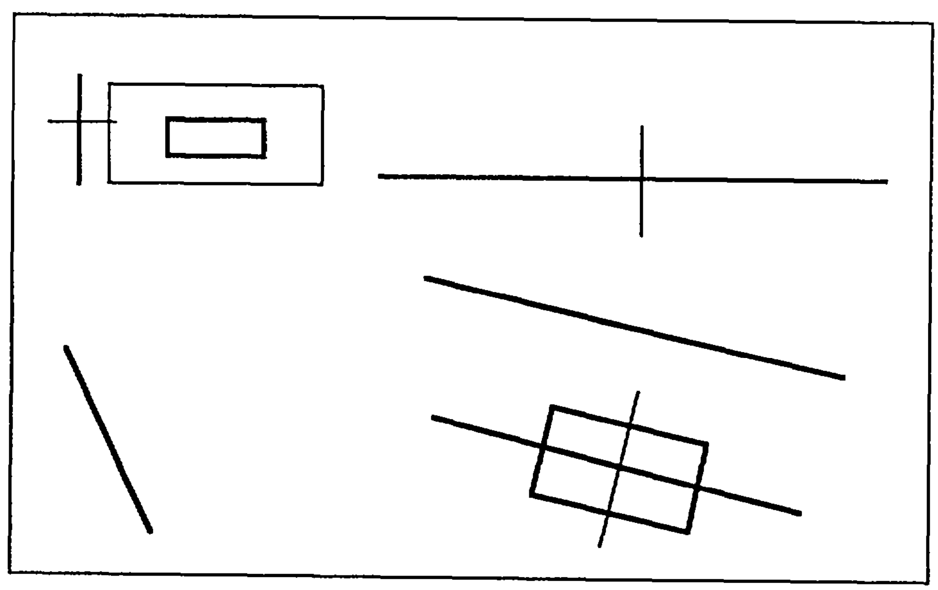


Fig. 4. Depictive search. Here various combinations of the shape depictors are used to depict properties of shapes in the watercolour landscape painting of Lyme Regis (Fig.5). In the simplest cases the depictors at the bottom left and middle right of the query represent only the length, orientation and position of the corresponding shapes in the picture. In the cluster at the the bottom right of the query all the attributes of a shape that can be represented using the system (eg length, width, orientation, size, and position, with tolerances) are combined.

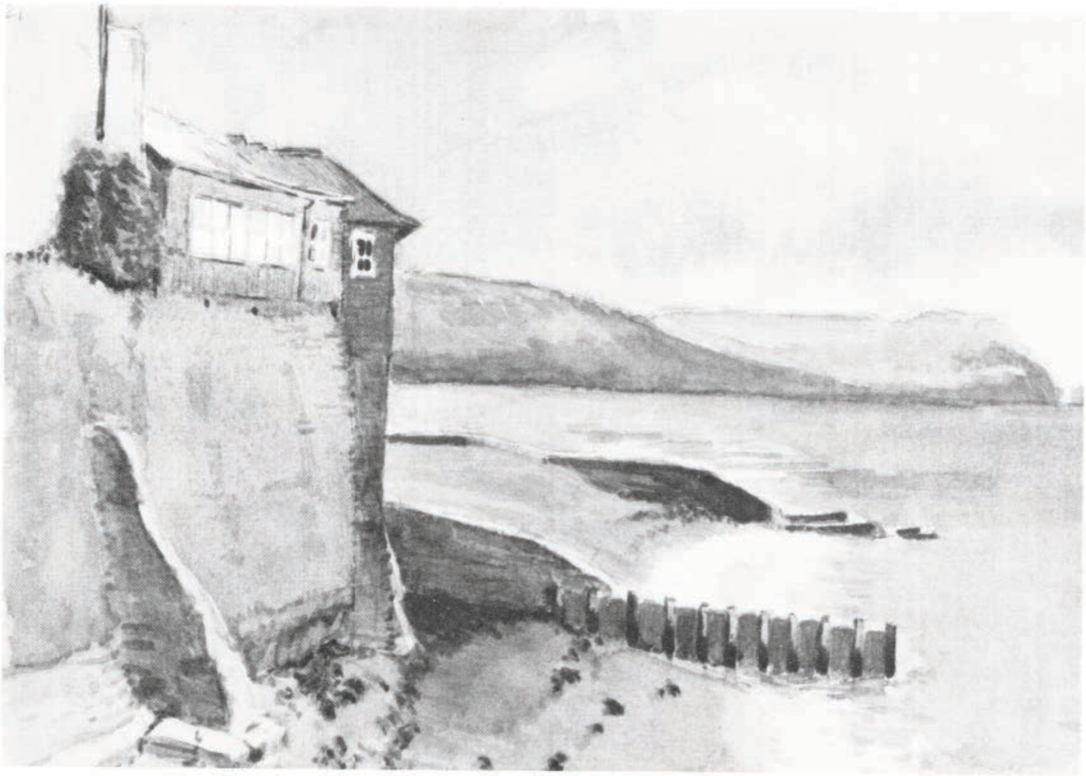


Fig 5. Stephen Scrivener, *Lyme Regis* , watercolour, 200 x 140mm, 1985. This picture is the basis for the depictive queries illustrated in Figs. 4 and 6.

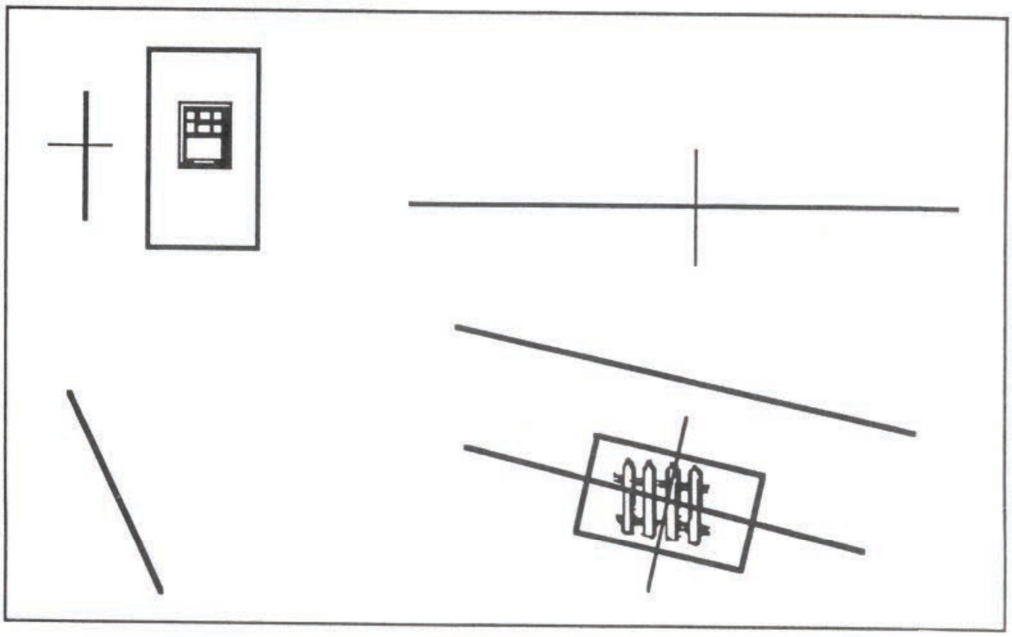


Fig 6. Decriptive-depictive search. Here the query representing the watercolour painting of Lyme Regis (Fig. 5) is augmented by the use of descriptive icons. It might be argued that these icons are depictive with respect to particular instances of the real world window and fence, or barrier, object types. However, with respect to the visual-spatial properties of *Lyme Regis* (Fig. 5) they are not depictive and are descriptive symbols for their respective object class. As such they are used as an alternative to writing.

MUSEUM TECHNOLOGY: NEW LINKS TO INTERPRETING, PRESENTING, AND CREATING ART

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ABSTRACT

Museum curators and exhibit designers are using interactive, computer programs to present information about art. With the adoption of this technology, the curatorial philosophy of museums is shifting from an object orientation to an information orientation, and this shift will effect the way we interpret and define art, especially electronic art. This paper traces the evolution of computers in museums and discusses the impact that high-tech exhibits and the changing philosophical role of the museum will have on the endorsement of electronic art. Technological advances in museum exhibits, presentations, and research facilities will alter the aesthetic criteria for defining art and initiate important changes in the way we evaluate and market art. In the end, a new awareness and sensitivity to the creative and aesthetic dimensions of electronic media will emerge, along with a personal approach to interpreting art that redefines the relationship between art and 'commodity' and enhances the relationship between art and technology.

For 25 years museum administrators have recognized the important role that computers can play in museums. Beginning in 1965, museums ranging in size from the Smithsonian Institution to small college museums began using computers to catalog their collections (Fig. 1). From there, interest in exploring the potential for computers in museums led to the establishment of the Museum Computer Network (MCN) in 1967.

Since then hundreds of museums have adopted some form of computer technology for museum management, research, or exhibit presentation. International conferences such as the Conference on Automatic Processing of Art History Data and Documents (Pisa, Italy) continue to provide support for the expanded use of technology in museums.

Computers in Museums

1965	Smithsonian Institution begins collecting data with computer.
1966	Metropolitan Museum studies computer use in museums.
1967	Museum Computer Network (MCN) forms at Whitney Museum of American Art.
1968	Metropolitan Museum and IBM co-sponsor conference on computers and museums.
1969	Museum of Modern Art creates computer catalog.
1978	International Conference on Automatic Processing of Art History Data and Documents convenes in Pisa, Italy.
1982	National Gallery of Art in Washington, D.C. produces videodisc.
1982	International Museum of Photography in Rochester, NY produces videodisc.
1983	Getty Art History Information Program begins several database projects.
1984	International Conference on Automatic Processing of Art History Data and Documents convenes in Pisa, Italy.
1988	University Art Museum at Berkeley, CA develops multimedia computer program.
1990	Museum of Modern Art, Philadelphia Museum of Art, Boston Museum of Fine Arts, Art Institute of Chicago, Brooklyn Museum, Metropolitan Museum, and National Gallery of Art demonstrate multimedia project on impressionist art.

Fig. 1. For 25 years museums have been evaluating the role of computers to collect and present information about art. Although this summary highlights several American projects, similar developments can be traced in other countries.

With sophisticated developments in computer technology, increasing affordability, and the emphasis on museums as an informal learning environment, the use of computers has become more widespread than ever. In 1982, the Art Museum Association compiled a national survey on current and anticipated computer use in art museums. In the survey, 85% of the respondents that were not using computers said they would adopt computers for collections management and presentation in one to three years [1]. That same year, the American Association of Museums established the *Commission on Museums for a New Century* and published a report that stressed the importance of introducing computers and other electronic technology, especially multimedia presentation programs, into museum learning [2].

Despite the growing use of telematics in a museum setting, museums and galleries have not widely endorsed electronic art as a recognized art form. Artists working in electronic media flock to science museums and high-tech trade shows for opportunities to exhibit their work. However, as curators and exhibit designers continue to explore the potential of computers as communication tools, they are setting the stage for the recognition and acceptance of various forms of electronic art by the mainstream art world. The growth of computer technology in museums is putting the tools of the electronic artist into the hands of curators and art educators who are gaining a working familiarity with the visual and conceptual elements that make up the underlying grid or structure of various electronic media.

More importantly, however, museums are increasingly integrating multimedia or hypermedia computer programs into their exhibits and educational programs, and these interactive programs are challenging the syntactical, stylistic, and conceptual boundaries between art forms. Hypermedia programs that provide random access to text, still and moving images, and audio recordings are augmenting the cognitive structure of art and fostering an information-oriented approach to evaluating art. These developments will ultimately impact the way we interpret and disseminate art and produce changes in the social, cultural, and economic strata of the fine art market--changes that will facilitate an open dialogue in the art community and create a more receptive forum for various types of electronic art.

THE COGNITIVE STRUCTURE OF ART

Museums exist for a variety of purposes. Museums are not only the protectors of objects, they are also communicators of information. However, communication in a public setting presents difficult challenges because a museum exhibit or educational program must communicate to visitors who differ in age, class, educational background, sex, and nationality, as well as interest and intelligence. In addition, exhibit designers must take into consideration research on media and cognition that shows that individual learning skills vary with different media [3].

Interactive hypermedia programs that use multimedia data to present information address these problems and enhance the learning experience by enabling people to explore areas of personal interest at individual levels of expertise. A museum visitor, for example, can investigate an artist, such as Jackson Pollock, by reading a biography, viewing some of his art, reading about political events that influenced his work, browsing through statements by critics, or viewing a video segment that discusses his art.

While meeting the educational demands of the museum environment, this information-oriented approach to exhibiting art is also reshaping and expanding the definition of art. In hypermedia presentations, a work of art is surrounded by a multifaceted cognitive structure that integrates dynamic syntactical relationships, multisensory and knowledge webs of data, modular dimensions in logic and time, and the semiotics of the computer interface design.

Dynamic Syntactical Relationships

Many hypermedia programs designed for the presentation and study of art include image processing and computer graphics applications that enable the user to modify individual art objects and integrate different art forms. The ability to manipulate images, text, and sound right down to the individual pixel or byte of digital data is contributing to new ways of structuring and interpreting art. The syntactical relationships between form, texture, color, motion, and sound can now be examined with intensity from many new perspectives.

Nelson Goodman described the visual image as a syntactically and semantically 'dense language' where the meaning of every mark is determined by its relationship to other elements in the image [4]. Computer graphics programs give new meaning to Goodman's description by making it possible to create an infinite array of syntactical relationships. Details can be isolated from an image or audio track and merged with other data. Individual colors, lines, and forms can be modified to study the impact of change on the original work of art. Images can be inserted into other images; text and sound can be overlayed on top of still and moving visuals. The syntax of the art object is a dynamically changing entity that is subject to new relationships and aesthetic criteria.

Multisensory and Knowledge Webs

However, with hypermedia museum programs, the syntax of art expands beyond the physical object to include a network of information webs. On a perceptual level, there is a network of multisensory data, and the structure of art becomes a dynamic integration of diverse interpretive elements: text, still and moving images, and sound. The conceptual interplay in this network is emphasized by the multimedia CRT screen that permits the user to make comparisons by juxtaposing whole images, parts of images, text, and motion video on one computer screen. The aesthetic and conceptual boundaries between art forms are visually redefined within the context of an integrated information network.

A hypermedia program also includes a knowledge web of associated facts and ideas. This web consists of two types of links: objective links that connect facts and subjective links that connect opinions and ideas [5]. Subjective links, in turn, can be subdivided into (1) expert opinions or predetermined links and (2) user-created annotations or paths through the database. The meaning of art becomes a dynamic structure that changes as new links are added and the web is reconstructed to incorporate diverse interpretations.

The network of links in a hypermedia program is traditionally depicted by linear flowcharts that emphasize the hierarchial relationships in the database. However, the multiple layers of associations and the dynamic flexibility and movement in a hypermedia program suggest circular webs of interaction (Fig. 2). The semantic structure of these webs can be compared to Roland Barthes's concept of plural text which supports multiple interpretations instead of a singular meaning. Christopher Burrett cites the introductory statements in *S/Z*, Barthes's hypertext-like translation of Balzac's *Sarrazine*, when comparing the concept of plural text with hypertext/hypermedia [6]:

> In this ideal text, the networks are many and interact, without any one of them being able to surpass the rest; this text is a galaxy of signifiers, not a structure of signifieds; it has no beginning; it is reversible; we gain access to it by several entrances, none of which can be authoritatively declared to be the main one; the codes it mobilizes extend 'as far as the eye can reach,' they are indeterminable...[7]

Modular Dimensions in Logic and Time

In a hypermedia program, the cognitive structure of art is also defined by the added dimensions of logic and time. Access to data and the display of information on the CRT screen are all subject to the organizational control of the underlying software, but the designer or user of a hypermedia presentation can manipulate the *psychological* dimensions of logic and time. With hypermedia, the interpretation of art is no longer restricted to the

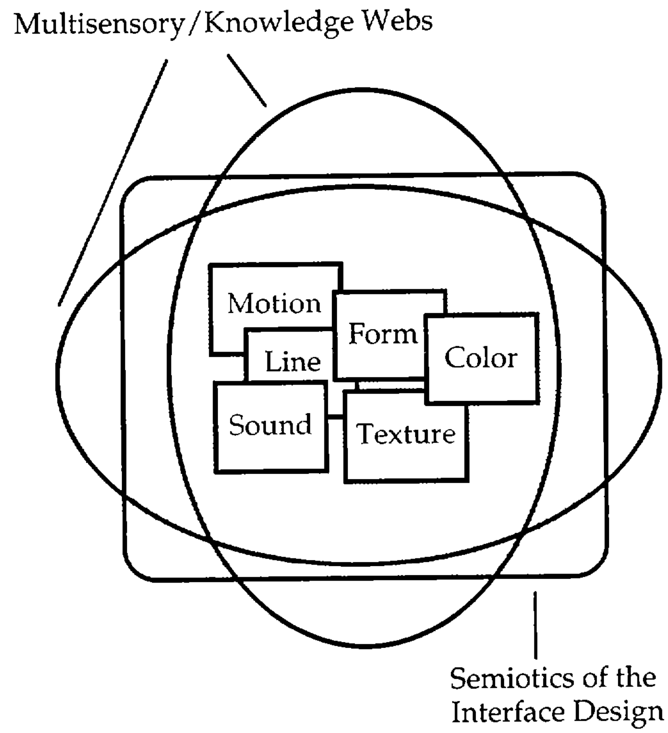

Fig. 2. A hypermedia program on art enables the user to build a cognitive structure that integrates dynamic syntactical relationships between design elements (line, form, color, texture, motion, sound, etc.), multisensory and knowledge webs of information, and the semiotics of the interface design.

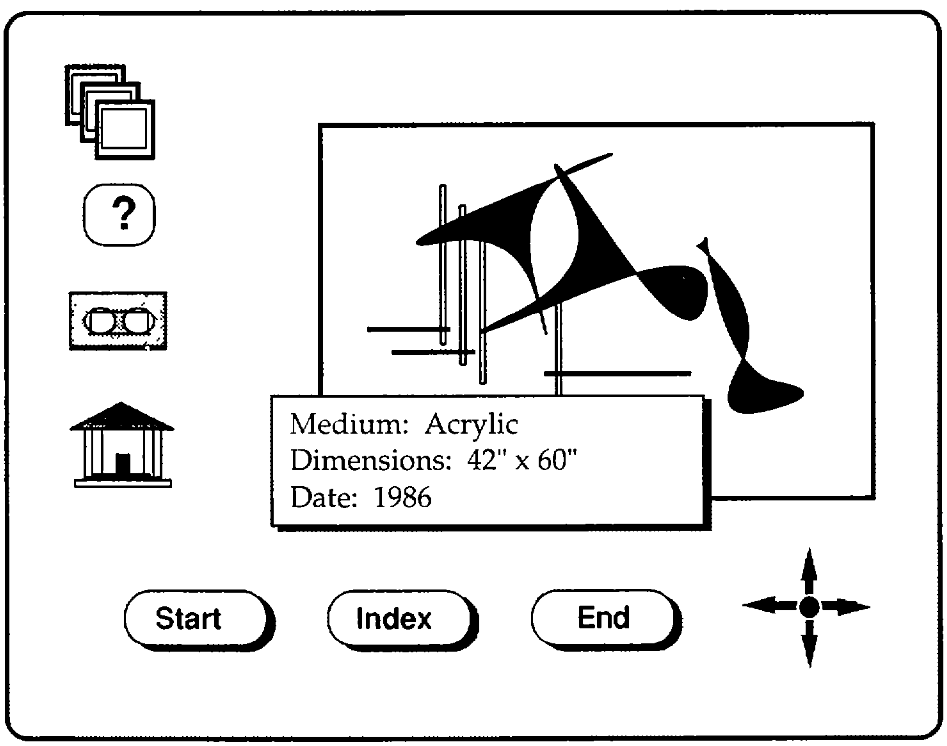

Fig. 3. In an interactive computer program, there is a conceptual interplay between the semiotics of the screen design and the visual imagery in the art itself.

sequential flow of associated events or ideas. Information can be broken down into modular chunks of data that users, guided by personal interests and individual levels of expertise, can randomly access in various ways; there is no right or wrong way of exploring information in the database. Time can be compressed by condensing events, such as the biography of an artist or the history of an art movement, into a sequence of still images or a few seconds of video. On the other hand, the analytical powers of the computer that make it possible to investigate pixels, highlight audio-visual details, and isolate individual still frames from a segment of video, enable the user to expand the notion of time and space.

Semiotics of the Interface Design

The discussion of the cognitive structure of art in a hypermedia program would not be complete without acknowledging the semiotics of the interface design and its impact on the presentation of a work of art. The user interface forms the critical link to the database information and ultimately, becomes the bridge to interpreting and understanding the art. Database information is accessed through a network of visual symbols: icons, color codes, diagrams, windows, and predefined screen layouts. As design elements are chosen to support and enhance, rather than interfere with, the presentation of the art, a dialogue emerges between the visual symbolism in the fine art and the semiotics of the screen design (Fig. 3).

Although specific guidelines for designing hypermedia interfaces have yet to be developed, experts agree that the interface should provide a 'seamless' link to the information in the database. No one knows exactly what the ultimate seamless interface should look like, but the goal is to use icons, screen layout, color, and sound in a way that minimizes the conceptual overload for the user by reducing the number of physical and mental steps necessary to access and process information. The underlying structure of the computer program and the integration of the diverse media on the computer screen should be transparent to the user and encourage exploration. In an art presentation program, this seamless approach to designing the interface will increase the symbolism between images and ideas and highlight new associations between space, form, motion, and time. In turn, the cognitive structure of art will assume a new level of interpretation and meaning as the semiotic dimensions of symbol design become an integral part of the presentation of a painting, sculpture, or other work of art. This interplay between fine art and communication design will pave the way for new art forms that incorporate the visual and philosophical components of two traditionally disparate artistic disciplines.

INFORMATION-ORIENTED ART

With the adoption of electronic displays in the museum setting, museums are expanding the definition of art by shifting from an object-oriented philosophy to a focus on information and communication. Interactive computer programs are removing the conceptual barriers to understanding art and stripping art of the mystique that has traditionally isolated fine art from the public. Parallel philosophical movements in museums and the field of electronic art are converging to create a synergy that will challenge the established elitism of fine art and lead to new social structures for evaluating and disseminating art.

The Art Mystique

The sanctity and mystique of the art object is being dispelled as museum visitors use interactive computer programs to modify original art by changing colors, adding new elements, and integrating diverse media to create new art forms. Non-artists can now create an infinite array of new works of art. Art and creativity are no longer mysteries that are only accessible to the gifted or knowledgeable. With interactive museum programs, it is possible for anyone to enter the 'virtual reality' of the artist's mind--to hear and read the artist's thoughts, to modify the art, to step into the creative process itself. The key to understanding the art is no longer restricted to the interpretations of a few scholars, curators, or critics. Hypermedia encourages individual interaction and personal involvement with the work. Like Barthes's concept of plural text, the art takes on a plurality of meanings derived from individual experiences and insights.

In the future, this focus on individual interaction with art will expand to include an increased emphasis on group interaction. Collaborative programs will allow multiple users to collectively modify and exchange information. This type of collective authorship will expand the cognitive structure of art to include individual networks of associations or links that can be endlessly joined to form complex cognitive maps that further diminish the significance of the art object (Fig. 4).

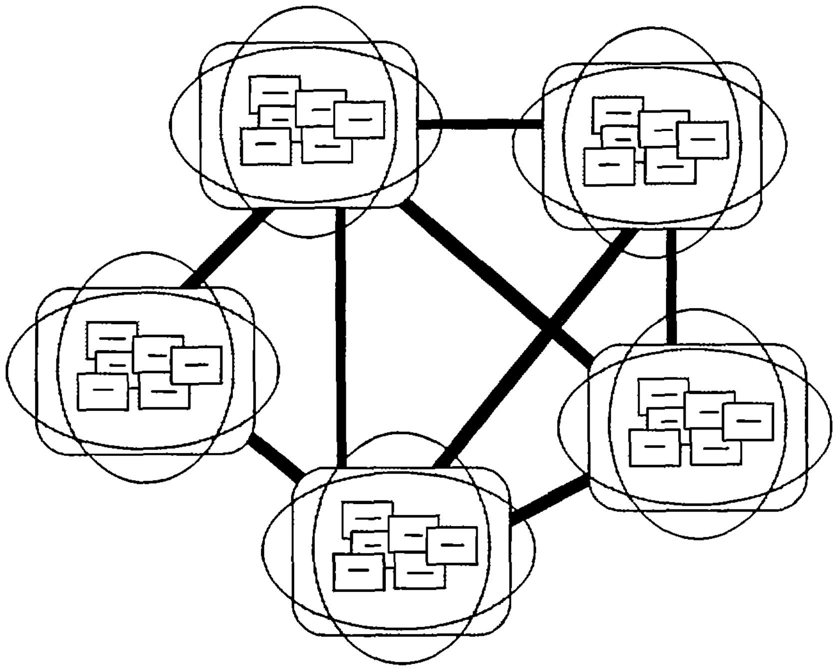

Fig. 4. Collaborative networking produces a cognitive map that links individual knowledge structures.

Merging Philosophies in Museum Didactics and Electronic Art

The integration of telematics and information-oriented exhibits into museum educational programs is simultaneously increasing curatorial and public awareness of parallel philosophical movements in electronic art. In the same way that museum presentations are highlighting the creative process and emphasizing the cognitive structure of art, artists like Harold Cohen [8] and Roman Verostko [9] are using the interpretive powers of the computer to analyze artistic creativity. They have developed computer algorithms that are carefully constructed sets of rules for creating art that enable the computer to make aesthetic decisions about the interrelationship of line, form, and space. These artists are not interested in the creation of art as an object-making process. Instead, they seek to unmask the complex decision-making process that guides the inception and development of a creative work of art. According to Cohen, "Whatever art is, it's also a dialogue about the nature of art..." [10].

Russell Kirsch, a specialist in image processing and pattern recognition, has advocated that art historians heighten their perceptual sensitivity to the artist's use of line, form, space, and texture by using computer graphics software to isolate and analyze individual elements in a work of art [11]. In addition, Kirsch and his wife Joan, a printmaker and art historian, have been analyzing the conceptual structure of the creative process. They have developed a set of rules or grammar to describe the structure of paintings by Richard Diebenkorn, making it possible for computer algorithms to simulate Diebenkorn's work [12]. Similarly, Raymond Lauzzana and Lynn Pocock-Williams have constructed a 'rule-base' for describing Kandinsky's work [13], and Terry Knight has developed grammars for analyzing stylistic changes in works by Georges Vantongerloo and Fritz Glarner [14].

Museums and artists alike are also experimenting with advances in telecommunications. Linked to the world via satellite and wired internally with 1,345 miles of cable, Canada's Museum of Civilization in Ottawa will be networked with 25 communications systems and will establish a telecommunications standard for all museums [15]. Similarly, artists are experimenting with computer networks and the power of interactive, collaborative communication. In 1983, Roy Ascott directed a collaborative work, *La Plissure du Texte: A Planetary Fairy Tale,* for the ELECTRA exhibition at the Musée d'art Moderne de la Ville de Paris. Using an electronic network, artists from 11 cities throughout the world created a story by 'dispersed authorship'. In 1984, for the Biennale de Venezia, Ascott organized a collaborative exchange of creative energy that involved 100 artists telecommunicating with text and images [16]. Another group of researchers, Vladimir Bonačić, Miro Cimerman, and Dunja Donassy (the artistic team >*bcd*<), used collaborative networking to explore the concept of dematerialized art that exists outside the limits of space and time. They created the cybernetic sculpture *Instantaneous* that used sixteen networked computers to act as independent parallel processors. The team's goal was to create 'dynamic objects' where the computer system and the work of art are one entity, and artists interact and communicate through a common medium structured by the computer system itself [17].

Future Implications

The shift to an information-oriented approach to presenting and creating art will necessitate different institutional structures for evaluating and disseminating art. Traditionally, the aesthetic merit of art has been closely related to its commercial value as a marketable commodity. The established criteria of 'high art,' issues of authorship, originality, genre, and style, have dictated marketing strategies in the past and been a major obstacle in the recognition of electronic art.

However, as museums and artists continue to focus on the cognitive structure of art, as opposed to the art object, new venues for evaluating and disseminating art will emerge. Museums are already distributing videodiscs of their collections, and commercial software is available to link these videodiscs to computers to create interactive, hypermedia programs. Museums will soon gravitate toward digital discs like CD-ROM for improved color accuracy, higher resolution, and greater flexibility for interactive applications. Advances in telecommunications will facilitate the transmission of complex software, large image files, and real-time video, and with these technical capabilities in place, new methods of publishing art will emerge that transcend social and cultural inequities to reach a globally integrated audience. Collaborative networking and teleconferencing will expand the potential for interaction between artists and provide new opportunities for collaborative projects between artists, curators, and the public.

New technologies for presenting art are also changing the curatorial language of art and providing new tools for interpreting art. In the past, art historians and curators have relied on text, slides, and photographic reproductions to document art. But multimedia technology can expand those options. Motion video, which can record the creation and installation of art as well as viewer interaction with art, provides valuable opportunities for analyzing the perceptual dialogue between imagery, space, sound, and time. Interaction with digitized art can simulate the creative process and add multiple levels of insight to the interpretation of the art. Conventional bibliographies that reference individual citations can be replaced by hypermedia paths that link multimedia sources in the database. All of these approaches to presenting information tap a wide range of cognitive skills and create new channels for learning and research. Of course, new technology does not operate in a vacuum. Experience and time will test the limits of these tools and establish directives for new forms of communication that will continue to reshape the language and definition of art.

CONCLUSION

Changes in the way we interpret, present, and create art are altering the social fabric of art by bringing art closer to the public. The cultivated elitism of high art that has distanced art from the public is yielding to a personal and intimate approach to learning about art--an approach that is characterized by increased accessibility and direct interaction. Art can be moved out of the formal context of the museum and enjoyed in privacy of the home where the meaning of the art is assimilated into the social structure of individual lifestyles. There is the freedom to choose what type of art to view, as well as how and when to view it, and this independence reduces inhibitions and encourages creative interaction with the art.

In short, the process of interacting with art is redefining the relationship between artists, curators, and the public. Multimedia presentations and collaborative networking highlight causal relationships, and the structure and meaning of art reflect a new order of authorization where the individual develops a personal approach to interpreting art. The key to understanding art is no longer dependent on the expert opinions of a single person or a designated group of evaluators.

The sociocultural revolution in the art world that is redefining the creative and interpretive roles of the artistic community is a reflection of a larger spirit of innovation that is being fueled by the electronic age of information. According to Junnosuke Kishida, honorary chairman of the Japan Research Institute, the computer age is forcing new concepts in creativity and invention by supporting a new social structure that emphasizes interconnections, merger, and synthesis. Kishida warns, however, that in order for this new spirit of creativity to flourish, it must be nurtured by interdisciplinary knowledge and a free exchange of information [18]. Curators and artists are rising to this challenge by using electronic technology to create collaborative systems and knowledge networks where art becomes the catalyst for an open exchange of information. These systems are generating a new level of consciousness about art. Art now derives meaning from multisensory data, the multiplicity of complex relationships, and the interaction of an integrated and diverse audience. The ultimate interpretation of the art is derived from an intricately orchestrated cognitive structure that is a unique product of space, time, and the creative interaction of the artist, curator, and the public.

Interconnection, merger, and synthesis, the hallmarks of widespread changes in social, economic, and political value systems throughout the world, are also the cornerstones for a new platform of interaction within the art community that will generate an increased awareness and recognition of electronic art. Interactive museum presentations will help dispel the novelty and suspicion of electronic media and encourage an equalitarian restructuring of the sociocultural hierarchy. Theoretical criticism will be challenged to yield to new perspectives, and a surge of creative energies, sustained by increased tolerance and a high degree of intellectual and stylistic diversification, will enable museum presentations and electronic art to achieve greater levels of cognitive insight and aesthetic integrity.

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ELECTRONIC ART AND SOLAR ART

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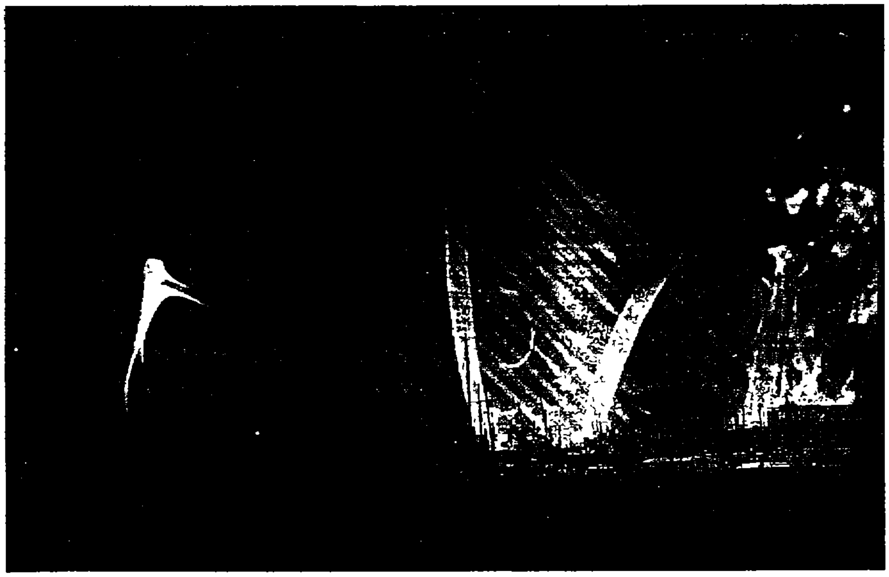
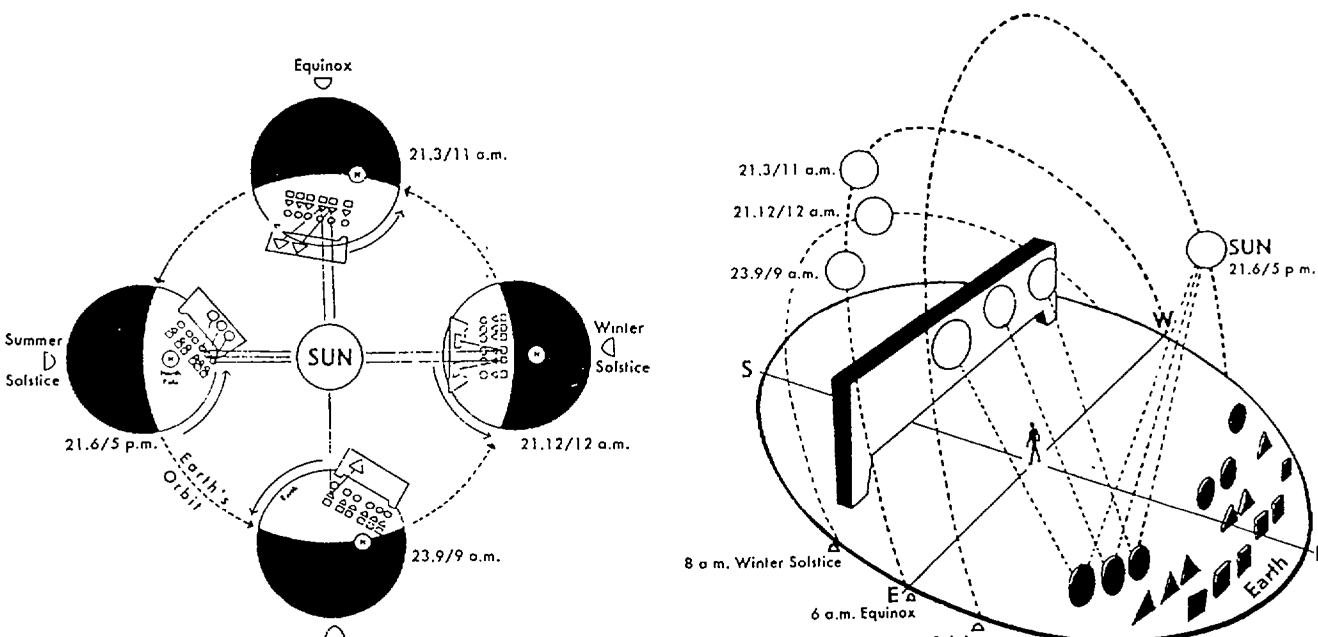
Abstract
-High technology opens phantastic possibilities for art and artists.
-With old techniques artists using simple means may create great new works of art.
My Solar Art -one of many possible uses of sunlight in art- intends to unite these two worlds: High tech art and painting and sculpture.

Sun Robots
I started this research years ago in the faculty of architecture of the Technion, the Israel Institute of Technology, and it is still going on. This paper is giving information about it, so that readers may consider "Solar Art" as an alternative, and experiment with it. If we look at the illustrations Fig. 1 and 2, even the expert might find it difficult to decide if they are Computer or Solar Art. Solar Art has some similarity to electronic art, but it is an apple from another tree.
Solar Art is a complex of various possibilities, not discovered all at once. It has robot and manual techniques. All my solar techniques have the same basic principle, they use reflectors (reflecting sculptures, which give the form) and colour filters (transparent paintings, which give the colour).
There are 3 robot techniques (Robot Art). The first for constructing a cosmic projector, which is not really a robot, but only an automat; I called it the "Robot Picture". The sun is the lamp, the earth the motor of this projector. Rows of fixed sun reflectors are moved by our planet relative to the sun and project kinetic pictures on outside walls (Fig. 3). The colour filters cross the path of the incoming -not the reflected- light rays. Thus the changes of colour and form in the projection are independent of one another. This system is used in all my solar techniques. The constructor plans the projection of the cosmic projector for each hour and day. Running time is six months, from solstice to solstice.
The second technique produces a real robot. I call it the Robot Painter. A robot painter not only projects, it also creates the pictures. It never repeats itself. It is an optical brain, which can distinguish between good and bad pictures. It projects only pictures according to the taste of its constructor.
This robot has movable reflectors and needs another source of energy in addition to earth rotation and revolution. I used wind energy. When three or more parts of a reflector system move independently from one another, they will forever produce new combinations, and their projections will never repeat themselves. It is the task of the constructor to stop movements and combinations of reflectors, which might produce bad pictures.
I experimented with these two techniques for years, but never made a permanent construction, a "Prototype". The third robot technique I called "Lightsymphony No. 1" after the name I gave to the prototype which I constructed. As far as I know, it is the only existing artificial non-electronic intelligence (Fig. 4-9).



P K Hoenich
fig 2



The principle of robot art

P K Hoenich
fig 3

The prototype is an apparatus, which functions as an automatic cosmic projector -using the same system as the Robot Picture-, but it is also a real robot, an optic brain, which creates countless kinetic or static pictures, using another system than the Robot Painter. It functions with sun light as well as artificial light.
But the prototype functions as a robot only, if it has a human visitor who plays with it. Man uses the robot as a tool to produce pictures, the robot uses man as a source of energy. The constructor uses both to activate his functional self portrait. I implanted my art into this optic brain, and some of my ideas, which the robot expresses with various visual symbols. It expresses the idea that our time is the space age.
The prototype looks like a framed picture (Fig. 4). The optic brain is in the frame (Fig. 5, 6). All parts of this optic brain are fixed. The visitor activates the brain by moving a mirror, which reflects sun light against the frame. Instead of a mirror he may move a lamp (artificial light) and produce kinetic pictures. A fixed lamp will produce various static pictures.
To construct this optic brain I had to try out predictable actions of man playing with the robot. It took me three years. To construct a functional self portrait is a fascinating task for an artist. It makes his creativity independent from his lifetime. This optic brain has three colour filters, two prisms and nine reflectors (Fig. 5). One of the reflectors is two-dimensional, it projects a concrete mirror drawing of a figure with raised arms. The three-dimensional reflectors, which project abstract forms, may suggest to the spectator something concrete. In Fig. 1 -a sun projection, made in manual technique for the picture concert "Time Travel"-, there is a yellow form, which may suggest the appearance of the Sun God in human shape with raised arms. I hope it will suggest this, but it might also be seen as a yellow flower etc.
For the optic brain it was very important to include a human form, so I made a mirror drawing. The brain has one two-dimensional reflector, intended to suggest a space ship. All other reflectors are three-dimensional, and project various abstract forms, suggesting cosmic space. Every three-dimensional reflector makes many different projections; Fig. 7 shows a projection of the robot uniting the space ship with man. Fig. 8, another projection of the robot, shows three figures coming out of an abstract form, which to me seems a symbol of the womb.
The prototype has only one mirror drawing of a figure, but when it functions as a robot it can produce multiple projections. I saw one, two, three and more figures arising from this form and thought: "The cosmos gives birth to man". Constructing the optic brain, I had not foreseen this happening. Years before I constructed Lightsymphony No. 1, I had written in my research report "Robot Art", that if an artist tries to construct a functional self portrait, the robot may in the end influence his constructor. It happened (Fig. 9). The projections of the robot inspired my oil painting "The Cosmos gives Birth to Man".

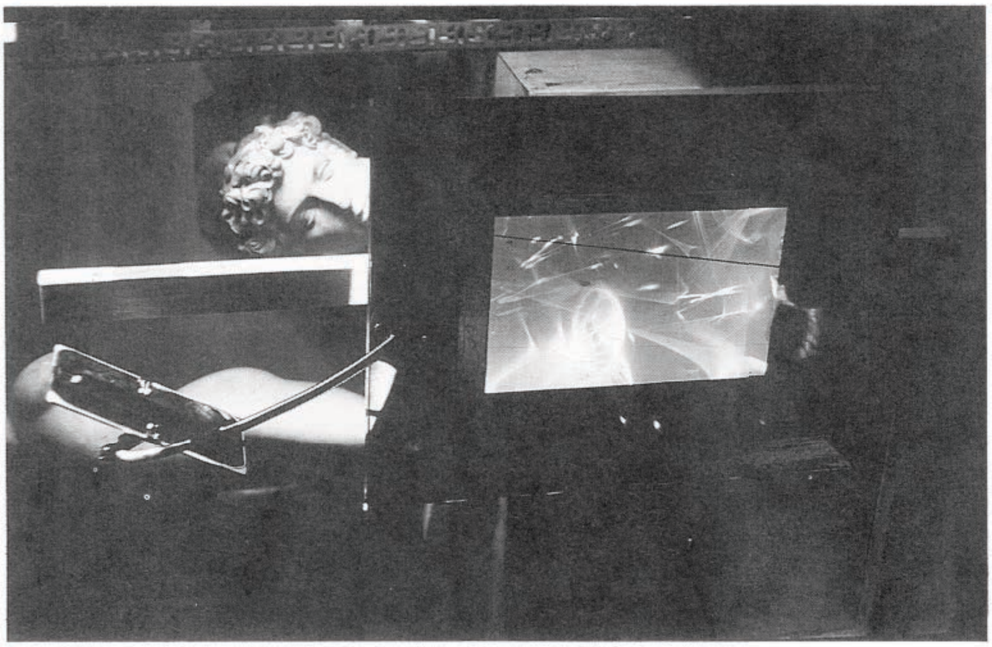


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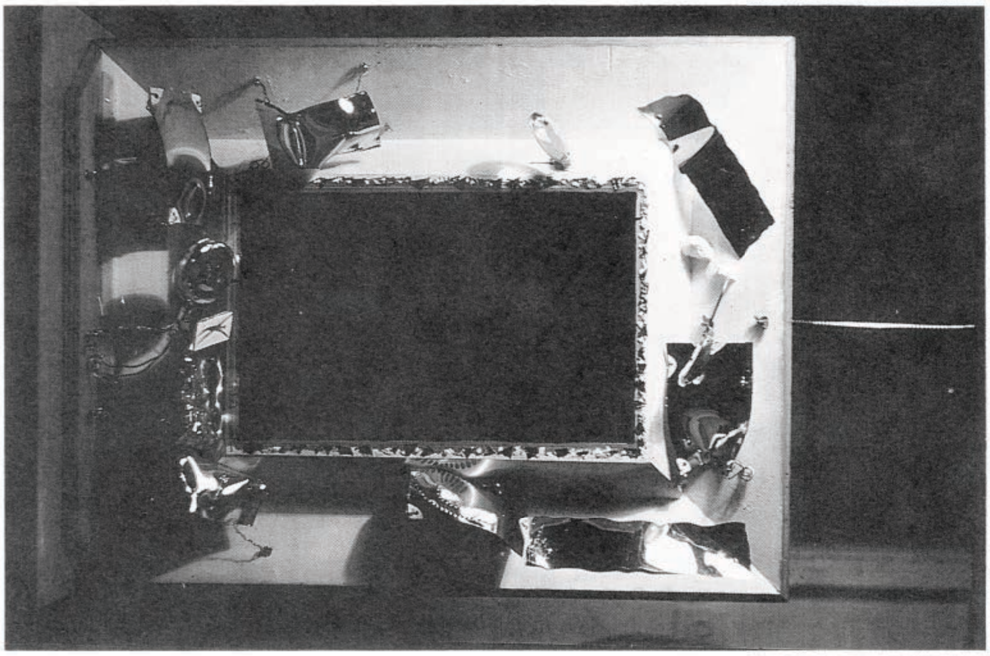
fig 4



P K Hoenich
fig 5

Manual Solar Techniques

I am fascinated by the robot techniques, but I seldom use them. I mainly apply the manual techniques of Solar Art. There are material and spiritual reasons for this development. In this short paper I report only the essential facts.

The material reasons: I found much interest for the robot techniques, but no commissions. On the other hand there were orders by cinema, television, publishers and print makers for solar art work. For cinema and television a robot would be of no use. It cannot see the actors or hear the requests of the stage director. Nor can it react to the various needs of book and print publishers. I needed manual solar techniques.

The spiritual reasons: Experimenting with manual techniques I think I have found two important new possibilities for the development of visual art. I am interested in using them. I know that artists and research workers may have illusions about the importance of their work. Anyway, I will report on these possibilities, and why I believe them to be important. Everybody may repeat my experiments. Let the reader then judge by himself their value and usefulness.

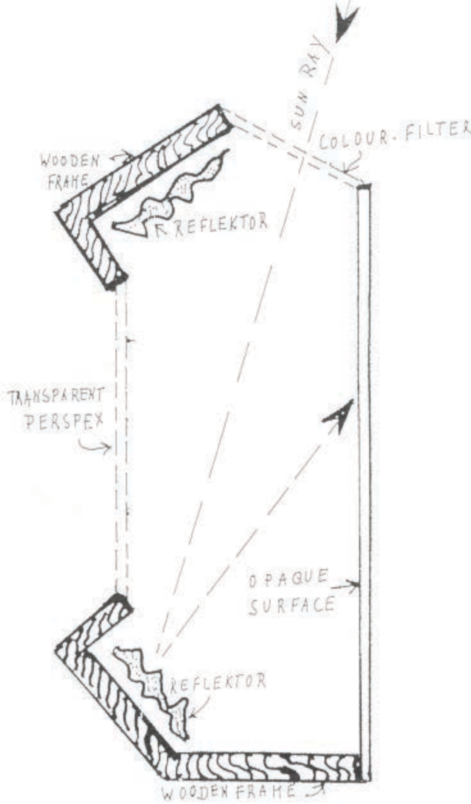
"Static Solar Art" is a paradoxical concept. A solar projection is kinetic. But we can reproduce solar projections by instantaneous photography and get static pictures to be used as slides or prints. My way of doing it:

I put colour filters in a window - a transparent painting or pieces of transparent plastic material in various colours. Sun light, traversing the filters comes into the studio in coloured stripes. I arrange a number of reflectors -usually 3 to 5- so that together they project a picture against a screen. The screen may be a wall of the studio, but for photography a translucent screen is preferable (back projection). The projection is photographed from the back of the screen. The reflectors are on the other side (not visible in the photo).

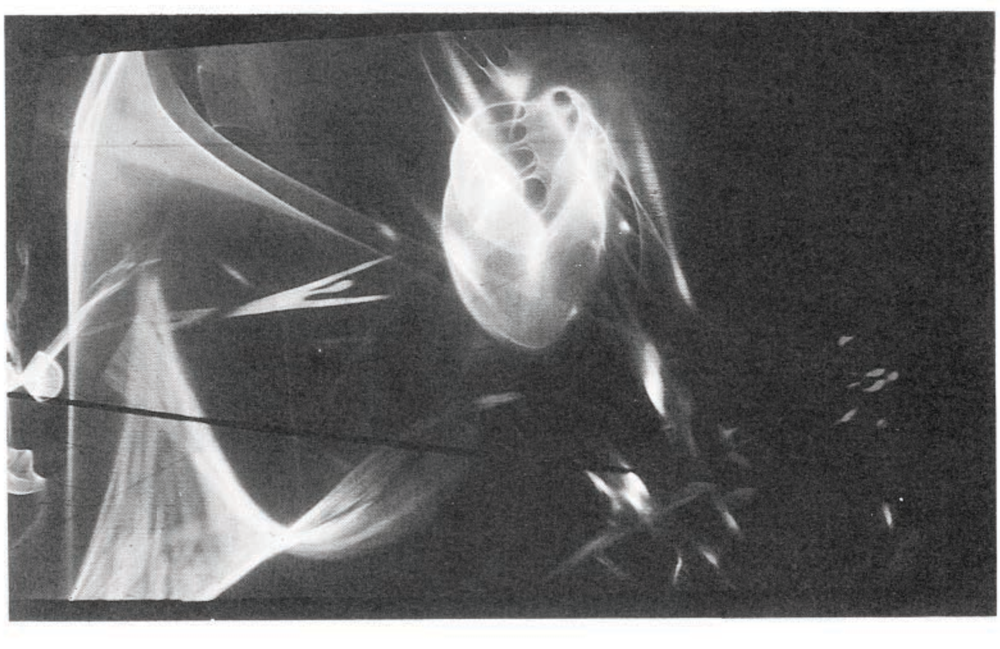
A new possibility for visual art, which I believe important. The velocity of light is of utmost importance for the quality of results achievable with this technique. When sun rays strike the reflectors, the complete picture with all its colours and forms emerges in "zero" time. Every change of position of one or more reflectors changes the picture. Generations of artists would have to draw and paint, in order to produce the countless variations of a picture, which can be created with sun rays in the shortest time. This use of the velocity of light I combine with the use of controlled indeterminability.

The reflectors are mirroring sculptures, modelled so that their diverse reflections conform to the purposes of the artist, but there are chance results, too. The cosmos creates with chance results. Everyone of us is the chance result of the combination of the parental genes. By applying these two factors with the manual technique for static solar art, the artist may have chances for better pictures than with other techniques, including other solar techniques.

Fig. 1 and 2 were already mentioned. But Fig. 1 is also a very good sample for possible uses of controlled indeterminability in static solar art. The spectral form in the background was produced by a plane mirror in a tank of water. The mirror was placed at an angle to the surface of the water and functioned as a water prism, which projected the sun spectrum onto my screen. By blowing on the water I could produce a sun spectrum moving like fire, and select the form best suited to my picture.



P K Hoenich
fig 6 Diagram of the vertical cross section of the Robot Projector for 'Light Symphony, no 1'



P K Hoenich
fig 7

Rotterdam, Fig. 2, shows another way of applying solar techniques. We can unite reality and sun projection, and create with both a work of art. This we achieve with both solar manual techniques, static and kinetic. There are two methods - we can project the sun picture on the scene in nature and unite both in a single photo. Or we can make separate photos of reality and sun projection, and unite both in the laboratory. Both methods are easily applicable in the studio, in the open, often only the second is useful.
I have already told how I use my three-dimensional reflectors, and I want to add how I make them. Glass reflectors are formed in an electric oven, or by glass blowing, and then covered with mirror. Metal reflectors are made from mirror polished sheetmetal (cold hammer).
The reader, who wants to experiment with manual solar art techniques, should first try an experiment with primitive means. Instead of constructing reflectors, he should look for ready made reflecting objects. He may cover a window with pieces of cellophane in various colours, use a sheet of white paper as a screen, and on a sunny day he will project hundreds of pictures in a few minutes.
The difference between the static and kinetic technique is that in kinetic technique the artist and his assistants move the reflectors by hand, while movie or video cameras are running. Here the artist has no possibility to use the velocity of light for selecting the best design or wait for a useful chance result. Sometimes he even has to form the reflectors while the cameras are running. He takes a mirroring plastic sheet in both hands and presses it into various forms for different kinetic projections.
He plays with light like a musician with sound. He can make improvisations like a virtuoso with his instrument. And this seems to me the second important new possibility for visual art.

Conclusion
I believe artists should not be bound to a single way of creating. They should use whatever seems good for them and their work. For me solar art is an alternative to painting. I believe it could be a useful alternative for many artists, and especially for electronic artists. It has a similar philosophic background as electronic art.

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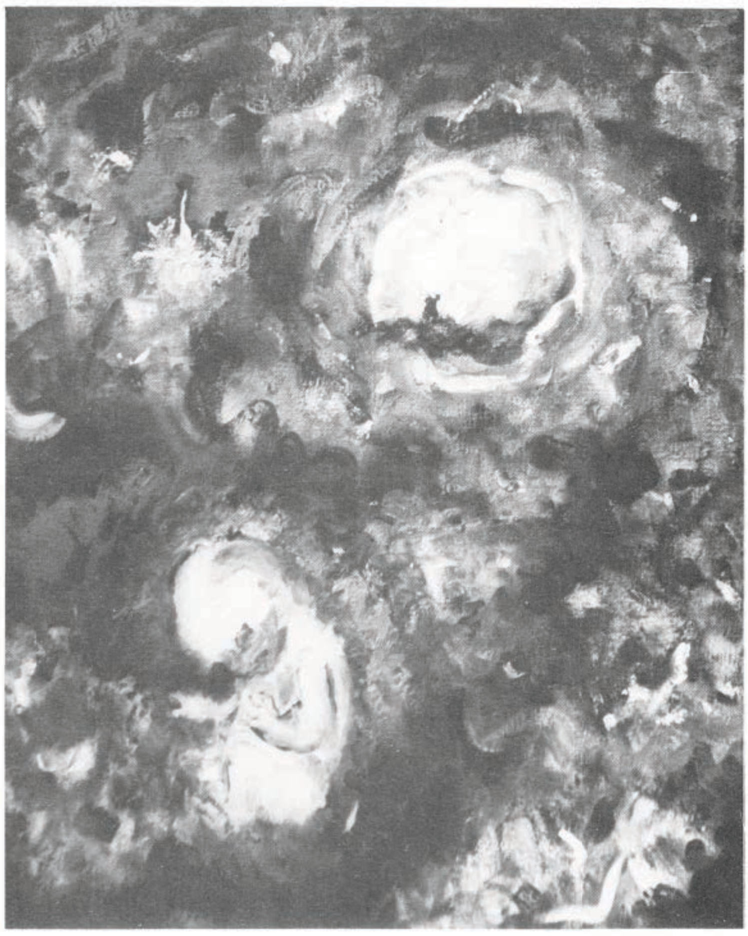
P K Hoenich
fig 8



P K Hoenich
fig 9 The cosmic birth of man .

The Emperor's New Art?

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Abstract

Premature over-promotion of any and all "artwork" created with computers has caused the critical establishment to draw parallels with the tale of "The Emperor's New Clothes". Simultaneously, computer artists accuse the art critical establishment of being uninformed, myopic, and hopelessly out of touch with the new media concerns. Artists disdain the oft-exhibited science fiction grotesqueries masquerading as art: bad critical reception is blamed on the inclusion of this "nerd aesthetic" in *their* art shows. On the other hand, some more technical-minded factions also wonder when computer artists will actually learn to program, or produce something besides canned paint system imagery and indecipherable, bad video tapes. Such squabbling and shifting of the blame from one group to the next is not the way to correct the problem.

Many of the standards by which we have evaluated computer art have evolved outside of the "high art" community. Yet the standards in our own computer graphics infrastructure tend to be much lower. Often the concepts of science and tools of technology are merely appropriated and exhibited as art without any authentic artistic transformation or social context. Work, when it refers to contemporary art world trends, often does so as a form of commentary rather than genuine individual expression. Without true understanding of either art or science and technology, this work can hardly help being superficial.

We need to fairly evaluate work using standards as high as those by which the rest of the arts are judged. We need to extend beyond the isolation of our small community and address broader issues. Most importantly, we need to take advantage of the uniqueness of computing, and push those properties to their extreme limits. Only as these issues are addressed and resolved will computer art gain in significance and authenticity.

At the SIGGRAPH '89 conference there was a panel session entitled "Computer Art - An Oxymoron?" that was intended to bring some members of the more established art world institutions together to discuss the status of computer art. The panel's loose consensus seemed to be that "Theoretically, it could exist at some point, but in practice, now, there weren't very many examples of interesting work to be found". The lack of involvement with idea and content was referred to. Yet some panelists, through misuse of jargon, revealed their own unfamiliarity with computers and the technical milieu.

With each question asked after the session, the gap in understanding widened further. Audience members confused technical issues for content; some people seemed to think that the current state of hardware and software was too primitive for real art to emerge - yet. Others used the terminology of the marketplace in prognosticating the future: meaningless phrases such as "narrowing the gap between imagination and reality" were in abundance. It was also implied that many artists' work is bound by the limitations of the prepackaged software. How can artists do much with this tool without an in-depth exploration of its language? Why do they rerender the works of other 19th and 20th century artists? A computer artist wondered what it would take to have his photo realistic work recognized as art, and that he would have work ready and available for review in the fall. None of the panelists offered their services. There was a general feeling of dissatisfaction after the session: artists felt that their questions were left unaddressed and that they were being written off as insignificant. Panel members had seemed unable or unwilling or embarassed to articulate specifically just why computer art was falling short of expectation. The two factions seemed to exist in parallel worlds, unable to pass through an invisible though palpable barrier. Has the computer art establishment woven, promoted, and cloaked itself in some miraculous cloth - a cloak of legitimacy? Are the critics who are unable to see it unfit for their jobs, as those citizens in Andersen's fairly tale, or are they like the child who declares that the Emperor is, indeed, naked?

Unfortunately, this is not an uncommon occurence. Every year, visitors to computer art exhibits and animation shows voice their disappointment. Every year, the high hopes and promises we have for the technology in an artistic context fail to materialize. These aren't just the grumblings of the philistine masses: artists, enthusiasts, and engineers alike join in mututal complaint. Yet we hold a common belief that there really is something different in using computers in the visual arts. "Radically different", "revolutionary potential", "unique requirements", "transformation of space and time", and "novel medium" are the types of descriptions found in articles on computer art. Is this just the hyperbole of the marketplace?

What went wrong? Can computer art become a legitimate, significant member of the art world, and be respected also for its technical achievement? When can we expect this to come about?

- When we can fairly evaluate work using standards as high as those by which the rest of the arts are judged
- When "How did you do it?" is not the only appropriate question to ask
- When computer art stops imitating other art styles, and artists show a greater commitment to learning the language of computing

The Ghetto

The mainstream "high" art world early on dismissed computer art as a peculiar hybrid, a carnival novelty like "spin art" or orchestrated laser shows. Still convinced of the fundamental differences and revolutionary possibilitites of computer art, rejected artists and engineer-artists created their own forum for theory, criticism, and exhibition of work. This forum has evolved into a community of organizations which have their own infrastructures; heros, critics, prophets, historians, public relations, conferences, awards and publications. Of course, vanguard art has always had to battle recalcitrant critics and a sometimes hostile public. This new art probably *does* need critics and criticism with a new viewpoint. But eventual recognition of the new work is assured only if the alternative work and infrastructure are equal in quality to that being challenged.

Our situation is not unlike that of science fiction writing vis-a-vis the world of literature. The Polish author Stanislaw Lem has made many astute observations worth presenting here for comparison [1]. He classifies the world of the literary arts into two general groups: The "Lower Realm", as exemplified by crime fiction, erotico-romance novels, science fiction, and the like: better known in the U.S. as "trashy books". The "Upper Realm" is characterized by the philosphers, novelists, and poets generally acknowledged to be worthy of distinction: Joyce, Sartre, Bellow, Sarrault, and so on. In this "Lower Realm", science fiction exists as a "socio-culturally isolated realm" of work, a ghetto of sorts. Its publications, conferences, and exhibits exist as "junior versions" separate from those in the mainstream. Rarely does any cross-fertilization with mainstream literature take place. Writers from what he calls the Upper Realm occasionally make excursions into genres such as science fiction or crime fiction, yet still retain their reputations as respected writers. They have already made their reputations in the cultural mainstream and are allowed such occasional lapses. (Although, it must be said that Doris Lessing was lambasted for having written what she calls "space fiction", in her "Canopus in argos archive".) Authors venturing into the Lower Realm are acclaimed and congratulated as one of the "brotherhood". Due mention is given in the publications, and their presence is offered up as proof of the validity of the genre. William Burroughs is an example of such an author who has not only been re-baptized as a science fiction writer, but has been claimed by cyber-punks in fanzines as one of their own! Lem also mentions that the "inhabitants of the Upper Realm are invited to the Lower; they accept the invitations, but there is no return service" [2]. People in the science fiction ghetto suffer from frustration and isolation when they attempt to gain invitation and acceptance into this Upper Realm, and are snubbed. (I offer the previously mentioned SIGGRAPH panel "Computer Art: An Oxymoron?" as an analagous situation: the critics were invited, yet provided little encouragement.) Out of this frustration, separate institutions and means of dissemination are developed. Consequently, people in their own in-groups tend to evaluate and promote one another's work. Criticism is sometimes more of a public-relations affair than an objective evaluation. Promotion is used as a method of justification. Honesty compels us to recognize these problems as our own.

Similarly, many of the standards by which we have evaluated computer art have evolved outside of the "high art" community. Much of what passes for computer art is judged by these lower internal standards. It is partly the fault of CG marketeers who have promoted everything indiscriminately as Art. The Arts as "softeners" and "humanizers" of the image of computers must be recognized as a powerful marketing strategy... In belief that the newest must be the best, dozens of premature efforts have been marketed as works by "great masters of a new age". And in our own short-term self interest, we have allowed it to happen. Some illustrators and image-makers of dubious talent have evolved as artistic savants.

This is a technology that seems to change overnight. Neither its inventors nor the critics of its uses are able to stop and reflect with much objectivity. Since artistic merit within our community is often linked with techniques and technical progress, work can become dated very quickly. Artists preface discussions of their work by informing us that "This is the first known use of ...", which is more appropriate to the marketing of the newest commercial product [3].

As a result of this early over-inflation of the value of computer art, seekers of authentic art were bound to be disappointed in having found only a few examples worth remembering. Instead of a new reality, they got the old one back, in pixels. In addition, it is now often difficult to filter out marginal work, because some of these practitioners have been long entrenched in the computer graphics establishment. One cannot fix the blame only on this establishment. Every year new artists join the cadre: often, instead of bringing in new ideas they merely rework old images with new techniques.

We need to extend beyond this isolated ghetto mentality, address broader issues, forge connections with the rest of the art world, and insist on higher standards.

How Did You Do That?

Considering computer graphics' origins in engineering, and its affiliation with industry, it should be no surprise that much of its imagery has evolved from the concerns and tastes of those groups. Often computer imagery is the visual result of the process of problem solving. The desired result is sometimes realistic in a photographic sense, and its desired appearance is anticipated in advance. It can also function as scientific illustration, and as a method of distilling large data sets into a format that enables easier analysis. Mathematical forms nonexistent in our everyday Euclidean space can be constructed and explored. New modeling techniques and photorealistic rendering algorithms have been invented to simulate the appearance of objects and scenes in the real world. In this context, the question "How did you do it?" is perfectly valid, and perhaps a compliment to the skill of the programmer. "Is that a photograph, or is it computer generated?" is a question often asked in admiration.

Evidences of technical advances comprised a signifiant proportion of earlier computer art shows, with new improvements showing up every year. Many of these advancements manifested themselves in forms familiar to us from the world of special effects: monsters, shiny reptilian forms, psychedelically complex environments, horrifying versions of the human form. As in special effects meaningless display of technical wizardry can be used to cover up nonexistent content. Remember "Howard the Duck"? Cleverness, verisimilitude, and complexity, and visual double-entendre are criteria for evaluation. Yet, in the art world such criteria have traditionally been a secondary issue at best. Thus, work like Arcimboldi's allegories of the seasons, human faces cleverly composed of tiny fruits, vegetables, and other appropriate seasonal items, or Dali's painting of Lincoln's face alternating with a lady's backside as a function of viewing distance will never attain first-rank status, and remain gimmicky technical curiosities.

In our small community, stereotypical imagery is recycled and reworked so often that it evokes laughter from the audience as a kind of in-joke. Shiny spheres, checkerboards, fractals, and warped human faces show up everywhere, as technical benchmarks, as calendar pinups, as stars of animation. Worried by such inbred imagery, artists have pointed out these errors to the engineers. However, it is not easy to clearly explain the difference between Arcimboldi and Leonardo, and misunderstandings have occurred. Being more "artistic" can be construed as rerendering old masters instead of more dubious historical pictures! Demo animations without content can be fixed by adopting stereotypical animation storylines! Mathematics can be turned into sentimental, romantic landscapes! And the the marketing departments of computer and software companies are only too glad to offer it up to the public as art.

Another misunderstanding and manifestation of the "How did you do it?" syndrome is the codification and reproduction of the work of some well-known abstract artists through the use of rules and grammars. Even if one could analyze the underlying picture structure, a re-creation made with those rules will never equal the original: the intent and the lengthy thought processes aren't there, the hidden mistakes - the pentimento - won't exist, the sum of tiny decisions making up the whole will be absent. What is left is a poor anemic impostor. Why be so obsessed with copying? Take those rules and use them to generate original work! Invent your own grammars!

On the artists' side, the misunderstanding could be said to be mutual. Nowadays computer artists' work comprise the bulk of computer art shows, but where is the revolution? After ousting the engineers from the limelight, their successors don't always offer much additional vision, innovation, or integrity. Why do artists, too, mimic other art styles, and use tools in trivial ways? This is an old lament: A. Michael Noll wrote in 1970 that "The computer has only been used to copy aesthetic effects easily obtained with the use of conventional media... The user of computers in the arts has yet to produce anything approaching new aesthetic experiences" [4]. Digitized, manipulated, scaled, warped, repeated colorized photo collages abound, creating their own family of stereotype. When artists work with canned programs with limited sets of options, they are hard put to put their own stamp on the result. More often what we see is appropriated imagery, clip art, instant image libraries which can be permuted endlessly, and carelessly executed virtual brush strokes added for extra "art mark" effect. And with great speed. "Faster and denser" might be added to the marketing belief that "newest is best". Just because one can do something, fast, doesn't necessarily mean everything *should* be done, fast. And even though recycling may be politically correct, it may not be healthy in the world of ideas, Postmodernism notwithstanding. Here too, computer art has many of the shortcomings of the rest of the current art scene. Epigonism is an accepted norm. "...work inevitably smothers itself in a receding spiral of stylistic vampirism" [5]. Artists must act as better filters and selectors of the perpetual stream of visual media detritus.

Many images from mathematics and science are presented as art. Often artists will simply appropriate some of this imagery as their own, and run it through format and color changes. Just using good design techniques and color selections does not automatically transform it into art, however. This appropriation and piggybacking on other disciplines is a bit of a cheat. Of course, artists and designers *can* be valuable partners with scientists and engineers in the thoughtful and aesthetic presentation of information. This is especially true in the realm of design. But computer artists can't just copy science and pass it off as art. The ideas must be assimilated, *understood,* and then transformed, otherwise they run the risk of being a bad simulacrum of science. The flip side of "How did you do it?" could perhaps be "But they don't even *know* how to do it"!

Misuse occurs in both the realms of engineering and art -there are flawless yet woefully tasteless and content-free images made with the latest techniques. There are also images made by people with visual sensitivity and awareness of artistic issues, yet computer use has added nothing to the work except for the value of self-consciously embracing the new electronic age. Here we get the worst of both worlds: trivialized research and trivial art. The mutual lack of understanding between the groups is a problem that still needs addressing. Artists and engineers are not familiar enough with one another's milieu to know what is first-rate, and what is just a hack. The point is not to discourage one another, but to help and *respect* each other's knowledge by encouraging dialogue and experimentation.

Good work is possible, and has been done, with *any* kind of system, but most does not live up to the inflated claims for "radical difference" or "new ways of seeing", although it does has novelty value. A cautionary statement from seventeen years ago still hold true: "...[a] basic dichotomy is present: on the one hand, those composers and artists who are concerned only with the *act* of being involved with the technology; and on the other hand, those who use technological means to achieve an end more relevant to the world we live in. Much of the interest in the former tends to die out as the novelty wears off..." [6].

So, What Is Interesting?

We all go on, nevertheless, in the belief that there is *something* in computer art that will become significant. A technology that is already so integrated into so many levels of work and daily life must have implications for the arts! The computer is probably the most complicated invention of mankind: so complex that no one person can truly comprehend all the interactions and states taking place within. Yet this certain *something* remains elusive. It is not just the fault of hostile art-world critics, over-eager marketeers, nerdy engineers, or primitive tools.

It may be instructive at this point to talk about work that has been acknowledged to be worthy. The names of certain artists are cited rather often: Robert Mallary, Harold Cohen, Manfred Mohr, Vera Molnar, Larry Cuba, and Myron Krueger. Looking at the work itself, one could hardly say that it is all alike. Yet there is a fundamental premise that is the same: all of the artists have devoted a great deal of time and effort to learn how to use computers. They have developed their own programs and methodologies. Yet they don't all require expensive systems. Harold Cohen has developed his own idiosyncratic expert system which encodes elements of his own personal style. Larry Cuba has used transformations and interpolations in combination with music to produce wonderful abstract studies in rhythm. Manfred Mohr's exploration of space structures using the computer's repetetive and spatial capabilities results in spare and elegant studies. Myron Krueger is developing a system to enable a playful human-machine dialogue. Vera Molnar has pursued the idea of transformation, and Robert Mallary has worked with visualizing and creating sculptural forms under computer control. It becomes clear that the software and resulting images or environments bear the stamp of their authors. Perhaps this is why canned programs for artists have their own look, which the artist is often fighting. By learning a programming language the artist at least has a chance supplying the direction for his or her work, rather than following the trends of the marketplace. However, not many artists have taken the advice of the composer Dick Higgins who, in 1970, published "Computers for the Arts", a pamphlet suggesting that composers, poets, and artists should all learn a programming language as a means of access to computers. It seems a rather obvious step to take, in retrospect. Musicians, writers, and filmakers all know the languages of their respective arts. Computer artists need to be more aware of the concepts of computing, and then be free to ignore those that they find irrelevant.

No one solving programming problems reaches a solution in the same way. (This is apparent to anyone who tries to modify someone else's code!) The artist is not constrained to one "correct" methodolgy or result. But learning the language is not necessarily easy. This is admittedly the harder road to travel. Anyone who is familiar with computers can give testimony as to how time consuming it is. Setting up one's work environment, the "getting ready to do some *real* work" syndrome is a real problem. But work does not have to look as "perfect" as that on television: if that is one's goal, perhaps one would be better off using the amazing systems already developed for that purpose.

Concepts that have origins in the world of computing offer many ideas and influences to consider: the modeling of complex behaviors, modularity, languages, self-simlarity, branching structures, procedural modeling, cellular automata and artificial life, expert systems and the promise of eventual AI. The social consequences are worth noting too. Consider the absolute *obsession* with technique, and the danger of becoming absorbed in computers to the exclusion of the "real world". Do we create these system so that we can be the gods of our own little universes? Consider the distance an artist puts between idea and execution. It is a torturous and circuitous route, this maze of instructions, hardware and code used to produce images. Why do we do it?

The idea of interactivity is often cited as one of the important concepts to evolve from the technology. It raises multiple issues in itself. In interactive systems, is the creator an artist, a programmer, an inventor, a dungeon master, collaborator? Is the participant an artist, a selector of limited options, or someone just having a good time? Do interactive systems show any real options for the participant, other than those already programmed in by the system's designer? Is being a participant rather like being the kid who was given a coloring book to fill in, in his own style, the lines which someone else has drawn?

The idea of a free-flowing dialogue between human and machine is still mostly at the stage of a "call-and-response", yet some environments like Myron Krueger's "Videoplace" are becoming more conversational. The everyday network communications mechanisms already in place that allow exchange of information all over the world are more flexible at this point, and are actually quite amazing. Networks, news groups, and email allow information flow all over the world between people who will never see each other. The technology is in the background, there is no conscious "art" to it, it just enables a channel whose content is constantly ebbing and flowing dependant upon the people involved. This "global community" of people hold ongoing conversations, send programs and data, as well as play. Network games are played amongst widely distributed people who are able to control the direction and activity of the game as it is being played. Additional bandwidth will undoubtedly allow for the flow of images and sound. New artist's networks have already been started and seem to be promising too.

We have embraced the technology and many of its concepts, yet seldom manage to push ideas far enough. It seems obvious that the problem is not with how much the system costs, or whether it can do ray-tracing or not. The problem is in whether the artist is able to direct his work and ideas as he or she sees fit, while dicovering the real possiblities and issues in the technology.

Conclusion

When will the cultural world at large become more interested in work generated by using computers? It will when computer art breaks out of its ghetto. It will when the promoters stop calling any image generated by a computer for whatever reason "Art". It will when we are more informed about different aspects of computing, algorithms, mathematics, visualization, and interactivity and how these ideas can affect our culture, instead of blindly appropriating them and passing them off, untransformed, as art. It will when we begin to learn more about our tools and the standards and issues of the mainstream. I am not implying that computer art should adopt the forms, ideas, and styles, of mainstream art- that would be denying its uniqueness. I refer, rather, to having an awareness, and a comparable high set of standards for discussing work.

Computer Art needs criticism that is fair, objective, and uncompromising. The trash and the noise must be filtered out. This means that the artists must stop depending on and listening to the apologists and promoters. Inflated marketing terminolgy won't provide any true understanding or direction for computer art. Instead of relentless public relations partying at conferences, let us instigate serious artistic and cultural dialogues, and engage in genuine self-reflection. "Nothing kills a legitimate movement faster than the failure to develop a principle of rigorous internal self-criticism" [7].

Some mainstream critics take computer art about as seriously as "spin art", and keep wishing it would die a similar natural death. Perhaps it will be noted as an historical curiosity, like Scriabin's "color keyboards", or the allegorical paintings of Guiseppe Arcimboldi. But, I believe that rather than abating like trendy fads usually do, computer art is increasing: these art-world critics should be at least wondering about the significance of its persistence. Criticism from the realm of computer art may assume more significance. This new generation may supplant members of established critical set, but let this new group also be committed to ideas and quality. Working with computers is difficult--and time consuming. It implies a long term commitment, a desire to learn the tools well, and leaving the expectation of instant art behind.

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Computer - Muse or Amenuensis ?

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Abstract

Most computer systems were, until recently, only graphic recording and output devices (electronic amanuensis) and though possibly useful, not significantly changing the role of art or the artist. The increasing interest in using machine intelligence as part of the creative activity has stimulated new developments in which at the very least the machine can be seen as a catalyst (electronic muse). Nevertheless, artists have hung tenaciously to their traditional roles and critics to their traditional criteria for evaluation. But the logical extension of the use of machine intelligence might more challengingly suggest a change in the nature of creativity and a change in the roles of the relationship of the artists creativity to that of the machine. It is the contention of the author of this paper that the use of such techniques as evolutionary and learning programs will inevitably raise fundamental questions about the role of the artist and the role of aesthetic judgement. It may force a division between evaluating the creative act at a conceptual level (the role of the artist ?) and the act of creativity at the level of an individual evolved manifestation (the computer's role ?).

Nature

Nature is arguably the oldest muse. The nature of this inspiration has oscillated between that of the forms of nature and that of the underlying structures. More recently with the increasing interest in genetics and evolution the interest has switched to nature as an information system. How are the instructions for order, beauty, variety and behaviour coded in DNA, how do they evolve, how do they learn? We are struck at once by how the extreme complexity and variety of nature can be coded in something as simple as the sequencing of the four nucleotides in DNA. We are staggered at the incredible complexity of contemporary living forms with billions of cells as evolved from single cell life forms and possible even from mineral replicators. We are humbled to consider that all living forms whether animal or vegetable consist of the same DNA nucleotides and that for example a human being and spinach contain roughly one-third of their sequence in common. And finally we are faced with the enormous problem that evolution has taken place over billions of years.

The role of the computer

There are many who have been tempted into speculation and work in the field of either metaphor or actual emulation of the principles of genetics or evolution in art and design.[1] Inevitably some of this work does not seem as interesting or as promising as the theory and ideas would suggest and I believe the reason for this is that the inspiration has still not been at a sufficiently fundamental level in considering how such work should act.

It is contention of this paper that it is not possible to design (as opposed to evolve) a computer program of sufficient complexity to produce anything approaching the billions of instructions in DNA. There are some very interesting programs which do indeed directly demonstrate the evolutionary process such as Richard Dawkins' Biomorph program.[2] This allows one to selectively bred and develop new generations of species. This can be done in two different ways. First by generating random mutations on a particular species displayed and then selecting one for further breeding (unnatural selection ?) The second possibility is to tamper with the string of chromosomes available and therefore directly affect the evolutionary process (genetic engineering ?). This program by Dawkins is a great inspiration and fascinating in its own right. It was not however intended as an art or design program and if it were to be considered as such then many further characteristics would be required. In order for the computer program itself to have some sufficient complexity the program itself must evolve from a simple program into a highly complex one. Second, we have to find some simulation or some substitution for the nature of the environment within which selection will occur rather than the arbitrary intervention of some other agent described above as unnatural selection. Some answers to the question of how nature itself decided on environmentally satisfactory solutions are emerging from chaos theory where very clear states such as dying out, becoming permanently periodic, chaotic, or having localised order are characteristic states which are in a sense solutions to particularly kinds of imposed natural problems.

Even popular television programs have been dedicated to explaining that the new science of fractals and chaos theory and every child is now aware of the Mandelbrot set.[3] Nevertheless both the general implications of this and the specific implications in terms of this paper are very far from clear. At the very least it suggests a way of working in which the artist is acting as the initial catalyst by establishing initial rules and some positive feedback system which generates growth. The artist must also have indicated some general way in which the interaction with the environment is going to occur. The most interesting way of working from this point on is to then hand over control completely to the computer and allow the billions of years of evolution to be substituted by the computers patient endless repetition of billions of cycles until some form of environmental outcome is achieved. This means that the computer has not acted as muse or a amanuensis to the artist but the artist has acted as catalyst to the computer. Similarly, it may not be satisfactory to control and select outcomes in traditional aesthetical or formal of other criteria but that perhaps, in the sense of the Dice Man, it is necessary for the artist to take the pledge and accept the outcome without reservation.[4] But this is not to suggest for one moment that the outcome is random. It is far from random because it has been controlled by the evolving forces and logic of the program itself. Random mutations may occur but any particular result is in not way random but as indeed chaos theory shows it has a very clear specific order of itself - "One man's chaos is another man's order".

Examples

Some examples of projects by the author which explore these concepts.

Aesthetic rules

In this experiment conducted initially in l975 the intention was to experiment with aesthetic rules, first deterministically and then in a learning program.[5] The proportional rules of the drawing of the Tuscan column were taken from James Gibbs, Rules of Drawing, written in l732.[6] James Gibbs described these rules as being "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", and as a simple example the beginning of the instructions for the Tuscan order read as follows - "Take any height proposed for this order upon a straight line, and divide it into five equal parts; one of those parts should be the height of the pedestal, according to the outer of the division of the scale on the left hand. Then divide the other four parts above into five parts according to the inner division of that scale; the other fifth part shall be the height of the entablature, and the other four parts betwixt the pedestal and the entablature shall be the height of the column, including its base and capital; and this height being divided into seven parts, one shall be the diameter or thickness of the columns". These instructions were initially translated simple into Fortran so that for example those instructions become -

```
IMod1  =    Iheight/5
IPed   =    IMod1
```
and so forth.

These instructions then predictably produce a deterministic reproduction of the proportions of the original columns. So far this is only of interest in as much as an explicit proportional information was unusual in computer based design programs at that date (and still is not particularly common). But the intention was that the machine should evolve these proportional or other proportional rules for itself and so the next step was to replace each of the fixed ratios given by James Gibbs such as a fourth/fifth ratio of pedestal to base and substitute a random number driven variable. This random number generator was controlled separately for each variable so that the Gaussian distribution at each point could be varied. The intention was that initially the program would produce entirely random columns with wildly differing proportions between the parts and that these would be evaluated by the 'teacher' and on the basis of this evaluation the computer would gradually learn to adjust the Gaussian distribution of the random numbers for each variable until it 'evolved' either a column to match James Gibbs' rules or one to suit the particular aesthetic preferences by the person to whom is being taught. In the event it failed totally and if anything the columns got worse and worse. Since that date I am pleased to report that understanding of nature of learning programs and how to apply these successfully in real life application has greatly improved and that a recent re-run of this program with a more sophisticated learning technique not relying on an external agency is producing very much more interesting and satisfactory results.[7]

Self replicating physical automata

In this example constructed in 1979 each cell of the working model was constructed using simple electronics in such a way that the light emitting diodes were used to display the next growth state of the structure.[8] This first model was deterministic in the sense that the imbedded rules were those for one of Stanislaw Ulam's automata.[9] Therefore the outcome was predictable but the implications of the potential of having sufficient intelligence in each cell of the model is such that it was able to itself to determine what was going to fit adjacently to it, gave a new meaning to the concept of a self replicating automata. What this actually represents is a piece of intelligent structure which is able to reproduce its own rules for growth and continuation. We thus have a structure which is capable of controlling its own growth and development, but the rules are fixed and the next step is therefore to try to develop systems where the rules and their complexity can also evolve.

The generator project

In the generator project for which the author of this paper was consultant to the architect Cedric Price the intention was to develop a computer program for controlling a flexible building to be located in Florida. The intention was that the changing needs the computer program would suggest variable configurations in the building arrangement. Furthermore overall control of the site was to be maintained by embedding electronic components into every part of the building fabric so that in a sense the building became literally 'intelligent'. It was at least intelligent in the sense that it knew where every part of its structure was, had some information being fed back on how it was being used and in response to changing needs was able to suggest changing configurations which was fed to a crane driver who was permanently on the site to move components. The architect was concerned that as people were not used to having control over such a flexible environment they might not make sufficient demands upon the building to test its real potential. We were also concerned that with the power of the microprocessors we were proposing imbedding in the building fabric there was a vast excess of computational power over that needed for the structure to control its own configuration. We therefore suggested that rather than having the rules for controlling the building being deterministic they should also work on a learning program so that the building would gradually learn to adapt the best strategy for adapting itself in response to changing needs and measuring its performance in terms of the way in which the building was then used. The problem of how to produce random variations in the form of a building was overcome by introducing a concept of 'boredom' such that when no change had occurred to the building due to changing in external program for some time then the building itself would become bored and make whimsical and arbitrary suggestions to the change of its form and then discover what response this evoked from those using the building.

The reptile system

This is a structural system consisting of two folded structural plate systems which have the characteristic of fitting together into a very rich and varied form allowing complex shapes to be built and to form straight line edges and openings without cutting components. Again for this project there was a simple deterministic computer program written such that components could be arranged in particular ways and the structure would then be drawn and structural calculations performed. There was also a significant development of a learning program for this project. The computer system worked by being 'seeded' with a minimum configuration of the two structural units in all their possible orientations in space such as closure was ensured. This seed then went through a series of operations of growing it, stretching it, developing it so that automatically large structural envelopes would be developed. Again the capability was built into the program for a very large number of iterations in an attempt to produce a particular configuration of the units in response to a particular problem. The designer conceives of the initial rules for achieving the conjunctions of the special units and is also able to derive more than one seed and the selection of a particular seed for a particular seed influences the complexity of the overall form. This is a direct analogous to having different varieties of the same plant seeds. In this case the question of external control to determine whether or not a configuration was successful were entirely by practical considerations such as it had to find a method of actually reaching the required boundaries of the structure and then some attempt at optimization was made such that it could attempt to find a solution to the structure which employed the minimum number of structural units. It was also for experimental purposes possible to reverse some of these criteria so that it tried to form the required enclosure with the maximum continuous structural surface which of course led to extraordinary complex wrinkled and crumpled surfaces. [11,12]

The universal constructor

The universal constructor is the most recent experiment and so named both in deference to Von Neumann and also because it was also a test bed of universal application. It consists of a number of cells which can be deployed in three-dimensional space. Each cell has 'intelligence' in the form of a fairly complex integrated circuit which enables it to display its own identity, to pass messages, to go into various states. Various configurations of the units and the landscapes on which they sit can be suggested and the experiment takes the form of proposing rules which are then programmed into the logic of the individual units which in turn will form some kind of overall configuration in response to a particular environmental problem. The particular purpose of this model was to experiment with direct interaction with the environment and the environment in this case was to be an active participator. So in a particular application the participator would configure the environment in some manner and then see how the computer system would respond and arrange structure in response to that environment. Again the intention being that the system would gain experience of dealing with both participators in general and specific participators in particular and try to evolve more complex rules for dealing with particular situations. [13,14]

See colour plate for illustration of the Universal Constructor in Use. Figs. 1 and 2 show the light emitting diodes passing messages between units and up stacks of units. Figs. 3 and 4 show an application where the changing light visit patterns represent changing positions in the Laban dance notation. In this particular application the participator instals a set of obstacles or a set for the dancers to respond to and the system then creates a dance response appropriate to that environment. Fig. 5 project by Faiza Mohd. Isa.

Conclusion

The initial question was

Computer - Muse or Amanuensis ?

and the answer is no because it was not intended to be an either/or question, but to imply that computers are now moving significantly beyond being either amanuensis or a muse and into new areas requiring a fundamental rethink of roles and aesthetic judgement.

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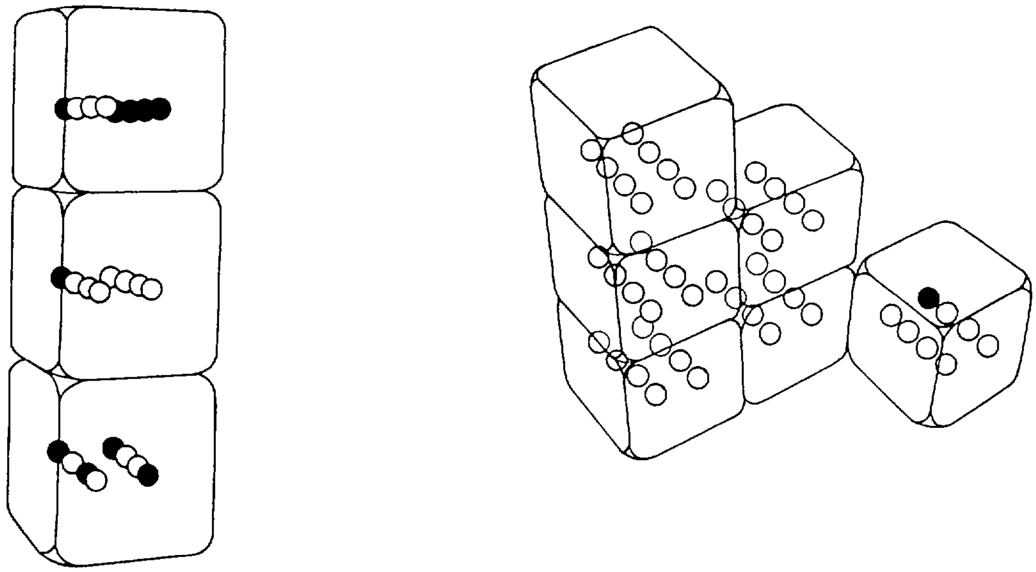
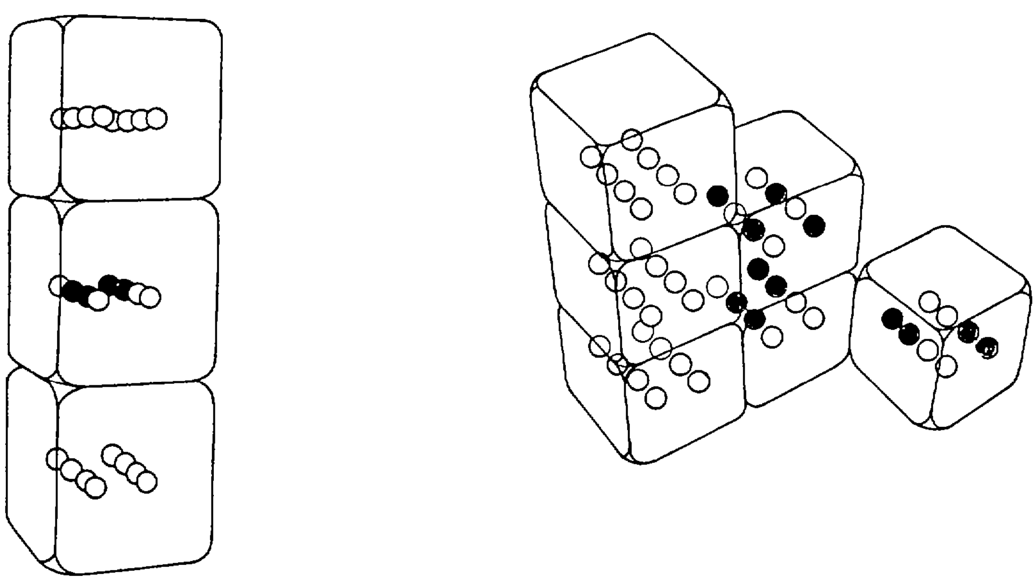
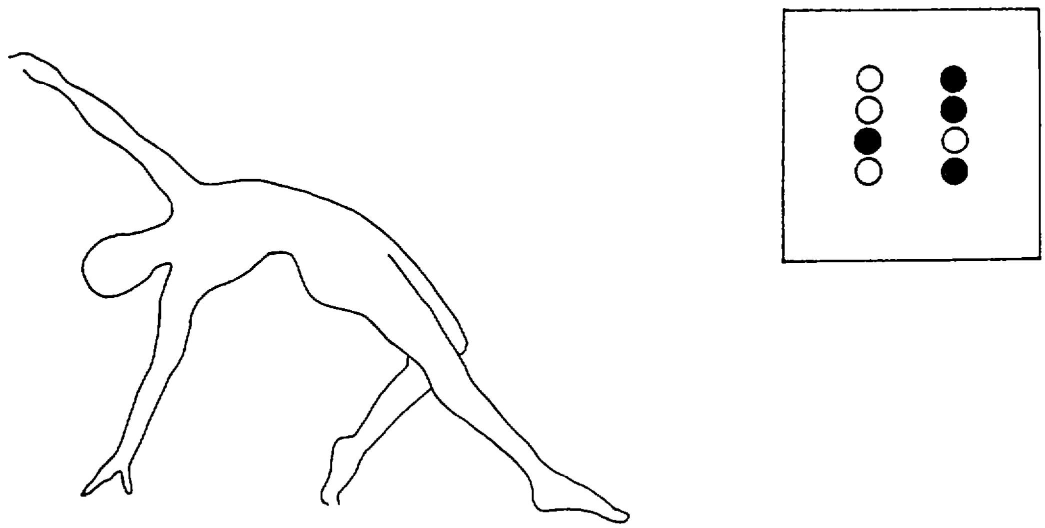


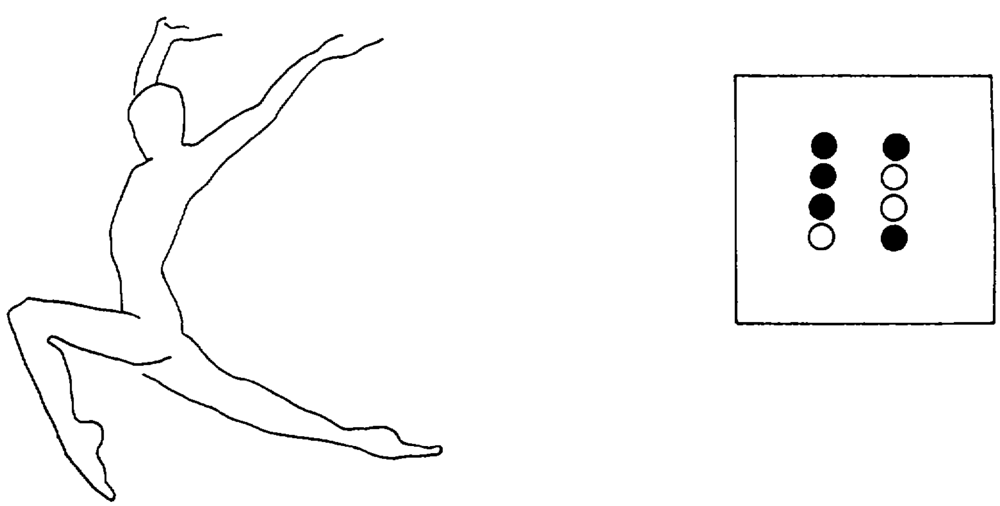
J H Frazer
fig 1 Light emitting diodes passing messages between units



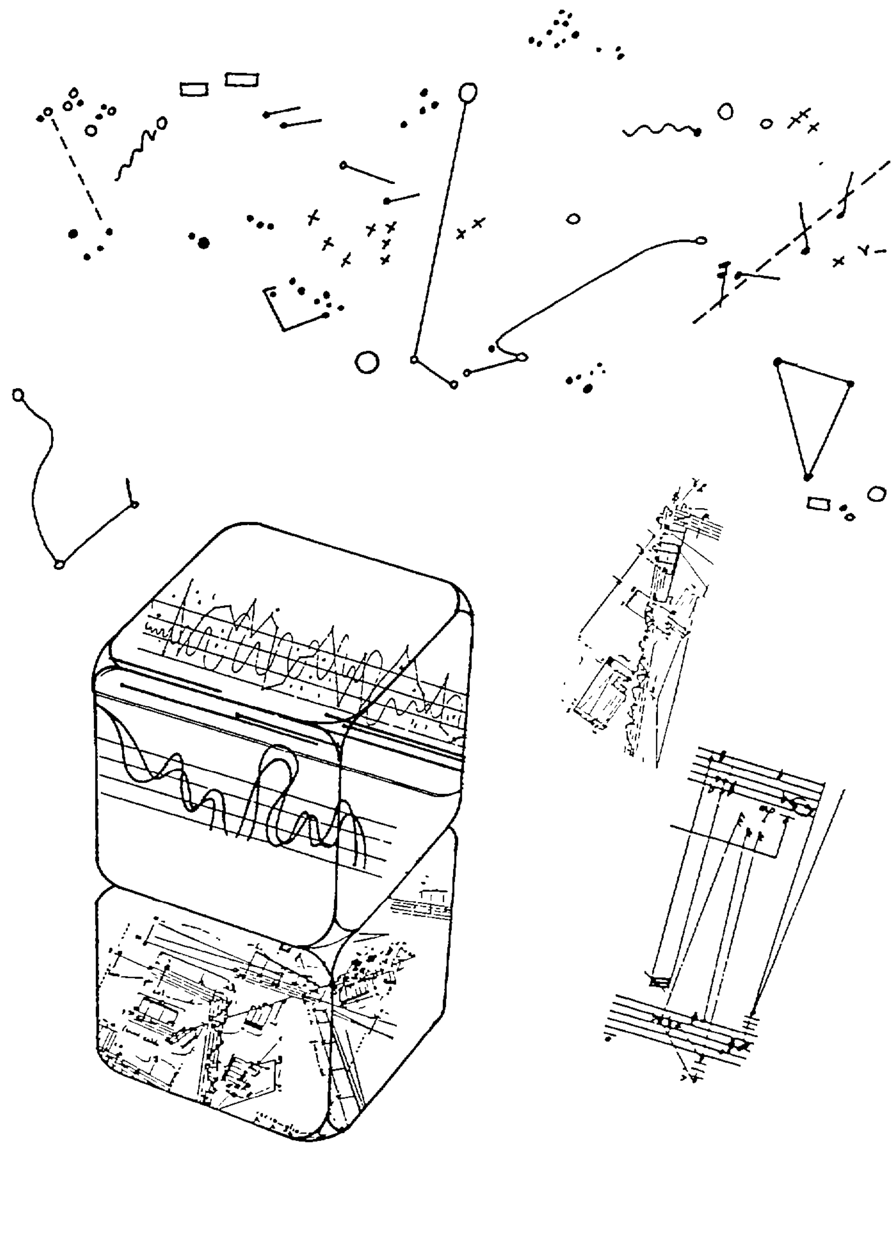
J H Frazer
fig 2 Light emitting diodes passing messages between units



J H Frazer
fig 3 Light emitting diode representing dance position in the Laban notation



J H Frazer
fig 4 Light emitting diode representing dance position in the Laban notation



J H Frazer
fig 5 Project by Faiza Mohd. Isa.
Complete dance and music system

Machine Culture.

Simon Penny
Electronic Intermedia at the University of Florida

ABSTRACT: This paper is about the relationship between technological change and socio-cultural change. In particular it is about the position of the artist with respect to these types of change. The origin of the Art/Science schism, the history of the technophilia of the art community and the contemporary signs of reconvergence are examined. In conclusion the paper speculates on appropriate activities for art and artists in the post industrial context.

The technology of a culture and its world view are bound to each other in an isomorphic symbiosis (a 'chicken and egg' analysis is beside the point). This was true in Plato's day: the contemporary technologies of potting and weaving structure Platos' images; and in Descartes': the idea of mechanical clockwork informs Descartes' view of the world. It is true now. (1,2). Since the Industrial revolution, technological development has been the major force for change in Western society. New machines like the steam locomotive became icons and images of power. The standardization of industrial mass production became a new structuring reality (...you can have any colour as long as it's black.).

In the sixties, electronics, particularly logic electronics, supplanted the brute machine as the image of 'progress'. The product of technology became ephemeral and information was commodified. The computer became the paradigmatic technology. By the early 1960's it became commonplace for people to speak not only of their genes but of their minds and private psyches as being 'programmed'"

The premises of this paper are: 1. That the machine has been and remains a major force in our culture, both literally and metaphorically. 2. That although art is a product of culture, and our culture is shaped by the machine, art practice has avoided considering 'the machine' as a cultural force. 3. Both art and industry are concerned with the production of objects. It is of crucial importance for contemporary esthetics that the implications of the ephemeralization of the machine are considered.

Modern Times

Some new technologies are eagerly embraced by society while some are resisted. Elting Morison contends that new technologies will be resisted if they promise to distort the fabric of society. His case study of the steamship Wampanoag is an illustration of this phenomenon of societal inertia. (3) However, in many cases the distorting potential of a technology is not forseen. The early inventors of the "horseless carriage" could not have predicted the way in which the automobile would radically change the design of our cities or the form of social relations. On the other hand, some new technologies are eagerly embraced. A very clear example is the pharmaceutical industry. The ready availability of antibiotics has altered our attitudes to pain, to illness and debility, indeed about the occurence of death. The availability of reliable chemical contraception has altered the position of women in the workforce, sexual morality and the institution of marriage.

Every niche and corner of our lives is inhabited by machines. Our lives flow and wrap around them. Our behavior is qualified by them and accomodates them: telephones, cars, airplanes, television, electric light and electronic banking. We are integrally bound to the logic of machines, they permeate our lives.

An immense mythology has built up around the machine since it began to radically change the face of the planet and the relationship of people to their work. This has as much to do with the machine being a convenient focus for an examination of the change in power relations between the nobles and the serfs, as any quality of the machine itself. The industrial revolution spawned two new neuroses: technophobia and technophilia, each debilitating. A history of the trumpeting of new technological developments as 'quick-fixes' for global problems would be an appalling catalog of human folly, from the locomotive to the green revolution and beyond. Technological utopianism is a pernicious virus.

Dark Satanic Mills

Before the industrial revolution, in the day of Francis Bacon, the arts and the sciences were united. Hamlet says: "....What a piece of work is man, how noble in reason, how infinite in faculty..."(4) Reason and faculty are undivided. In the development of industry and engineering, 'science' came to serve 'commerce', and 'art' (along with religion) was left to define itself in opposition to 'science'. Thus arose the classic schism: the rational/scientific vs the romantic/mystical. This schism persists as a major polarity in our culture to this day. 'Humanity' came to be defined exactly in terms of those qualities that differentiated it from the machine: passion, creativity, even fecklessness.(5)

Jacob Bronowski reconciles these antagonisms with his eminently sensible observation that Blake and Coleridge were contemporaries of Arkwright and James Watt, that the Industrial revolution and the Romantic revival were precisely contemporary. "It was the engine, it was the horsepower which created consideration for the horse: and the industrial revolution which created our sensibility." (6) So Impressionism could not exist without photography, the idea of the 'original' only makes sense in the context of mechanical reproduction. (7) Each new wave of technology allows us to re-evaluate our culture, to find new value in old things.

Artists and Machines

Why is it that while literature and cinema have become technologised, there has been a notable reticence on the part of visual artists? Perhaps it threatens their mode of production. Painters and sculptors are after all, artisans. At the advent of the Industrial revolution, William Morris made a claim for the 'craft' process, and saw a threat to the liberty of artisans in the processes of mechanical mass production. Since that point (with the occasional exception) art practice has defended the validity of the unique hand crafted item. Mass production of text occured with Gutenberg; writers made a sucessful adjustment to the condition centuries ago. The cinema was born of the industrial revolution. It was in its time, the technological medium 'par excellance'.

Why the values of the Craft Movement remained stained onto the art community is more problematic. My suspicion is that as the machine became more sophisticated, it began to encroach further into territory which was regarded as definingly human. For a machine to spin yarn or pump water is one thing. It is another thing entirely for it to create images (ie photography) and thereby threaten painting, one of those activites regarded as a crowning glory of the species. The response was to find something else for painting to do: thereupon hangs modernism. The suggestion that technological innovations made traditional art practices redundant, and thus prompted the explorations that resulted in modernism is one that is rarely entertained among art historians, but I believe that it is difficult to refute.

As photography 'perfected' painting, so the machine 'perfected' the production of goods. No artisans could compete with the precision- in- multiplicity of even the simplest thread cutting lathe. Only relatively recently with the multiples of Les Levine, Marcel Broodthaers and others, have artists addressed the process of mass production, but without major effect on the art market, which as yet clings doggedly to the idea of the unique precious object.

The relationship of the artist to the machine is problematic. In attempting to engage the science/technology complex; (which owns the dominant paradigm of our culture); the artist is presented with a powerful paradigm which is at odds with the artists' conventional procedures. This is the epistemological dimension of the schism outlined above. Its axes are: induction vs. deduction; holistic thinking vs. the scientific method of reduction of variables in controlled systems. I doubt whether anyone in this room has not at some time noted with horror the evaporation of their artistic vision in the process of resolving it to numerical variables.

We are at a curious historical cusp when the ultra- rapid calculation afforded by computers (these devices which are the epitome of the 'machine' project) allows scientists the opportunity to employ induction in simulatory research. The point at which information so derived is allowable as 'knowledge' in the scientific world signals a revolutionary point. At this point also, the same technology offers itself as an artists' tool, for much the same reasons. But it requires on the part of artists the engagement of values of the other side of the schism in order to exploit it. I shall discuss this convergence further, below.

Bachelor Machines

Why did it take so long for the machine to be brought in from the cold? Perhaps because the spirit of Cezannes' dictum: "Art is harmony parallel to nature" got confused with a pastoral/romantic mindset allied with the anti-industrialist sentiments of the craft movement.

There have been movements in modernism that have atempted to embrace industry, industrialization and mass production. Russian constructivism placed industrialization in a clear political agenda. Art history has found it possible to downplay the significance of industrialization in Russian constructivism in the same way that it downplays the significance of Marxism in the movement. Indeed, industrialization and Marxism are integrally related in this context.

Italian Futurism paradoxically clad industrialization in the garb of the political opposite, the extreme right. By and large they discussed it within the traditional media, with Russolo standing as an innovator among them. Bugatti, on the other hand, seemingly embraced the expostulations of Marinetti (after his baptism in industrial waste), so literally that he abandoned the gallery object completely and opted for motor car production. The association by the Futurists of machines with Fascism and a glorification of war no doubt reinforced the generally luddite stance of the art community; the futurists gave the machine a bad name.

The Dadaists saw WW1 as a war of the machine, as the logical outcome of rationalism and industrialization. In rejecting both, they simultaneously rejected the Futurist position for the more traditional romantic one which had its roots with William Morris.

The Bauhaus made an attempt to reconcile traditional artistic sensibilities with the new industrial production, but seems to have been sucessfully marginalized as being more properly a design movement.

As in so many other ways, Marcel Duchamp pinpointed the issues here, in his attempts to engage the machine as both icon and medium. As Jack Burnham reminds us, when Duchamp employed the bicycle wheel in a readymade, it was not a technologically nostalgist gesture, but state of the art technology: "From a practical standpoint, the Readymade bicycle wheel was an apt choice. Only a few years before Duchamp's appropriation it had been mechanically perfected. The ball bearing mounted axle and tension wire spokes made the bicycle wheel one of the lightest and most elegant devices then in common use.... The lightweight wheel, the chain drive, the tubular frame construction made the bicycle, along with the automobile, revolutionary forms of personal transportation." (8)

Burnham later goes on to say: "More than any artist previously, Duchamp confronted the psychic and practical difficulties of realizing a viable motorized art. A Kinetic art, somehow, presented a contradiction in terms. As a sculptural totem, the machine was unassailable. Yet to function in actuality, and artistically, it had to be injected with imprecision and irrationality. Then, perhaps, it could begin to live, in doubt and indecision, as human beings do..." (Significantly, here Burnham reinforces the old dualism, allowing humans the qualities of 'imprecision and irrationality'. Once again we define ourselves in terms of; in opposition to; our technology) "...Most revealing is the fact that Duchamp, according to Lebel, regarded himself as an "unfrocked artist " after his art became centred around the Rotoreliefs. No longer dealing with the gentle illusionism of painting, nor even the leverage of Dada's tools,(irony, fallibility, and repitition), Duchamp realized that he had placed himself on the brink of raw technology. Such a situation demanded that one either draw back or plunge into a rational world of impersonally controlled effects. He chose to do the former."(9)

The Mechanical Bride

Although conventional wisdom defines Kinetic art in terms of the exploration of 'motion' as an aesthetic element, I see two distinct projects. On the one hand was the mechanization of Op art. On the other was an attempt to examine the condition of 'machineness'. As such it was the first time artists consistently engaged the 'aesthetics' of industrial production. The project was problematised by Cezannes' dictum [quoted above] because the machine was not part of 'nature'. Although it was 'designed' it was also not part of (high) 'culture'. To utilise machines as models or physical components was thus to engage in a second order creative act, or more accurately, a one and a halfth order creative act. In many cases the confontation with 'raw technology' led to the work devolving to either the more traditionally aesthetic [Op art], or the merely 'machine'.

Two of the most significant solutions to these problems came from Tinguely and Takis. Jean Tinguely managed to build into his works a profound critique of machine culture and man-machine relationships, veiled by a ludicrous sense of humour. His 'drawing machines' incisively question the creative human vs. repetitive machine schism, over a decade before it became a central theme of the Artificial Intelligence debate. His machines however, remain ludricrous by virtue of investing the machine with representations of the 'romantic' definitions of humanity. They are haphazard and surprising. They are unproductive, clamourous, self defeating and self destroying. They are ultimately anti-machine.

The works of Takis, on the other hand, are silent. They exude a mysticism which is grounded in the mysteries of basic physics, of the interrelationship of the electrical and the magnetic. They possess a quiet profundity which is easily overlooked due to their unfamiliar frame of reference.

Cyborg art

In 1950, Alan Turing asserted that machine intelligence was possible and would be a reality by the year 2000. He also proposed what is now referred to as the Turing Test. This was the industry standard, as it were, in thought experiments. Its function was to assess whether the device can be said to possess 'intelligence'. It is the essence of simplicity: connect a person and a computer by teletype to a human examiner. If the examiner cannot tell the difference after a series of questions on any subject, the computer has achieved the goal. This test in fact, would prove that the machine was more intelligent than the person, for it would have to mimic human error and slowness at calculation.(10) The Turing test is now outdated, for much the same reasons that the IQ measurement is also outdated: they are both one dimensional. We are now comfortable with the fact that a computer can play chess with grand masters but can't find its shoes in the morning.

At this same time, almost precisely mid-century, two other major theories became public: Claude Shannons' Communication theory and Norbert Wiener's Cybernetics. Cybernetics was concerned with communication between systems. It made no implicit distinction between organic-organic communication, electronic-electronic or electronic-organic. This radical formulation was confirmed by Wieners' cybernetic diagnosis of the neurological condition 'ataxia' as being a disruption of feedback loops.

Shannons' paper "A Mathematical Theory of Communication" defines information in entirely mathematical terms, and is concerned with the way an encoded message may be corrupted by noise and entropy in its passage between transmitter and receiver. His is a technical definition of information and disregards semantic content. It must be emphasized here that 'successful data transfer' and 'mutual understanding' are both definitions of communication, but they mean wildly different things. This is one of many cases when a specialized scientific definition has been 'ported' into the humanities with disastrous consequences.

The work of Turing, Shannon and Weiner laid the a theoretical base for the explosion of computing and telecommunication as ideas as well as physical realities. Their work was the beginning of information technology, of the information industry and of a new chapter in mans' relationship to his tools. For the first time they were extensions of his mind rather than of his arm. Roszak distinguishes between 'strong' and 'smart' machines: "Strong machines (the steam engine, dynamo, airplane) have had their share of public appreciation; but smart machines have elicited a very different response, a self effacing awe that has more than a touch of the pathological about it." (11) The transition from arm to mind is full of import for artists, who have long straddled the gap between philosophy and 'craft'. It evokes an identity crisis which can indeed have a touch of the pathological about it.

In 1952, UNIVAC, the first stored programme computer, was loaned to CBS to predict the result of the Eisenhower presidential election, which it did within 1% accuracy, using a 7% sample. To a large public, this was shocking 'proof' of the arrival of the 'intelligent' machine.

These developments, combined with the introduction of the transistor as a consumer item, stimulated exploration into the relationship between electronic technology and art making. Landmarks in this enquiry were the publication of Jack Burnham's "Beyond modern sculpture" and the Cyberntetic Serendipity exhibition curated by Jasia Riechart.(12) The works in the Cybernetic Serendipity exhibition were hampered by a complete lack of historical context and comparatively primitive tools. They are characterized by an arduous scientism and a mindset that found 'artness' in the more or less arbitrary translation/transduction of one phenomena into another, (music into image etc.) and the utilisation of mechanized chance operation regulated by rigid and simple structuring algorithms. It was a pioneer event and was limited by shortfalls in both media and critique.

In "Beyond modern sculpture" Burnham embraces Cybernetic theory and builds around it a new model of art practice. He argues that inasmuch as mimesis has always been the concern of sculpture, from the caveman to early modernism, anthropormorphic robotry is the logical sucessor to that tradition in sculpture and argues that the 18th century clockwork automata of Vaucanson and Jaquet Drosz are significant predecessors of this trend. (13)

Conceptual art is most often critiqued as the logical end point of the modernist project. This may well be the case. What is seldom acknowledged is its contemporaneity with the growth of the Information Revolution and the idea of 'software'. Though it did not utilise the technology, conceptual art is philosophically related insamuch as it insisted on the 'artness' as residing in the idea and being separate from any physical realization of the work. One may correctly refer to this art as 'cultural software'. Once again it was Jack Burnham who drew attention to this parallelism in his essay 'Systems Aesthetics' and his exhibition "Software".(14)

This development created something of a crisis in the institutions of the art world. The livelihoods (and fetishistic predilections?) of people in those institutions depended on a reliable supply of new art in the form of objects. The program 'History of Modernism' had hit a bug. It was sucessfully debugged (at least temporarily) by the addition of a new line, a loop instruction: If< no new art objects> goto <expressionism>. Thus was the engine of history 'jump started' again.

Reconvergence

For all the touted schism between the humanities and the sciences, the disciplines seem to be converging. This may well have to do with conditions imposed by the technology now common to both. Digital manipulation of data seems to result in a fragmenting of information; dissociation and decontextualization; on a psychological as well as a technical level. Texts break up into sections and versions, and are placed in any order. No version maintains greater authority than any other. Hypertext erodes the linearity characteristic of written argument. This fragmentation is akin to the errosion of the Empirical method by such events as the 'proof' by iterative testing of the 'four color theorum' and other proofs by computer simulation.

Euclidean and Newtonian systems are also weakening under the influence of fractal theory and chaos physics. On a more general level, the destruction of the idea of 'authority' of texts by post-modern literary criticism is paralleled by the questioning of the authority of the scientific method by writers such as Feyerabend.

Is it purely coincidental that the examination of the position of the 'author' and the 'authority' of texts by Barthes et al. is roughly contemporary with the development of word processors and personal computers? Is there no more than a lexical similarity between the Baudrillardian notion of the 'simulacrum' and the explosion of digital simulation in laboratories, amusement arcades and 'virtual reality' research?

Consumer electronics and cultural redundancy

The technology has progressed at lightning speed, and its cultural position has changed as rapidly. All the power of a UNIVAC with its 5000 vacuum tubes is now mass produced and hand held, the price has miniaturized along with the size. Sophisticated electronics now appears in consumer goods, digital watches are disposable, free in the bottom of your cornflakes. Electronics has moved out from the research labs into the shopping malls and amusement arcades.

With the advent of "user friendliness" the technology is almost always a "black box", with 'in' and 'out' plugs and variables to adjust. More or less compatible user friendly units. It is no longer necessary, nor is it possible, to understand the mechanics of the device in order to use it. Nor are the mechanics amenable to visual understanding as in the case of the Kinetic work. "Truth to materials" is an outmoded esthetic. Whereas gears, pulleys and levers have a certain accessible visual logic to them, the IC chip does not. We can experience the effects of the technology, but not its structure.

As the physical operation of the new technology is occluded, so is its political/philosophical agenda. Roszak notes: "Information smacks of safe neutrality; it is the simple, helpful heaping up of unassailable facts. In that guise, it is the perfect starting point for a technocratic political agenda that wants as little exposure for its objectives as possible." (15) Although we avail ourselves of data bases, computer banking and the like, the spectre of databases which cross reference police, taxation department, medical and welfare records is indeed a frightening prospect. The information revolution is the realization of the megalomanic civil servants dream.

Models: new and pre-owned

The exercise of art practice in the realm of digital electronics is thus a thorny task, socio-politically and also methodologically. The logic employed is abstract, mathematical; truths do not necessarily correspond to observed sensory data. The logic of conventional art practice is directly sensorial, experiential, 'suck it and see'. The art object loses its objecthood, its singularity, in the mire of digital permutations. In fact almost every defining aspect of traditional art practice is brought into question in the application of this new media.

It may be that traditional art practice is so concerned with the visible and the tangible that it has no relevance to this intangible realm. Perhaps a new discipline, unrecognizable in terms of traditional art practice, will evolve to suit the new medium.

There are models for art practice which incorporates the electronic. One of the strategies of Nam June Paik was to orchestrate the symbolic defeat of the technocracy by transmuting its tools, defeating its image. Paiks procedure is remarkably shamanistic, reminiscent of sticking pins in voodoo dolls. This kind of approach remains symbolic and naive.

Another approach is that of the Australian artist Stelarc, whose work focuses on the idea of the obsolete body. In a recent interview he summed up his position in two statements: "What's philosophically and physiologically interesting for me is that technology seems to be welcomed by the body. In other words, if technology is miniaturized, and packaged in an inert material, the body acts as if the technology is not even there, ...technology at this point is merely a tool in the process of post-evolutionary development." (16) This program is familiar from the

Sci-Fi tradition. What makes Stelarcs work compelling is his dedicated illustration of the potential of this union, on and in his own body, in performance. His use of medical electronic devices in performance exposes a technology not generally publicly accessible, whose very existence goes some way to proving his point. The cumbersome control interface of his robotic third arm has recently been outdated by the development of nerve signal interface chips which, when implanted into the body, interpret nerve impulses to drive robotic prostheses. This trend towards finer and finer interpenetration of the organic and the electronic is evident also in the development of miniature retina scanning lasers to replace cathode ray and liquid crystal screens.

These two artists demonstrate a procedure for actually utilising technological items in art production, whilst avoiding technological fetishism. They have made some important distinctions: Firstly, it is important to distuinguish beween an attitude to technology per se, and a strategy for utilisation of technology in art practice. Secondly, there is a difference between devising new tools and ways of manipulating a new medium; and the work of producing artwork with those tools. Even now, in such events as the SIGGRAPH conferences, tool development is confused with artwork, esthetics takes a backseat to engineering. Twenty years ago James Seawright offered some esthetic / methodological advice on art practice in a technological context. His words remain valid : "If you start with a conventional definition or concept of an effect or phenomenon and design back from that towards the means necessary to get it, all too often you end up with a machine or a device which produces effects. You may be able to distort or deform the thing into some structural or visual sugestion of sculpture, but the integration of form and behavior, if present, will be sheer accident." (17)

I contend that the computer has only just 'become itself', in the way that the horseless carriage became the automobile. Until recently most computer activities were simulations of analog tools: typewriter, drafting board, keyboard, paintbox. Simulation, interactivity, hypermedia and 'virtual reality' are the core of the entirely new range of potential art modes that the computer opens up.

There is a growing number of 'second generation' electronics artist who are exploring these areas, among them Jeffrey Shaw and Robert Edgar. Shaws' project for the 200th anniversary of the French revolution, "An Imaginary Museum of Revolution" was described as: "A game in space, time and ideology played on interactive videodisc installations... a conjunction of library, museum and amusement arcade."(18) Although the project is too complex to describe fully here, it is clear that this is a creative practice which has internalized the lessons of the interactive arcade game and information retrieval systems, which has integrated software design as an aspect of art practice.

"Memory theatre one" by Robert Edgar (1987) allows the 'player' to navigate a multi dimensional virtual architecture in which image icons are integrated with quotations from Levi Strauss, Frances Yates, Roland Barthes and the New York Times, among others. Most rewarding is the way that the work metaphorically discusses the topology of memory, which is directly referencing the special qualities of the machine itself. The work, the nature of its architecture and its title also reference Dame Frances Yates' work "The Art of Memory". This adds a profound historical dimension to the work, tying the notion of the computer as artificial memory to a tradition of memory training dating back to the ancient Greeks.(19)

Interactivity has yet to be explored in any depth but it is clearly a very rich field. It is a powerful tool for inculcation of responses in the 'player' as is evidenced in childrens relationship to arcade games. The arrival of software porn and interactive games which impose fascistic values is as predictable as it is lamentable. The inevitable commercialization of "virtual reality" technology can only heighten the affectiveness of this interactivity. I am unaware of any case anywhere, when a new enpowering technology was not appropriated by the power elite to enhance its power and exploit the powerless. We have no reason to imagine the game will change now. Technological utopianism is indefensible.

Conclusion

In examining the possibility of art practice using micro-electronics, basic precepts about the nature of art and art production are brought into question; one is confronted with a series of conflated oppositions such as the rationality vs romanticism, and the science vs art opposition. The two systems of operational logic are at odds. If these and related philosphical problems were not in themselves enough; any artist engaging these media must also consider the socio-political implications of working with it.

To avoid embracing contemporary technology is to opt for voluntary cultural fossilisation, for an art practice that becomes quaint and irrelevant to all but a 'cultured' few. To embrace the technology is to live and work in the real world, to grapple with the forces that are shaping it. This to me is the responsibility of the artist.

Simon Penny.

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1 J.D. Bolter 'Turing's man.' Pelican 1986. xvi : "... technology is as much a part of classical and western culture as philosophy and science and that these "high " and "lowly" expressions of culture are closely related. It makes sense to examine Plato and pottery *together* in order to understand the Greek World. Descartes and the mechanical clock together to understand Europe in the C17th +18th. In the same way it makes sense to regard the computer as a technological paradigm for the science, the philosophy, even the art of the coming generation."

2 Theodor Roszak. The Cult of Information. Pantheon 1986. p18: "In the seventeenth century, at the very beginning of modern science, astronomers and physicists appropriated the model of the clock to explain the mechanics of the solar system and soon taught their society to see the entire universe as a clockwork instrument."

3 Elting Morison. Men, Machines and Modern Times. MIT Press 1984 Chapter 6: Men and Machinery. pp98-122

4 William Shakespeare. Hamlet. Act 2 scene 2.

5 These issues are discussed further in my essays: "New Territory, Art practice in the digital environment" Artlink magazine March/May 1988 and 'Charlie Chaplin, Stelarc and the future of humanity'Artlink magazine March/May 1989

6 Jacob Bronowski "The common sense of science" Vintage/Random House (undated) p12. Conrad Atkinson, in a lecture at Carnegie Mellon University in 1990, and elsewhere, has shown that the 'Romantics' are often misrepresented in cultural history writing. He demonstrates that, far from having their dreamy heads in the clouds, these people were, like William Morris, intensely motivated socio-political activists. see also: 'The country and the city'. Raymond Williams. Oxford 1973

7 It was Walter Benjamin who pioneered the analysis of the history of modernism in terms of this new industrial environment. cf. Walter Benjamin. The work of Art in the age of Mechanical Reproduction. in Illuminations. Harcourt Brace + World. New York 1968

8 Jack Burnham, 'Beyond Modern Sculpture' George Brazilier 1968, p227

9 Jack Burnham. ibid p230

10 This test is telling in its anthropcentricity, the implication being that human intelligence is the epitome of possible intelligences, which belies its ultimate grounding in Christian theology. This test also implicitly asserts that intelligence is a linear phenomenon, that degree of intelligence can be measured like a test of strength, the hammer and bell game at old country fairs. But intelligence is demonstrably a vector phenomenon and machine intelligence already far exceeds human ability in some fields.

11 Theodor Roszak. ibid p40

12 "Cybernetic Serendipity" a Studio International special issue, ed Jasia Reichart, 1968

13 I examine the theme of anthropomorphism more fully in The Intelligent Machine as Anti-Christ, S.Penny1990

14 Jack Burnham Systems Aesthetics. Artforum V viii #1 September 1968.

15 The Cult of Information. p19

16 Eyeline magazine (Brisbane, Australia) nov 1987, p8

17 Beyond Modern Sculpture p359

18 An Imaginary Museum of Revolution. Jeffrey Shaw and Tjebbe van Tijen. Editions De Struikrover, Amsterdam. 1988

19 see: Musings on an interactive postmodern metaphor. Fred Truck. High Performance #37, 1987.

THINKING OF ONESELF AS A COMPUTER

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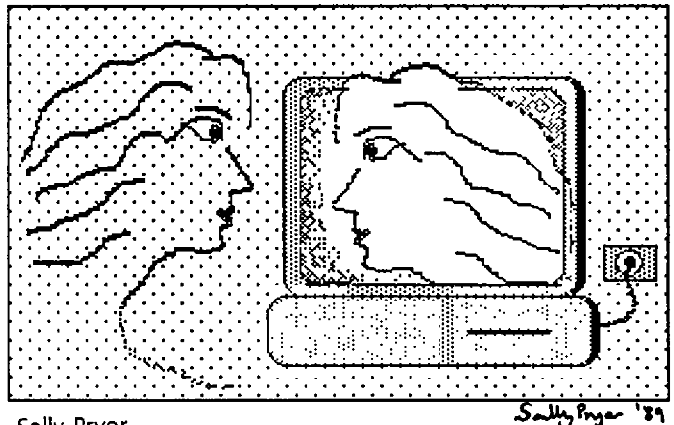

Sally Pryor
untitled

I've been an enthusiastic computer artist/animator/programmer since the early 80's. I'm fascinated by the new forms of artistic expression, communication, simulation, extension of the senses and pleasure that are made possible by computer graphics/animation and concepts such as virtual space, interactivity, artificial intelligence and networking. As an ex-biochemist, I'm also hopeful about the potential of these areas to form a kind of a bridge between the arts and sciences, although this certainly will not happen overnight.

What I'd like to explore here is the somewhat disembodied landscape surrounding the human and the computer, a landscape in which the computer is increasingly used as the metaphor for the self. These interests arise directly from my experience last year of developing symptoms of Repetitive Strain Injury (RSI) - pain, heaviness and weakness in my right arm and hand.

1. The Human/Computer Connection

"If you neglect your body it will revenge itself by making you lose your mind"[1]

If you're a cerebral sort of person, the kind of person who is more involved with what's happening in your head than in your body, the computer gives you a way to be even more like that. Aside from your arms, hands, eyes and brain, it's almost a nuisance to have a body when you're working with a computer. It gets in the way of the mesmerizing interaction between the screen and your mind, unreasonably demanding food and attention -or that's how it seems, stiffening your back and shoulders when you just want to keep going and going.

One of my dreams was always to have a computer graphics studio at home. Now that I have this, there have been many times that I have completely ignored all bodily sensations during marathon computer sessions. The most squalid moment was probably being force-fed by my partner while still sitting in front of the screen!

The computer gives you a very seductive way to extend your abilities and senses - to produce slick-looking documents when you can hardly type at all, to recall and digest large amounts of information, to visualise mathematical formulae, to model scientific processes, etc etc. I find, as an artist, that I can make images that I couldn't or wouldn't consider using traditional media. It's also fascinating to envisage the new forms of art that are possible with computers: for example art that interacts with the viewer in a meaningful way. The art-object as unique, financially appreciating artefact is seriously threatened by these developments.

But despite the very real sensual pleasure I feel from the images I make, I can't help noticing how un-sensual computers and their interfaces are. The senses of smell, touch and taste are barely represented in the hard grey plastic boxes and input devices. An interesting exception to this trend is Allison Druin's "Noobie"[2], a huge furry creature that children squeeze and touch in order to communicate with the computer.

The kinaesthetic body, which is absent in the current computer interfaces that are based on keyboard or mouse, may well enter the picture when the concept of virtual space becomes readily available. Using body suits and gloves, you could move your whole body to interact with a synthetic world that you see in special glasses. In this way the computer could provide a kind of virtual prosthetic device for the body: for example you move your arms, and in your glasses you see a DNA helix being split apart by probes. The possiblities here are fantastic.

But what about when we use computers to communicate with each other? "Reach out and touch someone" intones the phone company and we scarcely stop to remember that we can't actually do that with a phone call. The same is true for communication through computer networks: text takes the place of person-to-person interaction.

Timothy Leary[3] says that we could use virtual space to do all sorts of things with each other, such as a game of tennis between people in two different locations. In fact he says, the only thing that would be difficult would be exchanging bodily fluids, a humorous remark which draws attention to the absence of direct corporeality which pervades the concept of virtual space. What does it mean that this concept has been so eagerly taken up recently in popular culture? And why are we so captivated by the idea of a process that bypasses direct information from most of our own bodily senses?

"I'd just been an artist-in-residence working on a project I really believed in: using computer graphics as a way to introduce girls and women to the computer. I'd run out of money and was working again as a commercial 3D computer animator, flying hi-tech logos that were all form and no content. My shoulders were hunched, my hands suspended tensely over the keyboard, ready to two-finger type another comand the second the previous one was completed. A few keys had to be bashed to make them function. In my spare time I made images, working intensely with the mouse grasped tightly in my right hand. To unwind I drowned myself in a sea of TV."

2. The Computer as Metaphor

"Computers are our symbol, our logo"[4]

Throughout history there's been an intimate relationship between the latest technological advances and the metaphor for the self. This is somewhat of a 'chicken and egg' relationship - it's hard to say which comes first, the technology or the view of ourselves.

The Greeks lived in a technology based on craft and likened man to a clay vessel. More recently, the advent of clocks enabled Rene Descartes in the 17th century to liken a sick man to a badly made clock. Since then machinery has been very much the metaphor for self. This is largely subconscious: people speak of being rusty or sharp, broken down, running on empty, etc etc.

Today, as the boundary blurs between technology and the body, people seem to be shifting almost unconsciously from this mechanical model of themselves to one based on the computer. I notice this initially amongst scientific and technical people. The computer metaphor is increasingly used to explain or model human biological processes: for example references to information supposedly 'hardwired' in DNA, to the idea that biological organisms are really information processing devices or that the mind is just a complex pattern of information in the brain. Actually the brain comes in for alot of these computer metaphors - it is sometimes referred to as wetware', often considered to function just like a computer. I have even heard references to the 'wiring diagram' of the brain.

Recently a computer programmer was telling me that he was feeling off-colour: "my software's OK but I think my hardware has problems". In Denmark a young man became psychotic with what was called a 'computer syndrome' after many 12-16 hour a day sessions at his computer[5]. Apparently he was hospitalised with insomnia and anxiety after he began to think in programming language, waking up in the middle of the night thinking "Line 10, go to the bathroom, Line 11 next". He told doctors "there is no difference between the computer and man".

While this last example may be extreme, I have caught myself jamming my finger, thinking "UNDO" and expecting this to happen. I know I'm not the only person to start thinking of myself as a computer.

"One morning I woke up and decided to do something about how increasingly tense my shoulders felt, so I arranged to have a massage. The masseur unlocked some of my frozen muscles and sent me to an osteopath, who, in the course of his work, commented that the tendons in my right arm were like those of a sheep shearer. Coming from a farming family, this comparison did not alarm me (actually I felt proud!) until he said that the reason shearers drink so much is that they are in so much pain. It was then that the pains, heaviness and weaknesses in my arms, wrists and hands were correlated with tendonitis; I paid attention when there was a

medical label. It enabled me to take sick leave from work and to permit myself to rest. I have not flown a commercial 3D logo since, I became a teacher instead."

3. Mind/Body Dualism

"Matter is a word, a noise....matter is spirit named"[6]

What does it mean to think of yourself as a computer? To me it seems to reflect the Cartesian mind/body dualism, with mind equating with software and body with hardware. To understand the mind/body dualism I will turn to the writing of Elizabeth Grosz[7]:

"With rare exceptions in the history of [Western] philosophy, the mind and body have been conceived in isolation from each other, functioning as binary or mutually exclusive terms. The attributes of one are seen as incompatible with those of the other. In, for example, Descartes' influential writings, the body is defined by its extension, that is its capacity to be located in, to occupy space. By contrast, the mind is considered as conceptual, based on Reason."

Thus the mind is considered conceptual and non-spatial; the body spatial and non-conceptual. "Subjectivity and personhood [is identified] with the conceptual side of the opposition while relegating the body to the status of an object, outside of and distinct from consciousness."

"This binary opposition is commonly associated with a number of other binary pairs: culture and nature, private and public, self and other, subject and object...Mind becomes associated with culture, reason, the subject and the self; while body is correlated with nature, the passions, the object and the other....Excluded from notions of subjectivity, personhood or identity, the body becomes an 'objective' observable entity, a thing...The fact that the body is the point of origin of a perspective, that it occupies a conceptual, social and cultural point of view cannot be explained on such a model"

"It is very difficult to get a clear understanding of tendonitis and RSI. The area is contraversial and heterogenous, Many claim that it is all in the mind and that there is no observable damage to the body, although the Lancet[8] has reported an Australian study where muscle biopsies of RSI sufferers showed striking abnormalities in both muscle tissue and cells. It's clear that emotions such as boredom and stress are intimately involved in the development of RSI, however bad ergonomic design and lack of regular movement also are very important. The trance state that seems all too easily to develop when using a computer freezes the body's postion and the blood can't flow freely to nourish tissues and remove waste products. Repetitve movements and (I suspect) alot of mouse action only make things worse."

4. An algorithm for the Self?

"Your body is a burden. It is simply meat"[9]

The mind/body dualism means that mind, equated with the self is considered conceptual and not spatial; body, equated with the other is considered spatial but not conceptual. Applying this to a computer metaphor for the self, we end up with the body as hardware and the mind as software.

What could this mean? To me it reflects the idea that one's subjectivity or sense of self could be reduced to software, to a set of instructions that could operate independently of the body. Understanding oneself would become a problem of coding, of finding the right algorithm. The body, being hardware, would be replaceable, possibly redundant.

This idea is seductive and has been taken up enthusiastically in various circles: most notably parts of the AI community, cyberpunk Sci Fi and increasingly, popular culture. "Your body is a burden" says a 'Cyber Dada Manifesto'[10], "it is simply meat....all physical and emotional feelings can be chemically simulated..be totally efficient...the end of the world is coming but it's the beginning of the perfect techno world" and so on.

Hans Moravec in his book 'Mind Children'[11] speaks of a post-biological world, where the human brain is freed from its mind (and body) and loaded into self-improving, thinking machines that he calls "mind children". He talks of our "uneasy truce between mind and body" and recommends that "human thought [be] released from bondage to a mortal body". The essence of himself, he says, is "the pattern and process going on in his head and body, not the machinery supporting that process..the rest is mere jelly".

'Jelly', 'meat': these are not terms that imply respect. The body seems to take the blame for all perception of vulnerability, need and mortality. "We have been taught to neglect, despise and violate our bodies and put all faith in our brains"[12]. The assumptions seem to be that the real you is the thoughts in your head, that if you can leave the body behind you will never have to feel pain again. If only this were true!

"I'd seen myself primarly as a brain attached to a stick figure - a kind of semi-intelligent robot. I thought my body's function was to carry my mind around; my arm's role was to execute my ideas. Food was just a fuel to keep the whole thing going. I felt beyond the body, superior to people caught up in what I privately called the 'Jane Fonda Syndrome': obsessively working out at the gym, dieting, sculpting, painting and improving their bodies so that they met the current standards of desirability. Sport seemed foolish too: just another way to be intensely competitive with others."

5. A Cork Bobbing in the Ocean

"He said I treated thoughts as if I generated them myself but in his view they were like animals in the forest"[13]

If the concept of an algorithmic self denies the body's role in subjectivity, what else could be omitted? To investigate this question I'll ignore the public/private dualism and look at Descartes' personal life.

In his early twenties, Descartes had a series of three dreams which changed the course of his life and of modern thought. In his sleep, the Angel of Truth appeared to him and, in a blinding revelation, revealed a secret that would "lay the foundations of a new method of understanding and a new and marvellous science"[14]. Descartes embarked on a quest to understand how the mind works, inventing analytical geometry so that a mathematical model could be derived. This task proved more difficult than he had anticipated and he never finished his treatise. But he also never returned to the source of his inspiration. His writings do not mention the role of dreams, revelations, insights as the foundations of thought. Instead he gave all his attention to formal, logical procedures that supposedly begin with zero.

So we're talking here about the unconscious. According to Jung as interpreted by Robert Gordon[15], "when we say 'I' we are referring only to that small sector of ourselves of which we are aware...Jung compared the ego, the conscious mind, to a cork bobbing in the enormous ocean of the unconscious...He concluded that the unconscious is the real source of all our human consciousness- our capacity for orderly thought, reasoning, human awareness and feeling... The disaster that has overtaken the modern world is the complete splitting off of the conscious mind from its roots in the unconscious. All the forms of interaction that nourished our ancestors- dream, vision, ritual and religious experience- are largely lost to us, dismissed by the moderm mind as primitive or superstitious."

An algorithm for the self could only include the parts of our ourselves of which we are aware - the conscious mind - and would have to omit the unconscious, an area we can barely grasp and certainly not directly. The unconscious expresses itself through the body and in symbols rather than in verbal or abstract forms.

You hear alot about the quest to develop artificial intelligence and almost nothing about developing (say) artificial dreams, compassion or imagination. This must be linked with the fact that "computers are at their worst trying to do things that are most natural to humans -seeing, hearing, manipulating objects, learning languages and commonsense reasoning....It is comparatively easy to make computers exhibit adult-level performance in solving problems on intelligence tests or playing checkers and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility"[16].

"I've had an extremely naive attitude to my body. I've treated it like I treat my car: I do the minimum required to keep it on the road. The RSI experience frightened me because I realised how vulnerable it is and how many of the things I enjoy (like making art) require the use of my hands. Clearly my attitude has got to change. And it is, slowly, although I feel tremendous resistance to paying attention to the stories and secrets of my body. I've chosen a form of exercise, Middle Eastern Belly Dance, that intrigues me despite its appropriation by titillation. My mental interests are irrelevant in class, I get a fleeting glimpse of a completely new sense of myself moving fluidly through space. Of course I still don't practise between classes, I'm still more likely to read a book or watch TV. I've set up my computers now so I can use the mouse with my left hand. This works quite well but I hope it doesn't just mean I'll ruin that arm too."

6. Throwing the Body out with the Bath Water

" the cyborg is our ontology"[17]

What else might be the concept of an algorithmic self omit? To return to Elizabeth Grosz, "Patriarchal oppression justifies itself through the presumption that women, more than men, are tied to their fixed corporeality...[Women] are considered more natural and biologically governed, and less cultural, to be more object, and less subject than men. Women's circumscribed social existence is explained - or rather rationalised - in biological terms and thus rendered unchangeable[18]."

So the feminine is allocated to the other/body/emotions/object side of these dualisms and hence would implicitly be omitted from an algorithmic concept of the self.

For Descartes the body differs from material objects -including machines- only in its degree of complexity. Thus he links the body not only with the other, the animal and the passions but also with the machine. But aren't machines and emotions a bit incompatible?

To explore this tension I will return to Descartes' private life. He was very interested in automata and apparently possessed a mechanical doll or automaton named Francine[19], which probably used clockwork mechanisms to move and make sound. Very little is known about it/her except that it was named after (and possibly built to resemble) a well-documented illegitimate daughter from whom he was unhappily separated. Apparently the doll acted as a sort of travelling companion and met its end on a sea voyage when the ship's captain discovered it in a packing case and angrily threw it overboard.

So here's a clue: Mr 'I think therefore I am' in his private life linking the body, the machine and the emotions through an association with the female, specifically a female robot. I must admit that there is some doubt about whether this story about Francine is just an urban myth. But even if this is the case, as a metaphor the story is powerfully expressive.

The modern equivalent to Francine in popular culture is the female cyborg: part organism, part computer. Very few representations of supposedly female cyborgs fail to fill me with alarm. A common image is of a Playboy-style woman's body and posture, rendered in the sleek perfection of chrome. I can't relate this image to my own experience of being female. A recent advertisement for computer graphics software consisted of such a cyborg, detailed breasts lovingly rendered in chrome, with the text, "I ROBOT. YOU BOSS."

One of my students, Carmel Kremmer[20], asked "Could it be that computers are being designed as silent, powerless, co-operative substitutes for women - in the workplace, in the home, in bed even? Automated companions who provide "the illusion of companionship without the demands of friendship."[21]?

Is this an extremist view? I don't know, but I do agree with this statement from the authors of 'Gender at Work' [22]: "Computing is in fact no more Uni-sex than Playboy....We have to be clear about what is going on at the symbolic level and speak out about it."

"I'm under pressure at the moment and very busy. I've even missed my regular dance classes. My right arm is particulary tired and my back aches. I now know several things I could do to help (such as going to a class, mental visualization exercises etc) but I'm so busy that I'm mostly ignoring it. Today I feel frustrated and ridiculous. I worked on this paper for four hours straight yesterday and now my back is very sore. I tell myself I will do the right thing and take breaks every 3/4 hr today: when I do I'm shocked at how fast the time goes. We make a big effort at the University to encourage students to be aware of ergonomics and taking frequent breaks from the computer. But I still see them hunched over their screens and keyboards, mesmerised, hours seeming like minutes. When I say something they sit up guiltily but I know that they don't believe it could happen to them. And why not, I didn't either."

7. Return of the Angel

"Data, data everywhere and not a thought to think"[23]

I've identified three areas of ourselves which would be omitted from the concept of an algorithmic self - the body, the unconscious and the feminine. I'm sure that these are intimately linked, I'm also sure that this list is incomplete. I know I have a blind spot, I just don't know where it is.

I've focused alot on Descartes because he is the defining man of our scientific and technological culture, the Cartesian coordinate system as it were. Leola Jacobs [24] postulates that the paradigm of technological knowledge assumes a rational, cartesian, sex-neutral and disembodied subjectivity. Could it be that the concept of the self as software provides the ultimate Cartesian, sex-neutral, rational and disembodied subjectivity? Could it also be that the algorithmic self offers the ultimate refuge from animality, the unconscious and even the feminine? Perhaps it's appropriate that Time magazine named the computer "Man of the Year" for 1982?

For the reasons I've outlined, the concept of an algorithmic self frightens me. I think it's vital that we invite the body, Descartes' Angel and Francine back in from the cold and integrate them back into our conception of ourselves and into our model of the computer.

This is particularly important so that we do not just replicate and reproduce current values in the defining technology of the future. We need to be aware that computers are not a neutral tool, that they arise from and embody the values of a cultural and philosophical context. It's time to ask whether the computer reflects a discourse of disembodied and abstract reality, a discourse of power and control over the other, the object, the emotions and ultimately the feminine.

As I said earlier, there a 'chicken and egg' relationship between the latest technology and our model of ourselves. So not only do we make computers and then explain ourselves in the new terms, but also we see ourselves in a certain way and make technology in that image. So what does this tell us about the way we see ourselves?

I referred earlier to the concept of virtual space. Timothy Leary's bodily-fluids joke is funny, but it also highlights the fact that virtual space can be seen as representing a retreat from direct experience of the senses, each other and our environment. Is this a solution to the problems of modern life?

Perhaps the violent reaction to computers that one sometimes receives from people outside the field is a response to this remoteness, to this abstraction, to the idea of reducing the self to an algorithm, to a piece of information in a giant data base?

So the question is, what can we as artists, scientists and technologists do to return these missing babies to the bath water? What should we do? What responsibility do we have as people with a priviledged (though it can seem marginal) access to the defining technology of our age?

In closing I would like to quote two authors who, while writing about apparently different areas, converge at the crucial need for a holistic point of view:

"Our body is ourself. It is our only perceptible reality. It is not opposed to our intelligence, to our feelings, to our soul. It includes them and shelters them. By becoming aware of our body we give ourselves access to our entire being- for body and spirit, mental and physical and even strength and weakness represent not our duality but our unity."[25]

and

"The machine is not an 'it' to be animated, worshipped or dominated. The machine is us, our processes, an aspect of our embodiment. We can be responsible for machines 'they' do not dominate or threaten us."[28]

"I'm starting to feel a bit spacey sitting here at my computer working on this paper. It's so easy to capture my thoughts and to work with them: editing, moving them around, making images, picking up writing from other documents etc etc. I'm very involved in this process. My body, when I remember to notice it, begins to feel stiff, even so I must FORCE myself to stop work for a while. But first I type this text, then add something else, then change something else......."

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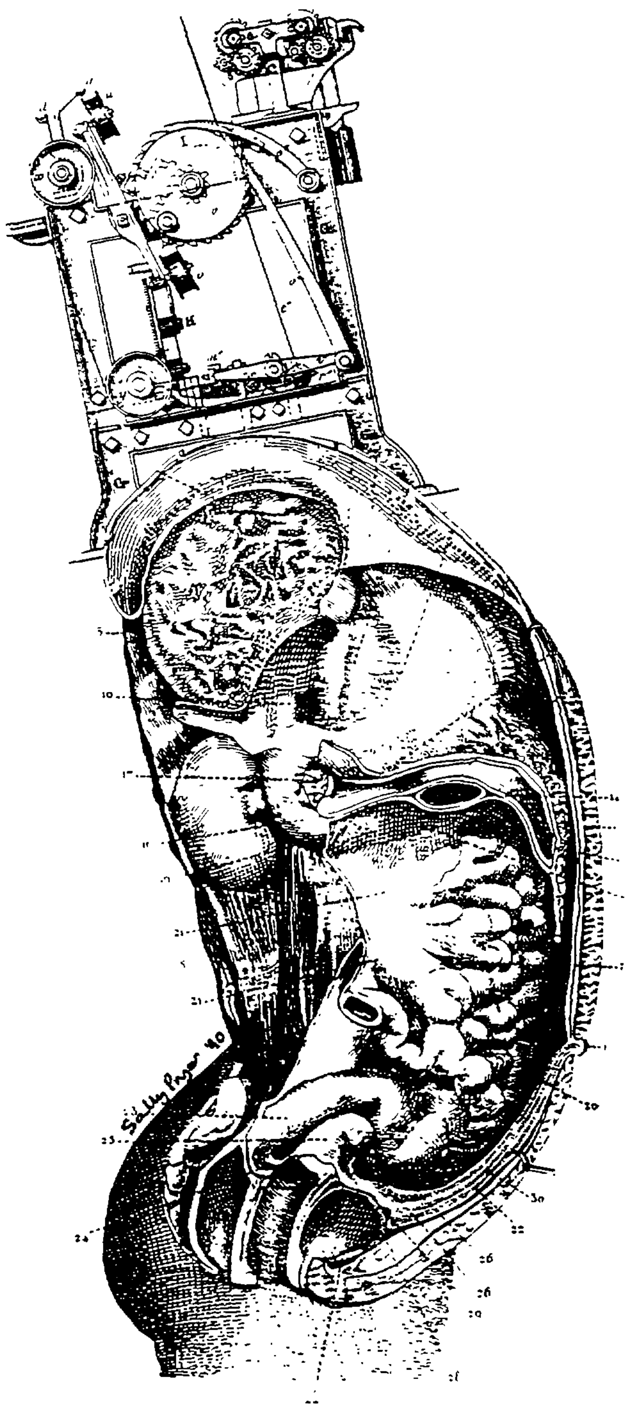
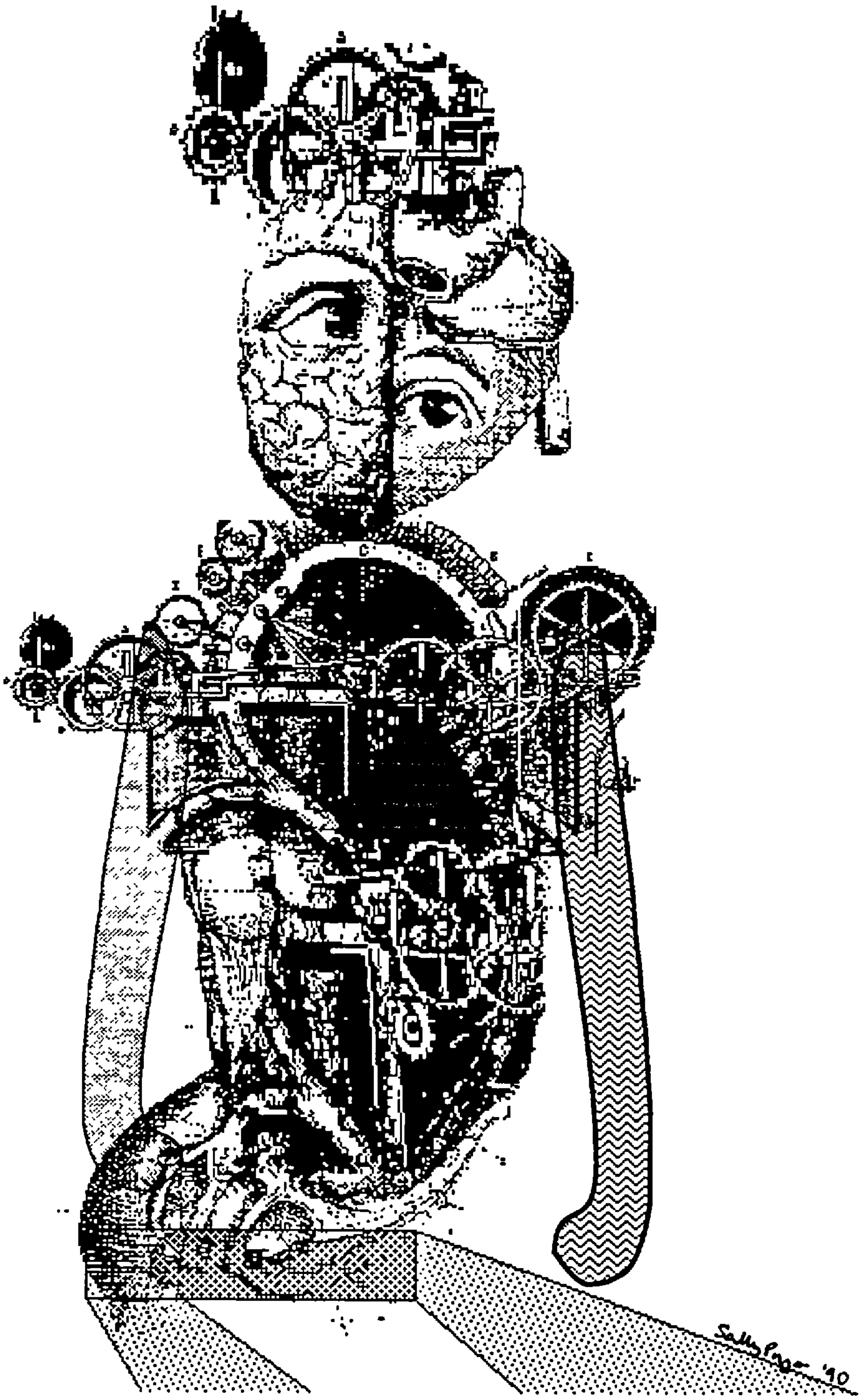
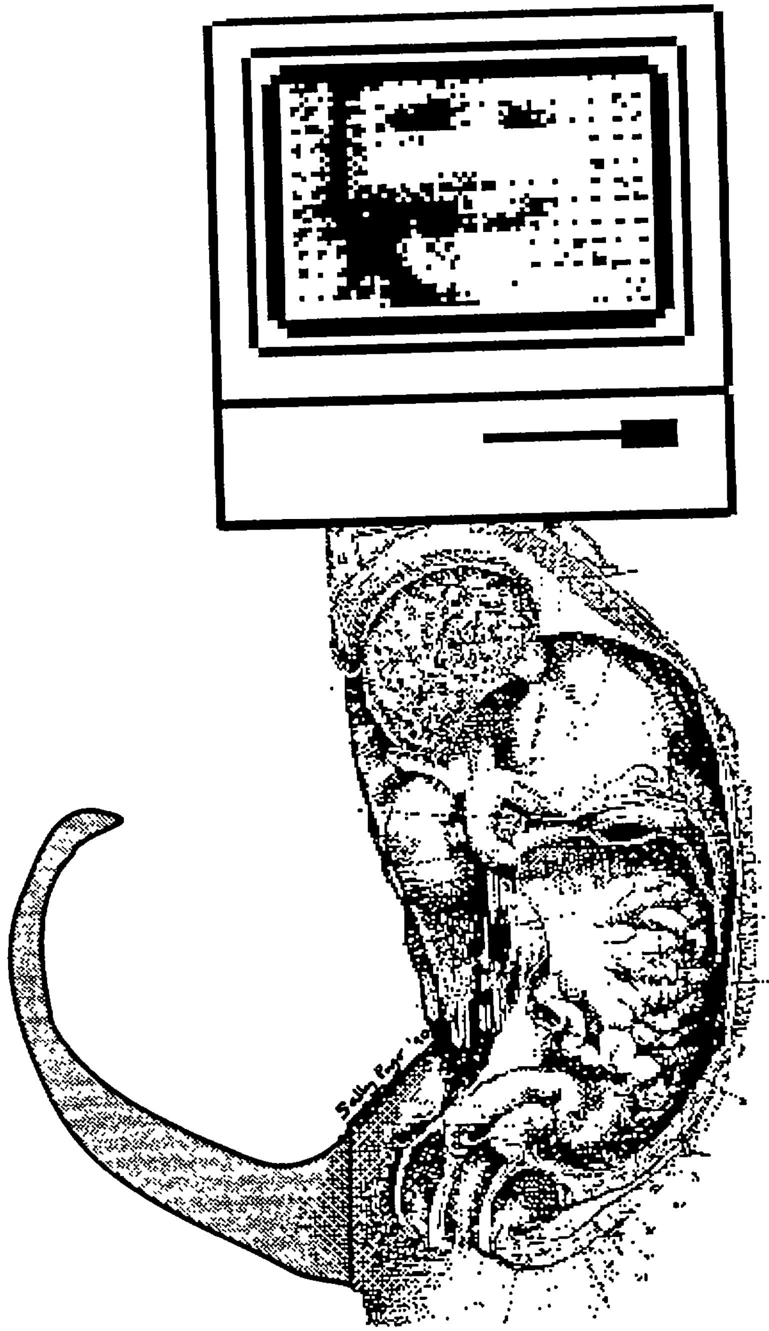


Sally Pryor
Cyborg-1



Sally Pryor
Cyborg-2



Sally Pryor
Cyborg-3

THE INTELLIGENT MACHINE AS ANTI-CHRIST

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ABSTRACT: This paper outlines a general drive in our species to anthropomorphism, and makes particular reference to the anthropomorphic machine. It traces a line forward from the Venus of Willendorf through Greek sculpture to Artificial Intelligence and robotics. The psychology of anthropomorphism is considered. The idea of the robot as personification of fear/fascination with the technological complex is considered in this context. The relationship of cultural production to technological change is examined.

"...And what rough beast
its' hour come round at last
slouches toward Bethlehem to be born?"

(W.B.Yeats : The Second Coming.)

Two cultural tendencies seem to converge on the millenium. (1) One is ancient, the other is relatively young. The first is mans' desire to simulate himself, the urge to anthropomorphism. It seems that human intelligence has always interpreted the world outside in terms of itself: "Man is the measure of all things". We are bound to anthropomorphize.

One of the propositions underpinning this paper is that no particular medium of creative pursuit has a monopoly over any particular subject matter or concern. We could not suggest that the concern "love" is only available to the medium of poetry, nor that poetry can only be about 'love'; traditional cliche notwithstanding. Likewise I propose that anthropomorphism inhabits various aspects of cultural practice at various times, it is not confined to any one discipline, period or cult.

The second tendency converging on the millenium is the gradual erosion of the established qualities by which the race defines itself to be unique. In earlier times, man defined himself with respect to animals and the distinctions were clear and stable. Now it is with respect to the machine that man defines himself. This is paradoxical because the machine is itself a product of man.

As the machine encroaches ever further on these sacrosanct human qualities, it induces fear. There is a psychological fear that we will be made irrelevant by our own creation, as the aging parent is by the adult child. The second fear is a pragmatic one: a fear of retrenchment as workplaces become automated. These fears have become 'personified' in the Robot, the anthropomorphized machine.

In using the term 'Robot' here I must clarify that the term has two concurrent and only vaguely related forms. The first, historically, is the robot in literature, amongst which we must count Frankensteins' monster as a precursor. (Life, once again, mimics art.) The term 'Robot' is itself a product of literature, it was coined by Czech playwright Karel Capek in his play 'Rossums' universal robots" of 1921.(2) The second is robot of science and industry. These correspond roughly to the two types of fear outlined above.

A robotics professional might object that current and future generations of industrial robots become less and less anthropomorphic. Indeed, all new technologies are modelled on previous technologies and 'become' themselves through development. In the case of the motor car the model was the horse-drawn carriage, in the case of the robot it is the human body. There remain many decidedly anthropomorphic projects.

The point at which an device ceases being a robot and becomes and automated machine or system is to my knowledge, not clearly defined. A toaster can be regarded as a primitive robot. In the same sense the point at which a form ceases to be anthropomorphic is ill defined. This question was a major issue in modernist sculpture. As the focus of this discussion is anthropomorphism I will concern myself with robots which possess anthropmorphic features. For the purpose of this argument I claim a wider than usual definition of the term to include not only objects whose static form resembles the human, but devices whose functioning is modelled on human processes. In these terms, although externally less anthropmorphic than its fictional cousin, the modern industrial robot is still predicated on anthropmorphic premises.

Robotics and Gender Politics

It is sobering to reflect on the gender of the creators of robots both in fiction and fact. They tend overwhelmingly to be men. One wonders if there is not some kind of a sexist agenda built right into the entire study. On a psychological level one might hypothesize an overcompensation for 'womb envy'. On a social/political level it is conceivable (no pun intended) that they may well express a desire to make women redundant and powerless. In this regard, it may be construed as a covert expression of patriarchal values.

This desire to replicate human life by other than the usual means is not restricted to robotics. Biological engineering and particularly in-vitro fertilisation are major enterprises of that variety. In her eclectic essay of 1984, Donna Haraway notes: "Pre cybernetic machines... were not self moving, self designing, automouous. They could not achieve mans' dream, only mock it. They were not man, an author to himself, but only a caricature of that masculinist reproductive dream. To think otherwise was paranoid. Now we are not so sure. Late twentieth century machines have made thoroughly ambiguous the difference between natural and artificial, mind and body, self developing and externally designed and many other distinctions that used to apply to organisms and machines." (3)

In-vitro fertilisation can also be seen as a scientific realization of the ancient alchemical enterprise to create the homunculus, which, one might hypothesize, was prompted by a similar male drive. I am not aware of any alchemical exercise to create 'the little woman', nor of female alchemists. These qustions are however, a diversion from the subject of this paper: the enterprise of artificially procreating real people is a study in itself. In this paper I concern myself specifically with the creation of simulated people.

Gods in the Image of Man

Anthropomorphic sculpture is the earliest of the forms of simulated people. We must assume that before sculpture was regarded as a *cultural form* , a conventionalized practice, it was considered simply as a *representation* . Whether the Venus of Willendorf was a representation (in the sense of a portrait) of a specific woman or represented womanhood in general, or represented a fertility deity; we might confidently assert that she was not made to be put in a museum. The Greeks, the Egyptians, the Chinese and the Indians we must recall, stuccoed and polychromed their sculpture to achieve the closest possible verisimilitude.

Greek myth is replete with stories of the non genetic creation of people. The stories of Talos and of Galatea are two examples. They are both statues breathed with life by the Gods. Deities in general tend to be anthropmorphic: from the various Greek, Egyptian and Hindu deities with their human bodies and animal heads, to the God of the Hebrews. (Who was created in whose image is a moot point.) I suggest that the 'Robot' of literature and cinema should be considered in this way, an anthropmorphic 'deification' or objectification of a perceived 'power' in contemporary culture.

Kinesthesia and Clockwork

We are dynamic beings whose nature is located in movement as much as it is in form. As Buckminster Fuller said: 'I seem to be a verb'. We move through space and a significant part of our perceptual machinery is devoted to recognising time based pattern. We recognise things by the way they move, as much as by their static appearance. Cassius, in Shakespeares' Julius Caesar says: "'Tis Cinna; I do know him by his gait; He is a friend."(4) It was not long before the static likeness was made redundant by the development of practical mechanics which could *articulate* form. By 100AD, Hero of Alexandria had constructed many mechanized sculptures and tableaux powered by water.

It could be argued that 'sculpture' became a form of conventionalized cultural practice, became 'fossilized', at the point when technological development produced a technique more appropriate for creating likeness: a technology which could describe change through time; movement. This drive to anthropomorphism demonstrably occupies whatever technological and cultural niche provides the most sophisticated representation at any one time.

Medieval alchemy and Kabbalistically inspired necromancy are replete with attempts to create homunculi, as related in Goethe's Faust. We should recall that Dr Frankenstein served his esoteric apprenticeship studying the works of Cornelius Agrippa, Albertus Magnus and Paracelsus. His monster was not wholly new, a product of the new scientific attitude, but was also the realization of the alchemists quest for the homunculus. Nor is the idea of an alchemically produced homunculus specifically western, ancient Chinese alchemy texts relate similar enterprises. Yiddish literature hosts a similar product of mystical science, the Golem.

Between Hero of Alexandria and Baroque Europe, the development of mechanical automata continued in Islamic culture. It is said that the Caliph of Baghdad had a golden tree upon which perched many silver mechanical birds which sang and flapped their wings. (This story is also related of the Byzantine Emperor Porphrygenitus.) They may have had anthropmorphic machines as well.

The invention of clockwork in the C17th enabled devices to become autonomous of external power sources. This brought about a plethora of new automata, the most spectacular being 'the clerk' by Jaquet-Drosz (1774), which dipped its quill into an inkwell and wrote a page of perfect copperplate text. Vaucansons' mechanical duck (1738) is extraordinary in the extent to which it simulated organic processes such as digestion. The device would 'eat', and shortly afterwards, shake its tail in a characteristically duck-like way and eject some foul smelling waste matter. Although these works achieved world renown, they were regarded as curiosities and spectacles and were not allowed into the hallowed halls of fine art.

Clockwork was the paradigmatic technology of the day. It was more than just a tool. It helped shape the world view of the culture. With the proliferation of clockwork and the new reality of machine divided time, people (among them Descartes) discussed the motion of the planets and the functions of the body in terms of this technology. Many of the clocks contained within them clockwork models of the movement of the planets and mechanized human and animal figures, the great astronomical clock of the Cathedral of Strasbourg being an extant example.

The proliferation of reliable and precise mechanical techniques during the industrial revolution allowed for more complex automata. Among these were the Theatra Mundi, mechanized theatrical dioramas popular in Europe and the USA in the C18&19th, which persist only in Department store Christmas window displays. (5)

Mechanical Reproduction and Modernism

Industrialization also introduced the spectre of industrial degradation of society which seeded an enduring cultural schizophrenia towards the machine, our slave and our master. Movements such as the Craft Movement of William Morris promoted and anti-industrial, anti-technological attitude among the makers of culture. These occured for the best possible reasons at the time. There was great cause for concern during the industrial expansion: for life and limb, liberty and the preservation of culture and tradition. (6)

From this point on the machine personified became the focus for this schizophrenia. Frankenstein is an early expedition into the area. By the time of Fritz Langs Metropolis, the familiar formula is complete: Rotwang says: "At last my work is ready. I have created a machine in the image of man, that never tires or makes a mistake. Now we have no further use for living workers...Give me another 24 hours and I'll give you a machine which no one will be able to tell from a human being." (7).

Charlie Chaplin in Modern Times depicts a naive and romantic symbolic defeat of the machine exactly by those qualities which make people unmachinelike. It is this act of definition *with respect to* or *in opposition to* the machine which indicates that it was no longer "nature", but the machine, against which man measured himself. Furthermore, there would be no need to make such protestations if it was not feared that the machine had the upper hand. As Albert Einstein responded to the publication of a book entitled '100 authors against Einstein': "If I were wrong, one would have been enough".

As late as the mid sixties, sculpture theorist Jack Burnham still employs this romantic dualism: "Without the advantages of cybernetics Tinguely has come closest to "humanizing" the machine. A precise definition of "human" is elusive. It is not an extension of the anthropomorphic precision which characterizes the automata collection at Neuchatel. Rather, to be "human" is to expose oneself through animal vulnerability and fallibility. Standing alone in a room, one of Tinguely's metamechanical works appears nakedly subject to the whims of the gods -like the standing male nudes of archaic greece, the kouroi."(8)

Why have the anti-technological values of the Craft Movement remained stained onto the art community until the present day, while the immediate industrial conrterxt changed radicallly? My suspicion is that as the machine became more sophisticated, it began to encroach further into territory which was regarded as definingly human. For a machine to spin yarn or pump water is one thing. It is another thing entirely for it to create images (ie photography) and thereby threaten painting, one of those activites regarded as a crowning glory of the species. The suggestion that technological innovations made traditional art practices redundant, and thus prompted the explorations that resulted in modernism is one that is rarely entertained among art historians, but I believe that it is difficult to refute.

Giant Brains

During World War II electronic computing machines in Britain and the USA were developed by the likes of Alan Turing and John von Neumann. In attempting to endow these machines with powers of logic and reasoning, these researchers were modelling the mind outside the body. The model for this reasoning could not be other than human, and hence we enter the period of 'abstract' or 'disembodied' anthropomorphism. Alan Turing declared that artificial intelligence would be a reality by the year 2000 and devised a test (now known as the Turing test) by which one could assess computer intelligence. The test was sucessful if a human questioner could not distinguish between the responses of a human and a machine. It was baldly anthopocentric as it presupposed that the only and ultimate form of intelligence was that possessed by people.

In the following two decades, computer research split into two parallel streams, each with its boom periods. One of these streams was based in analog computing and emulated the sensorimotor behavior of its biological models. This was cybernetics.

Cybernetics is predicated on the notion that machines and living beings are essentially similar in the way they relate to the world. (This is the same as saying that machine behavior is modelled on animal behavior.) Norbert Weiners sucessfully applied this theory in his correct diagnosis of ataxia, a human neurological disorder, as a feedback loop problem. (The door swings both ways, we anthropomorphize machines and we interpret human behavior in mechanistic terms.)

J D Bolter notes: "Weiner compared the new electron tubes to neurons and wanted to subsume the study of both under one discipline. Wiener's outlook was clearly as much influenced by pre-electronic control devices (feedback loops in various machines) as by the digital computers just being built ....Those following Wiener's approach spoke of creating artificial brain cells and neural networks and allowing the machine to learn as a baby was presumed to do, ...But the theory of neural networks, which was developed mathematically, met with little or no practical success ...Specialists more or less gave up the idea of building a machine which would mirror the elements of the human brain, they no longer demanded a literal correspondence between man and machine. (9)

The other path of development was that of simulating mathematical logical processes in automated binary digital processes. The difference here is between the modelling of biological processes in *analogous* electronic processes and the devising of an automated logic which arrives at the same logically correct results as the human mind, but via radically different procedures.

This automation of reasoning is called 'Artificial Intelligence'. In his recent book, Hans Moravec outlines this separation: "The cybernetics researchers, whose self-contained experiments were often animal like and mobile, began their investigation of the nervous system by attempting to duplicate the sensorimotor capabilities of animals. The artificial intelligence community ignored this approach in their early work and instead set their sights directly on the intellectual acme of human thought... mechanizing human reasoning. This 'top-down' approach made impressive strides at first but has produced few fundamental gains in over a decade."(10) By 1956, an early artificial intelligence program called Logic Theorist had already found a more elegant proof of theorum 2.85 of the Principia Mathematica than any produced by human mathematicians, including Russell and Whitehead.(11)

It becomes more and more evident that abstract reasoning is only the most easily automated corner of what we loosely refer to as 'intelligence'. Hans Moravec emphasizes this point: "Organisms that lack the ability to perceive and explore their environment do not seem to acquire anything that we would call intelligence."(12)

In any case, abstract logic is a human invention and the production of machines that simulate such processes must properly be regarded as anthropomorphic. J.D. Bolter remarks: 'the artificial intelligence specialist is not interested in imitating the whole man. The very reason that he regards intelligence as fundamental is that such intelligence corresponds to the new and compelling qualities of electronic technology. Today, as before, technology determines what part of the man will be imitated.'(13) In these terms, the development of Artificial Intelligence can be seen as the sucessor in this history of anthropomorphism, in the transition from mechanical to electronic technology. In popular literature, Hal, the computer in Kubrick's 2001, is an expression of this new generation of 'disembodied' anthropomorphism.

In the sixties, Jack Burnham embraced Cybernetic theory and built around it a new model of art practice. He argued that inasmuch as mimesis has always been the concern of sculpture, from the caveman to early modernism, anthropormorphic robotry is the logical sucessor to that tradition in sculpture and argues that the 18th century clockwork automata of Vaucanson and Jaquet Drosz are significant predecessors of this trend. "It is doubtful if non-anthropomorphic sculpture can exist. Since the creation of the first non-objective and Constructivist sculptures in the early part of the twentieth century, artists have consistently denied the anthropomorphic and mimetic content of their works. Each sucessive generation of nonobjective...sculptors has accused the previous generation of anthropomorphism....What we will examine as Cyborg or post kinetic art is really the first attempt to simulate the structure of life literally. *Thus, sculpture seeks its own obliteration by moving toward integration with the intelligent life forms it has always imitated."* (14)

'Personal' Computers

The computer has become the defining technology of our culture. Whether or not it is in fact the case, the computer is linked in the public mind with the spectre of machine borne intelligence. As this new tool is a tool for reasoning, rather than a tool for concrete manufacturing, the debate for human identity in the face of technology has become focused on the mind. In what way is the machine mind different from the human mind? What can we think that a computer can't? And the flag that the mind waved was *creativity* .

There is a peculiar parallel of reductionist arguments here between: the sucessive redefinition of the essentially human in the face of developing technology; and the history of modernism in the visual arts, in which sucessive avantgardes voluntarily jettisoned defining aspects of the artwork in the quest for its essential nature. Curiously too, both arguments arrived at the same endpoint: the creative idea. In the visual arts this point was called 'conceptual art' at which point the artwork became entirely disembodied. (15)

Globally, the 1980s saw a conservative swing on all fronts. In art this was a recoiling from the "free form '70s". Modernist reductivism had taken art to the edge of the cliff and in fear of total annihalation, those with vested interests began furiously back-pedalling and attempted to reinvest the 'object' with some sort of value. The expressionistic gesture as psychoanalytic sacrament was resurected on the Ouija board of contemporary culture as if it never died, and the simulation was taken as the thing itself. The doubts of

Thomas were whitewashed.

If the rough beast is the 'non- aunthentic', simulation in general, then all our simulating technology, (more or less intelligent) is the anti-christ, then postmodern theory and Baudrillard in particular have led us all to embrace it, like lambs to the slaughter.

One hopes that the debate over the defining characteristics of the human organism will not follow this kind of retrogressive behavior.

Conclusion

From the Venus of Willendorf to Artificial Intelligence, there would seem to be an intense desire to emulate the Gods in their power of creativity, to create life. (16) This attraction remains permanently 'sexy', it carries the power of a taboo. In some cultures, including traditional Islamic culture, it has been forbidden even to pictorially represent people.

Contemporary researchers allow their domains to be called 'knowledge engineering', 'expert systems' and 'neural nets' to capitalise on the attraction of these taboo activities; the names are marketing strategies. Artificial Intelligence might more properly be called 'automated logic'. Claude Shannon never called his pioneering study "information theory", but the much less sexy name 'coding theory'. Some of these names have been coined by scientists, others by journalists with a keen sense of topics which titilate the consumers of the media. .

On a deeper level, the assumptions about the nature of intelligence that lie at the core of Artificial Intelligence theory are brought into question. JD Bolter has noted that the qualities of the technology define what form the anthropomorphism will take (see above:(13)). But the 'disembodiment' of intelligence begs questions concerning the relationship between 'the body' and intelligence, and the question of 'understanding'. As Hubert Dreyfus stated in 1979: "...intelligence requires understanding, and understanding requires giving the computer the background of common sense that adult human beings have by virtue of having bodies..." (17) In the same essay Dreyfus quotes Marvin Minsky's deliberations on the subject :

> "*We still know far too little about the contents and structure of common-sense knowledge. A 'minimal' common sense system must 'know' something about cause-effect, time, purpose, locality, process, and types of knowledge...We need serious epistemological research in this area*"

Dreyfus responds: "Minskys' naivete and faith are astonishing. Philosophers from Plato to Husserl, who uncovered all these problems and more, have carried on serious epistemological research in this area for two thousand years without notable success.... But Minsky seems oblivious to the hand waving optimism of his proposal that programmers rush in where philosophers such as Heidegger fear to tread, and simply make explicit the totality of human practices which pervade our lives as water encompasses the life of a fish." (18)

With historical distance, contemporary Artificial Intelligence may be regarded as a latter day version of Vaucanson's Duck. An interesting machine in itself, it can however lay little claim to being 'alive'. It can neither 'desire' its food, nor catch the scent of its own excrement.

In the Next Exciting Episode...

Meantime the anthropomorphized (and intelligent) machine remains a cultural obsession. One needs look no further than the plethora of Robot movies produced in the USA, but globally consumed. Bladerunner, Robocop, Starwars, Tron, War Games, Westworld, 2001, Short Circuit: the list goes on and on. These movies tend to gravitate to two main theses: either man is creating his non-organic successor, or man and machine will amalgamate and supersede genetic evolution. Are we reaching the point at which our drive to anthropomorphism will complete its gestation period and burst forth fully developed from the shells of our bodies, in some ghastly 'Alien' style cinematic version of the Book of Revelations? Or will the millenium usher in an epoch of peace, light and universal harmony? Stay tuned.

Notes and References

1. The millenium, we should recall, is an arbritrary date, predicated on two notions specific to our culture: the Christian religion and the base 10 counting system.
2. Karel Capek:'Rossums' universal robots'. 1921
3. Donna Haraway:" A manifesto for cyborgs" Socialist Review 1984. pp65-107
4. William Shakespeare: 'Julius Caesar' Act1 scene 3.
5. These 'theatra mundi' are themselves reminiscent of the 'memory theatre' projects of the Elizabethan magus Robert Flood, and his predecessors Giordano Bruno and Guillo Camillo. These are themselves the sucessors of a long line of mnemonic systems which seem to date back to preliterate Greece. cf. Frances Yates: 'The art of memory" Viking 1966
6. Precisely why this fear has endured among the makers of culture is not so clear. Socially the repercussions have been profound, as C P Snow noted in the 'fifties. C P Snow 'the two cultures" in The New Statesman, 6 Oct 1956.
7. Fritz Lang: "Metropolis" 1926
8. Jack Burnham: "Beyond modern sculpture" George Brazilier 1968 p245
9. J D Bolter: "Turings' Man." Pelican 1986 p213
10. Hans Moravec: "Mind Children" Harvard University Press 1988 p16.
11. Logic Theorist was written by Allen Newell, Herbert Simon and Cliff Shaw. For this piece of AI history I am indebted to Fred Truck and the manual to his interactive artwork ArtEngine.
12. Hans Moravec: ibid p16
13. J D Bolter: ibid p213
14. Jack Burnham: ibid p332
15. Another curious parallelism is that at the point when the idea of downloadable software was on the verge of becoming a commercial reality, artists were creating, without computers, in conceptual art, works of pure information which could reasonalby be termed 'cultural software'.
16. The second conference on Artificial Life occured in New Mexico in february 1990. The proceedings of the first conference are published under the title: "Artificial Life. The proceedings of an interdisciplinary workshop on the synthesis and simulation of living systems." Ed: Christopher Langton. Addison Wesley 1989
17. Hubert Dreyfus: 'What computers can't do.(revised edition)'. Harper colophon 1979. p3
18. Hubert Dreyfus: ibid p36

COMMUNION AND CARGO CULTS

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Abstract

The countries of the first world discuss the inappropriate introduction of technology within the third world. One illustration are the Cargo Cults developed in the South Pacific as a result of insensitive exploration and exploitation. Nevertheless the first world remains largely unaware of the inappropriateness of the ultra-rapid development and introduction of information technology within their own culture. The development of high-bandwidth human computer interaction via 'virtual' interfaces will lead to intimate symbiosis between human consciousness and artificial intelligence. One possible consequence of this is a new religion based on the current grass-roots belief in technology epitomized by the popularity of subjects like Chaos Theory. Tightly coupled human computer symbiosis promises an electronic communion for this new religion and the possibility of a new hi-tech cargo cult that, unlike it predecessors, actually 'delivers the goods'.

Cargo

Cargo cults are a largely 20th century development and have evolved as the result of insensitive and inappropriate introduction, by an alien culture, of a new technology into a resident society who were previously unaware of that technology and its potential and value. The term is strictly used to describe the cults that developed in Melanesia and the best documented come from Papua New Guinea. Jarvie (1) describes these cults as having the following characteristics:

- they are doctrinal offshoots of Christianity - the followers of native pagan religions do not usually subscribe to them;

- they are usually led by a native prophet who announces that, provided certain conditions are met, the millennium will come about. This will usually occur in the near future and is often predicted for a specific date;

- a central tenant of their doctrines is that when the millennium comes it will be accompanied by the arrival of ships and aircraft often piloted by ancestors and always loaded with a cargo consisting of material consumer goods (which are, of course, delivered to the ruling classes - traditionally the white overlords - in this same manner);
- another aspect of the millennium that is often prophesied is the inversion of

the order of society - the black native subjects will rule the whites and, in some cases will become white and visa versa. An assumption here is that the native people are Gods favourites and that the white interloper has misappropriated the shipments of cargo sent by God to his chosen people.

A familiar aspect of these cults are their 'religious' symbols. These include aircraft, ships, landing strips, radios and many other items of the paraphernalia of modern communication systems but made from simple and roughly hewn and decorated materials. The visual appeal of these tokens has made them collectors items in the first world where they are converted into valuable and so-called primitive art. This often leads to an image of the cultist as a 'noble savage' seeking spiritual enlightenment by attempting association with a technology which they don't fully comprehend (their assumption that cargoes come from God for example) because of the inappropriate way it has been presented to them. Herbert Umlaut (2) warns that this is a misleading fantasy: Cargo Cults are the consequence of single-minded possessive greed and that the largest cargo cult of modern times was the German Third Reich "those guys wanted to possess the entire world". Other authors have also recently discussed world-wide cargo cults (3).

A dominant feature of Cargo Cults is their basis in the misinterpretation of an inappropriately introduced communication technology. It is my belief that a modern communication technology - digital Information Technology (IT) - is being introduced as a similarly inappropriate way and within the very heart of the dominant first world culture. The lack of understanding of this technology by the majority suggests that a likely consequence will be the development of a major new international Cargo Cult. Some developments of this cult are already discernible. One in particular is the public response to the recent developments in mathematics and science that have been dubbed Chaos Theory.

In presenting this essay I make several assumptions. Some of these have been discussed in more detail in my previous publications (4). Some of the more important are that:

- intelligence has evolved as a survival mechanism and that personalized, or ego-oriented perception of intelligence is largely illusory;

- advances in information technology will lead to the evolution of super-intelligences that have significantly more capacity and potential than humans;

- these super-intelligences will dwell within extended networks rather than within individual nodes of a network and that;

- in order to survive humans will have to enter into a close symbiotic relationship with these new intelligences.

In this essay I do not wish to defend or attack these assumptions. Others are busy doing that (5). Instead I intend to speculate on the likely effects on humanity and on art of developments of this kind. Firstly it may be useful to illustrate the symptoms of the evolving Cult of Information Cargo.

Messiahs and Mandelbrot.

Science and technology have long provided the substance for a dominant belief system. They evolve directly from Christianity and are complementary to its patriarchal causalistic dogma. A theological revolution - the Reformation - gave birth to the modern scientific method, modern capitalism and vitalized technological colonial exploitation. The eighteenth-century polymath Pierre Simon Laplace suggested an "intelligence" that "would embrace in the same formula the movements of the greatest bodies in the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes". Newtonian determinism is here applied to consolidation of the deity itself in much the same way that Ramon Lully and Leibnitz had previously applied logic for this purpose. Laplace's interpretation of that "same formula" is what modern scientific interpretation would doubt. The search for prime causative factors or relationships is still as vigorous as ever.

Towards the middle of the 19th century many, following Laplace's example, believed that science was close to describing everything in the universe (the millennium was due?). The high academic art of this period like the works of Alma Tadema, Leighton and others echo this optimism. Then Michelson and Morley's experiments to measure the speed of light suggested something was amiss and the Empire of Certainty - the empire of the mechanical, Newtonian, universe began to crumble. Einstein, a God-fearing Jew, tried to patch it all together again but soon Heisenberg (with uncertainty) and Godel (with incompleteness) put a stop to that. During the 20th century that empire of certainty has been further eroded and nothing has contributed more to its demise than the new theories of Chaos.

Chaos is profoundly simple and, perhaps in consequence, much misunderstood and maligned. Chaos demonstrates that even the simplest of deterministic systems can produce behavior that cannot be predicted and is therefore termed chaotic. Note that chaos in this sense is not synonymous with randomness: Chaos does not directly oppose the empire of certainty. It does, however, insist that in order to be certain about some thing one must know everything about that thing. (Which is, of course, a tautology). Knowledge of a subset of everything, however rich that subset may be, won't help. It's all or nothing. Seemingly insignificant variations in the input (what is known) conditions to a system can, and often do, lead to major variations in the output. This difference cannot be predicted. Chaos theory does however provide us with clues and, in particular, the concept of Self Similarity. Chaos theory has given science an important, perhaps indispensable, attribute - a proof of unknowing, of mystery:

> The way that can be told
> Is not the constant way;

The name that can be named
Is not the constant name.

The nameless was the beginning of heaven and of earth;
The named was the mother of the myriad creatures.

Hence always rid yourself of desires in order to observe its secrets;
But always allow yourself to have desires in order to observe its
manifestations.

These two are the same
But diverge as they issue forth.
Being the same they are called mysteries,
Mystery upon mystery -
The gateway of the manifold secrets. (6)

Along with Chaos has come the concept of information transaction as a fundamental physical paradigm. The universe may be considered as a virtually infinite multi-dimensional cellular automaton. Discussion of this interesting area is beyond the scope of this essay however those who would like to pursue this concept further may like to read Poundstone's intriguing and amusing extrapolation of John Horton Conway's Game of Life (7).

It is perhaps worth reiterating that our understanding of Chaos, which has essentially invoked a new paradigm of mathematical and physical modeling of the universe, is a direct consequence of digital computing machines. As I have discussed elsewhere (8) we have already witnessed revolutions that have been a consequence of the introduction of information technology. We should expect to see many more as the technology becomes fundamental to many other disciplines.

The techno-belief that states that: whatever happens we can invent ourselves out of trouble has been a guiding principle of the market forces economy. Its consequences are everywhere: the planet is massively overpopulated and polluted. Chaos theory introduced a valuable new element that addresses the expansionist bias of the previous technological belief system. In demonstrating that very small changes in input can lead to unpredictable and potentially large changes in output (like for example the greenhouse effect or other similarly catastrophic "natural" events) Chaos bring a measure of much needed "common sense" back into play. But the principal contribution of Chaos to the techno-religion is its inherent mystery. All good religions require mystery and mysticism (the unknowable, the one, the holy ghost, etc. ...). Thanks to Chaos science and technology now encompass this essential component. Chaos also brings an integrating effect:

They said to Him: Shall we then, being children,
enter the Kingdom? Jesus said to them:
When you make the two one, and

when you make the inner as the outer
and the outer as the inner and the above
as the below, and when
you make the male and the female into a single one,
so that the male will not be male and
the female not be female, when you make
eyes in the place of an eye, and a hand
in the place of a hand, and a foot in the place
of a foot, and an image in the place of an image
then shall you enter. (9)

Despite the nature of the subject that gives rise to the label Chaos there are a number of similarities, of constants, that cross subjects and disciplines with ease. Self similarity is one. Feigenbaum's constant, which measure the rate of period doubling in any number of chaotic processes is another.

Chaos then brings both mystery and unity to the new techno-religion. Both are essential characteristics of a holistic religion. Chaos has developed in parallel with scientific visualization which has been a major contributing factor to our exploration, development and understanding of these new universes of interest. Visualization has also helped to bring these concepts to a wide audience and science popularization has become a major component of modern entertainment. Benoit Mandelbrot was in Australia in early 1990 and when he visited the relatively small community of Canberra over 1700 people turned up to the 150-seater lecture theater where he was booked to speak. This adulation of a figure who, in many other periods, would have probably remained obscure, is a characteristic of the popular identification with Chaos Theory and is, incidentally a classic example of the development of a cargo cult.

Images of Chaos fill our television screens in programs from science to music videos. Exhibitions in art galleries are devoted to the subject. Science and technology have, after a long period of popular rejection, been brought back into the mainstream of public interest in a way that is unparalleled by the popularity of the theories and images of chaos. Mandelbrot together with many of the other pioneers are often treated like gurus - prophets of the millennium who foretell of the imminent death of our planet from pollution and overpopulation unless we act immediately to remedy the error of our ways. This is pure cargo cultism and the Information Cargo Cults are here already, established and have a growing number of followers, particularly amongst the young.

The major characteristic currently missing from this emergent religion is Communion: the need for an individual member of the religion to consolidate their belief via an intense and personal link-up with the source or godhead of that religion. It would seem to me that developments in the computer human interface (CHI), driven by the escalating performance of computing systems, will soon provide a relatively intimate communication pathway between human and machine (10). Graphics as a basis for CHI is already becoming too slow and recent developments of so-called "virtual realities" can be seen as attempts to utilize whole body language, including speech, hearing, gesture, vision and, in some leading-edge research touch, in order to increase the bandwidth of communication and interaction.

This intimacy will be the basis for a closely coupled symbiosis between human and machine intelligence. If this potential offends any reader they should bear in mind that even today computer systems control most of our essential services. If this technology should fail our supply of money, goods, basic services and communication would also soon fall over leading to widespread starvation and death. We have already established a symbiotic relationship with technology and what I'm suggesting here is only a change in degree.

With this intimate symbiosis comes the potential for nirvana on demand. A modern games arcade has sophisticated flight simulator technology which just a few years ago would have cost millions of dollars and only be available to a elite few. Now anyone with a dollar in their pocket can sample these delights. The VPL Data-Glove which, three years ago, was an expensive, made to order, research tool has now been emulated by Nintendo who offer it as a $160 peripheral to their domestic games systems.

I can't believe it will be long before a merger of neuroscience, cognitive science and machine intelligence offers the possibility of an intimate communication between human and machine intelligence and with it the potential of communion, of a "once-in-a-lifetime" spiritual experience, for just a few dollars in the slot. Plug in and tune in. The elitist mystical experience can become democratized and available to much larger numbers than ever before. Information Cargo Cults, unlike the predecessors, may, via simulation and stimulation, actually deliver the goods.

If electronic Zen courtesy of the local games arcade is a worry then imagine how the TV evangelists, who have proved their success with a relatively simple, non-interactive, broadcast medium, will attempt to use the technology. And lets not forget that many religions, who will almost certainly move in on this new dynamic communication medium and method of enlisting recruits, do not have the intrinsic benevolence that is supposedly at the roots of Christianity and its offshoots. The inquisitors as they burned young girls who didn't conform to the mores of the day did so for the principles of love, fellowship and forgiveness. Other religions have no such qualms: in some killing unbelievers actually earns browny points in heaven. He who dies in the holy jihad with the name of Allah on his lips goes immediately to the highest heaven where there is an eternity of bodily pleasures to be sampled (11).

If we look for a role for art in the service of the new techno-religion we find it has already been established and follows a traditional pattern. The Renaissance Teams described by Donna Cox (12) are already fulfilling much the same role as did their renaissance forbearers in the service of the Church of Rome. Giotto and other journeyman artists painted cartoons of the bible stories on the walls of the churches in order to communicate their lessons to the illiterate parishioners.

Now Cox and others bring images from the new religion, via visualization, in order to communicate a new order of ideas to a largely innumerate public.

We can also draw a parallel between the way that the first world treats the traditional cargo cult artifacts (by inflating their material value in an inappropriate way that denies or overlooks their intrinsic value) with the way the art mainstream has reacted to the images of chaos (and other computer aided artifacts) that appear in galleries. The curators and critics pontificate about colour, form, construction and even the framing without any respect for the inherent meaning of the work or its larger scientific and social context (13).

Welcome to the Pleasure Dome

Virtual reality has been adopted nowhere more eagerly than by the computer games manufacturers. Already, as indicated above, sophisticated simulation technology is now integrated into the games arcade where it's available for just a few dollars. Multiply those few dollars by the millions of games played daily and we appreciate big business and the highly competitive nature of the companies involved. They generate the kind of profits that allow for immediate exploitation of leading edge technologies - witness Nintendo's development of the data-glove. Both Nintendo and Mattoy are now believed to be developing their own low-cost versions of a stereo, head-mounted vision system.

These producers also train a new generation of consumers. The children's market is a significant force in the economy. These kids are being conditioned to accept a high level of technological sophistication and, even more important - access to that technology - as a birthright.

High-tech is also hitting other major consumer niche marketplaces like pornography. There are any number of similarities with the games market - in particular a constantly evolving level of satiety - consumers are rarely content for long and always desire more and superior stimulation. With the advent of intimate computer human symbiosis comes the potential for toll-free infinite orgasms as a promotional medium with guaranteed success. Or, for a fee, select your favoured sex, age and activity then plug in and experience your pleasures at first hand with complete sensory feedback and amplification.

More traditional and social forms of entertainment like cinema will also be effected by this new simulation technology. Lucasfilm founded their games division several years ago and most of the major studios now have a presence in the area. Art has always had a role as entertainment and the new art will be no different.

Politics and Control

Art in the service of authority has a long history. It's strewn with portraits of first religious and then secular leaders and with allegories that espouse their philosophies and images that communicate their messages. Authority has always been a major developer of the current new technologies - they are essential tools in the management of large institutions from multi-national industry to governments. The tools give an unprecedented access to personal data and parasitic companies have evolved to exploit this potential. In Australia a company specializing in on-line financial searches faces indictment for a precedent setting court ruling. Their clients, major national banks and international credit-card companies who paid for this work are, surprisingly, exempt from the litigation.

I have long held the opinion that our concept of personal freedom is nothing more that a measure of the incompetence of the institutions that govern us. Modern information processing and networking promise to remove those levels of inadequacy and civil rights groups are rightly concerned by the new opportunities for abuse if not for outright corruption.

It would seem to me that trying to oppose this new order is fruitless - these are, after all, essential tools for administration and regulation. Our concern is not with their regular use but rather with their potential for abuse. An interesting example comes from the 1970's in the United Kingdom where a group of parliamentary opposition members tried to oppose police access to a new social security database. Despite the fact that the Home Secretary assured them that this would not be allowed just one week later the opposition members were able to demonstrate that every police station in the UK had regular access to the system.

What we need to be doing is looking at ways that such a ubiquitous system, which could cause so much damage if it fell into the hands of an unethical and corrupt authority, can be regulated from outside. Our concern should, as always, be with access and opportunity, the keystones of democracy and consultation. Here again I believe that the mechanism we seek is already established and has been developed by, amongst others, the games manufacturers: the computer kids are already active in the networks.

Art in the service of authority acts to encourage the conformity which simplifies government. What we seek is the mechanism for encouraging a requisite diversity - an art of democracy.

Hacking out the New Frontier

Information technology has generated a debate concerning its intrinsic nature. Clearly it is not just a tool, nor is it a medium. Its chameleon nature has led to many identifying it in the post-modernist mainstream. This definition is, I suggest, more a consequence of misunderstanding by people who are more acquainted with the limited results of application-based systems rather than those who have a deeper understanding of the technology itself and of its social, commercial, aesthetic and political implications. Our early applications of the technology include simulations of traditional media like typography, page-make-up, paint and photo-collage systems which offer the ability to copy and manipulate borrowed images ad infinitum. The computer is a copyists tool without precedent. Whilst this encourages the post-modernist interpretation it represents only a limited, and in my opinion, backward looking, approach to the technology.

Interaction, between a human and an artificial intelligence (AI) (14) or between two humans moderated by an AI is something new, something that this technology offers uniquely. Some artists like Stephen Axelrad produce interactive work that fits clearly within the post-modernist paradigm and, as a consequence has been picked up by the art mainstream - Axelrad is now part of the Castelli stable. Others, like David Rokeby, Simon Veitch and Myron Kruger are opening up new areas and their work, like pioneering artists of the past, is often rejected by the mainstream.

The model of photography may be useful. Photography began to develop an identity as a medium in its own right when it became cheap enough for amateurs (people who had not had a professional image-making training) to get involved. In their relative innocence they broke the rules and began to isolate and identify unique aspects of the new medium.

It's tempting therefore to suggest that is only now that sophisticated low-cost computer systems, like Commodore's Amiga, are generally available that we will begin to see rules being broken and the post-modernist clichés being rejected.

The development of user-friendly computer-human-interfaces (CHI) has enabled the marketing of these systems. CHI is far too often based on the premise that human learning (a challenge) is undesirable and software should be packaged to emulate something that the human already knows about. By encouraging "the user illusion" CHI become a two-edged sword (15): on the one hand it is responsible for large numbers of people getting involved with the technology but on the other hand it actually encourages the misleading post-modernist perception.

In looking for a resolution to this dilemma I believe that we should look at those members of the community who have not yet been initiated into one or another mind-set. Since this conditioning is largely a result of education, and in particular of discipline specific higher education I suspect that we should look toward young people and children.

This group already make themselves know via the spray-can and subway walls. The images they produce have a high public profile - they exist alongside major urban commuter routes - and demonstrate several important characteristics:

- the images that they produce are often dynamic and sometimes beautiful. They demand attention;
- they are implicitly and occasionally explicitly political;
- the process is generally illegal - the work is anti-authoritarian;

- they are the work of young people who have not yet (by definition) evolved "mature" moral and ethical codes. They are free to explore in an uninhibited manner but are also often unaware of the deeper consequences of their actions;

- the work is most often an identifier - often the artists pseudoname. The work is one aspect of the maturing process - the adolescent identity crisis.

Many young people have now moved from the physical commuter routes into the information networks. Their viruses are endemic in the low-cost pc world and, as they grow older and get access to more sophisticated technology their worms are entering the global networks. Although we must be concerned about the amount of damage the artifacts of electronic graffiti are causing we should also be pleased that at least one section of the community is ahead of the pack. Art has always had a role to encourage the diversity that is requisite to the conformity pressures issued by authority.

One role of art is to encourage freedom. Graffiti is a grass roots artform that measures democracy. The western side of the Berlin Wall was covered in multicoloured political slogans. The Eastern side was gray and bleak.

Graffiti is the artform of youth and we must look increasingly to young people and children to limit the ubiquitous spread of information technology from both the commercial and political marketplaces. As the power-mongers develop more sophisticated methods of constraining freedom the graffiti hackers will find ways to limit this constraint. Whether we like it or not (and many complain about the "disfiguring" aspects of visual graffiti and most of us who use this technology get upset when the damage caused by virus and worms effects our own databases) it is in our interests to acknowledge, if not support, this democratic and freedom enhancing role of electronic art.

The Frankenstein Complex

As we are all aware the new technology is developing and being introduced at an ultra-rapid rate of change. Many are afraid and feel intimidated. A common response that I have personally witness in disciplines from graphic design to engineering is to pretend it isn't really happening. The professional reactionaries, the trade union movements, have almost consistently opposed the technology as it has developed.

It is my opinion that attempting to ignore or to oppose these developments is, in the long term, the most dangerous route of all. They represent an order of power that is unprecedented in human history. Our future freedom is at stake, some would argue that our very survival as a species is at issue and knowledge, involvement and participation are the only keys to our success.

The Emergent Matriarchy

There is a significant gender bias in the development of technology. I suspect that it springs from the male-dominated and patriarchal Christian religion ("go forth and multiply") and in particular from the reformed Protestantism with its emphasis on distrust (questioning - protest) and the associated "work ethic". The scientific method is associated with the reformation. The male principle also brings a hierarchical consciousness: leaders and follows; shepherd and sheep. By contrast the female principle is soft and concerned with nurturing, loving, caring and with hetrarchical communications and government.

Stelarc (16) suggests that the imminent symbiosis between human and machine will make maternity obsolete and this threatens the traditional role of woman. Although this, to me, seems to contradict the "feminist" viewpoint most of the people supporting this premise have been women. Sally Pryor (17) recalls Descartes dualism of mind and body and suggests that the male is identified with the mind and the female with the body. Artificial Intelligence is without body - the mind dominates and the body - the female - is rejected. Linda Wallace (18) suggests that one consequence of male domination (and I would add also a consequence of the domination of the patriarchal Christian Church, particularly the Church of Rome, with it's emphasis on "original sin") has been a loss of trust in the body. In consequence technology has developed as a search for "proofs" for previously natural phenomena and abilities that were lost along with this trust. This reiterates the popular opinion that pre-Christian religions were matriarchal and that many spirit phenomena were common practice. In this context Cyberspace can be seen as a technological implementation of astral projection.

The current leading-edge technological development is implementation of a global high-bandwidth network that will link computer to computer and people to computers. Although the technology that has made this development possible is clearly patriarchal, phallic and male dominated the network itself show characteristics that seem to be much more matriarchal. Networks are about sharing and communication - they are intrinsic hetrarchical structures. Is it conceivable that a gender-shift will take place as a result of technological development - that a male dominant technology will create a dominant and ubiquitous female structure?

The network will extend over the globe and as far into space as humans have sent their remotes. In addition to suggesting that this structure is inherently feminine I also suggest that it has close correspondences with both Freud's idea of the Oceanic Consciousness and Jung's Collective Unconscious. The human symbiote in tomorrows global network will discover that network awareness is oceanic awareness.

Toward a Conscious Planet

The global network will grow to include millions of nodes. It's even conceivable that it may include the humble minions in your pro-active credit card, or those dinky devices that control your microwave, air conditioning, washing machine and that are now stuck on library books and consumer products to prevent theft. The growing global network represents a neural network that is evolving in a largely unstructured and indeterminate way. Is it possible that it may "wake up" and become self-aware at some time? I think so and suggest three possibilities - self awareness may result from:

- the human symbiote's contribution to the network;
- individual artificial nodes of the network achieving self awareness as a consequence of AI and super-intelligence and/or;
- the sum of all nodes - artificial and human - creating an autonomous network awareness.

In particular I believe that it's likely that humans, who have evolved as a competitive species with an embedded illusion of ego, will via the network evolve a species identity. They will transcend the ego-oriented, competitive paradigm and likely replace this with a cooperative species oriented identity. This is another aspect of the feminization intrinsic to the network. Work with other higher order mammals (19) suggests that other species may join us in this global awareness.

This network induced meta-consciousness will be a planetary intelligence that bears similarities with De Chardin's concept of the Omega Point when the sum total of Earth's intelligence - the Noosphere - achieves critical mass and "awakens" into a global consciousness and self-awareness. Jung's Collective Unconsciousness will be transcended to become a Collective Consciousness.

The prospect of a planetary consciousness with both will and identity suggests room for optimism for the solution of global ills like overpopulation and pollution. A conscious planet is likely to want to cure its sickness then ensure its future health. It also proposes a new role for art. Art may become the expression of a global awareness and consciousness. Describing the universe as an artwork is as relevant as describing it using the scientific paradigms of Newton, Einstein, Conway or Mandelbrot. This cosmogony does however bear more similarities with the Eastern religions than with proto-scientific ethic associated with Christianity.

The God of Christian tradition had purpose and created mortals in order that they could prove that they were good. The Hindu God Brahma, by contrast, was bored and divided himself into pieces (thereby creating the universe together with us mortals) in order only to amuse himself by observing our foolish antics.

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11 These bodily pleasures are usually provided by young submissive girls and this reminds us that many established religions are undesirably sexist. Fundamentalist Islam goes so far as to suggest that women should have the pleasure parts of their genitals removed at puberty in order to ensure that they remain obedient and submissive. The World Health Authority recently estimated that up to 80 million women are currently mutilated in this way. Until quite recently fundamentalist Christians also removed a girls clitoris as a preventative "cure" for masturbation and prescribed frontal lobotomy as a cure for female promiscuity (whilst, of course encouraging the male to "sow his oats"). Needless to say these cures worked and their scientific and medical efficacy was established.

12 Donna Cox, Renaissance Teams and Scientific Visualization: A Convergence of Art & Science, Collaboration in Computer Graphics Education Course, ACM SIGGRAPH, July 1988, pp 81-104.

13 A good example of the misunderstanding of chaos theory by the art world comes from Jeremy Baines in a letter to the editor of Modern Painting (Vol. 3 No 1 Spring 1990 pp 68-69) criticizing an article on fractal's and aesthetics by Dr. W. P. Atkins which appeared in a previous issue. Baines maintains that ... "any line of Shakespeare or any part of a work of art is a seamless and organic part and reflection of the infinite whole which is artistic creation"... Although this sounds like a good defense of fractal concepts we find in the same letter Baines concluding: .."fractal's are ultimately irrelevant to art"...

14 I use the term artificial intelligence loosely and believe that AI like organic intelligence will evolve autonomously from its current humble status to potential super-intelligence in a very short period of time. See (4) above.

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Prosthetics, Robotics and Remote Existence: Post-Evolutionary Strategies

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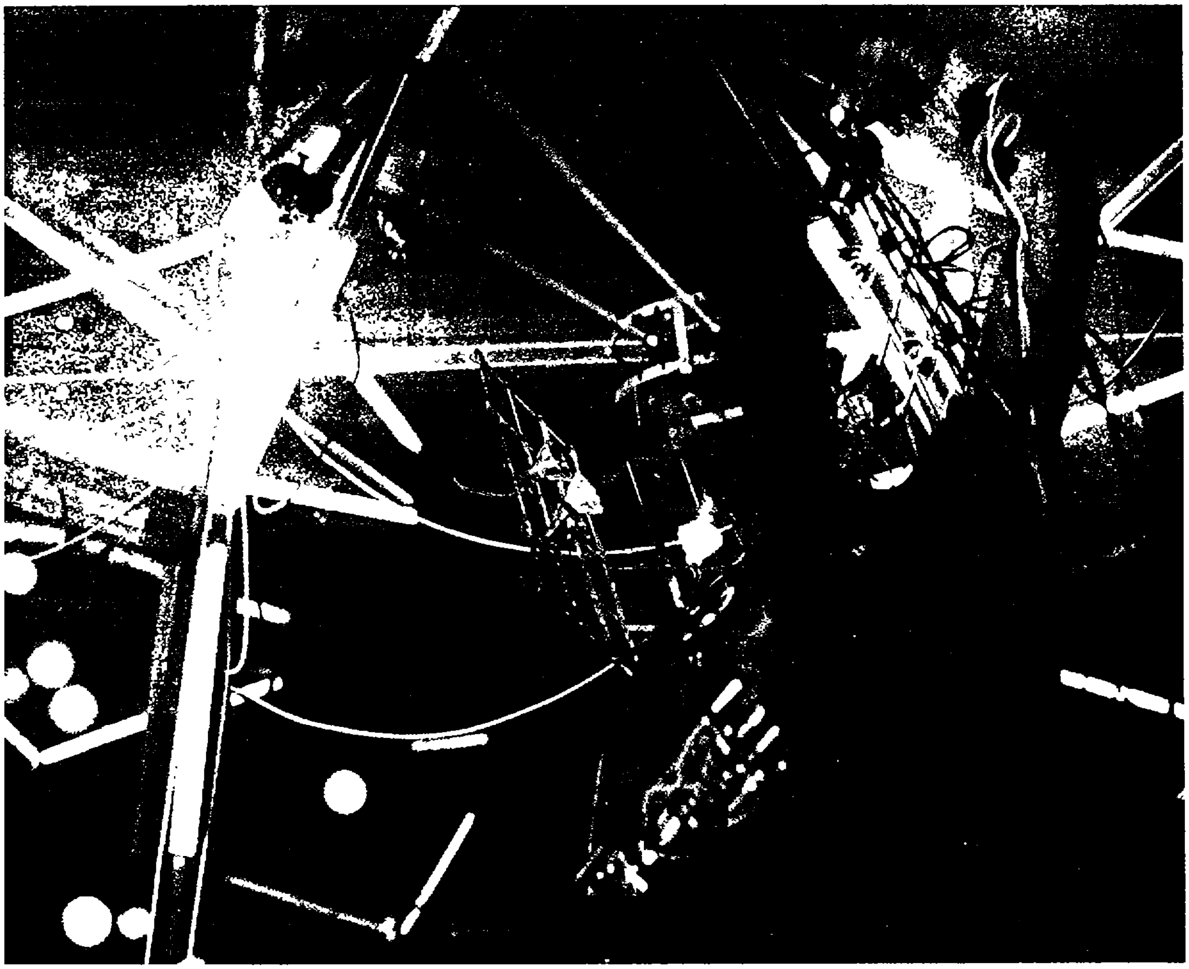
1. OBSOLETE BODY. It is time to question whether a bipedal, breathing body with binocular vision and a 1400cc brain is an adequate biological form. It cannot cope with the quantity, complexity and quality of information it has accumulated; it is intimidated by the precision, speed and power of technology and it is biologically ill-equiped to cope with its new extraterrestrial environmment. The body is neither a very efficient nor a very durable structure. It malfunctions often and fatigues quickly; its performance is determined by its age. It is susceptible to disease and is doomed to a certain and early death. Its survival parameters are very slim -it can survive only weeks without food, days without water and minutes without oxygen. The body´s LACK OF MODULAR DESIGN and its over-reactive immunological system make it difficult to replace malfuncting organs. It might be the height of technological folly to consider the body obsolete in form and function, yet it might be the highest of human realizations. For it is only when the body becomes aware of its present position that it can map its post-evolutionary strategies. It is no longer a matter of perpetuating the human species by REPRODUCTION, but of enhancing the individual by REDESIGNING. What is significant is no longer male-female intercourse but human-machine interface. THE BODY IS OBSOLETE. We are at the end of philosophy and human physiology.



Stelarc
"Amplified Body, Laser Eyes & Third Hand"
photograph by Tony Figallo

Human thought recedes into the human past.

2. **REDESIGNING THE BODY/REDEFINING WHAT IS HUMAN.** It is no longer meaningful to see the body as a <u>site</u> for the psyche or the social, but rather as a <u>structure</u> to be monitored and modified. The body not as a subject but as an object -NOT AS AN OBJECT OF DESIRE BUT AS AN OBJECT FOR DESIGNING. The <u>psycho-social</u> period was characterized by the body circling itself, orbiting itself, illuminating and inspecting itself by physical prodding and metaphysical contemplation. But having confronted <u>its image of obsolescence</u>, the body is traumatized to split from the realm of subjectivity and consider the necessity of re-examining and possibly <u>redesigning</u> its very structure. ALTERING THE ARCHITECTURE OF THE BODY RESULTS IN ADJUSTING AND EXTENDING ITS AWARENESS OF THE WORLD. As an object, the body can be amplified and accelereated, attaining planetary escape velocity. It becomes a post-evolutionary projectile, <u>departing</u> and <u>diversifying</u> in form and function.

3. **THE INVASION OF TECHNOLOGY.** <u>Miniaturized</u> and <u>biocompatible</u>, technology lands on the body. Although unheralded, it is one of the most important events in human history -focussing physical change on each individual. Technology is not only <u>attached</u>, but is also <u>implanted</u>. ONCE A CONTAINER, TECHNOLOGY NOW BECOMES A COMPONENT OF THE BODY. As an instrument, technology fragmented and de-personalized experience -as a component it has the potential to SPLIT THE SPECIES. It is no longer of any advantage to either remain "human" or to evolve as a species. EVOLUTION

ENDS WHEN TECHNOLOGY INVADES THE BODY. Once technology provides each person with the potential to progress individually in its development, the cohesiveness of the species is no longer important. What is now intriguing is not the mind-body distinction but the body-species split. The body must burst from its biological, cultural and planetary containment. The significance of technology may be that it culminates in an alien awareness -one that is POST-HISTORIC, TRANS-HUMAN and even EXTRATERRESTRIAL (The first signs of an alien intelligence may well come from this planet).

4. AMPLIFIED BODY, LASER EYES AND THIRD HAND. If the earlier events can be characterized as probing and piercing the body (the three films of the inside of the stomach, lungs and colon/the 25 body suspensions) determining the physical parameters and normal capbilities of the body, then the recent performances extend and enhance it visually and acoustically. Body processes amplified include brainwaves (ECG), muscles (EMG), heartbeat (ECG), pulse (PLETHYSMOGRAM) and bloodflow (DOPPLER FLOW METER). Other transducers and sensors monitor limb motion and indicate body posture. The sound field is configured by buzzing, warbling, clicking, thumping, beeping and whooshing sounds - of triggered, random, repetitive and rhythmic signals. The artificial hand, attached to the right arm as an addition rather than a prosthetic replacement, is capable of independent motion, being activated by the EMG signals of the abdominal and leg muscles. It has a pinch-release, grasp-release, 290° wrist rotation (C.W. and C.C.W.) and a tactile feedback system for a rudimentary "sense of touch." Whilst the body activates its extra manipulater, the real left arm is remote controlled-jerked into action by 2 muscle stimulaters. Electrodes positioned on the flexor muscles and biceps curl the finger inwards, bend the wrist and thrust the arm upwards. The triggering of the arm motions pace the performance and the stimulater signals are used as sound sources as are the motor sounds of the Third Hand mechanism. The body performs in a structured and interactive lighting installation which flickers and flares responding and reacting to the electrical discharges of the body -sometimes synchronizing, sometimes counterpointing. Light is not treated as an external illumination of the body but as a manifestation of the body rhythms. The performance is a choreography of controlled, constrained and involuntary motions - of internal rhythms and external gestures. It is an interplay between physiological control and electronic modulation. Of human functions and machine enhancement.

5. **THE HOLLOW BODY.** Off the Earth, the body's complexity, softness and wetness would be difficult to sustain. The strategy should be to HOLLOW, HARDEN and DEHYDRATE the body to make it more durable and less vulnerable. The present organ-ization of the body is unnecessary. The solution to modifying the body is not to be found in its internal structure, but lies simply on its surface. THE SOLUTION IS NO MORE THAN SKIN DEEP. The significant event in our evolutionary history was a change in the mode of locomotion. Future development will occur with a change of skin. If we could engineer a SYNTHETIC SKIN which could absorb oxygen directly through its pores and could efficiently

convert light into chemical nutrients, we could radically redesign the body, eliminating many of its redundent systems, malfunctioning organs -minimizing toxin build-up in its chemistry. THE HOLLOW BODY WOULD BE A BETTER HOST FOR TECHNOLOGICAL COMPONENTS.

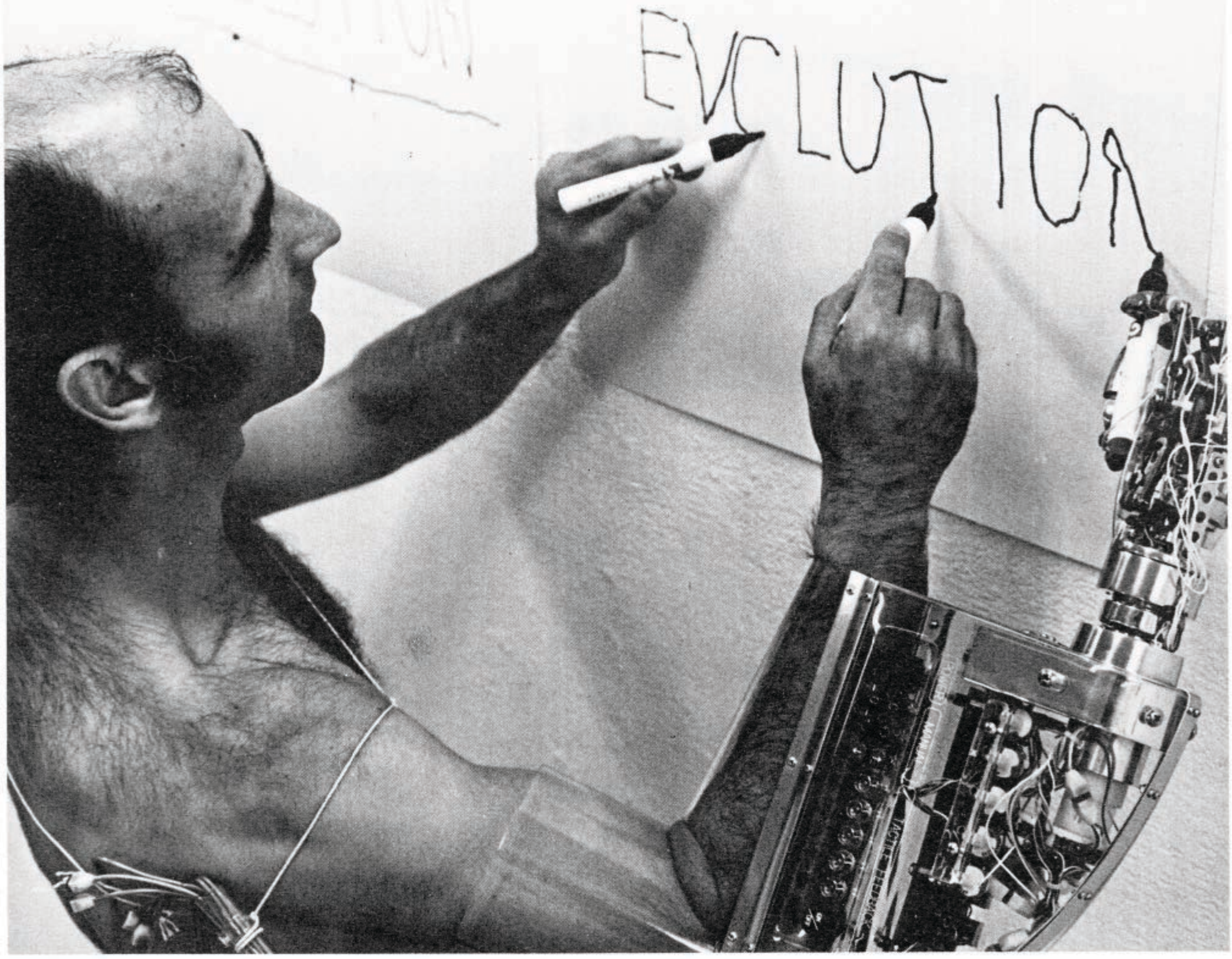
6. PAN-PLANETARY PHYSIOLOGY. Extraterrestrial environments amplify the body's obsolescence, intensifying pressures for its re-engineering. There is a necessity to design a more self-contained, energy-efficient body, with extended sensory antennae and augmented cerebral capacity. Unplugged from this planet - from its complex, interacting energy chain and protective biosphere -the body is biologically ill-equiped, not only in terms of its sheer survival, but also in its inability to adquately perceive and perform in the immensity of outer-space. Rather than developing specialist bodies for specific sites, we should consider a pan-planetary physiology that is durable, flexible and capable of functioning in varying atmospheric conditions, gravitational pressures and electro-magnetic fields.

7. NO BIRTH/NO DEATH - THE HUM OF THE HYBRID. Technology transforms the nature of human existence, equalizing the physical potential of bodies and standardizing human sexuality. With fertilization now occurring outside the womb and the possibility of nurturing the fetus in an artificial support system THERE WILL TECHNICALLY BE NO BIRTH. And if the body can be redesigned in a modular fashion to facilitate the replacement of malfunctioning parts, then TECHNICALLY THERE WOULD BE NO REASON FOR DEATH - given the accessibility of replacements. Death does not authenticate existence. It is an out-moded evolutionary strategy. The body need no longer be <u>repaired</u> but simply have parts <u>replaced</u>. Extending life no longer means "existing" but rather of being "operational." Bodies need not age or deteriorate; they would not run down nor even fatigue; they would <u>stall</u> then <u>start</u> -possessing both the potential for renewal and reactivation. In the extended space-time of extraterrestrial environments, THE BODY MUST BECOME IMMORTAL TO ADAPT. Utopian dreams become post-evolutionary imperatives. THIS IS NO MERE FAUSTIAN OPTION NOR SHOULD THERE BE ANY FRANKENSTEINIAN FEAR IN TAMPERING WITH THE BODY.

8. THE ANESTHETIZED BODY. The importance of technology is not simply in the pure power it generates but in the <u>realm of abstraction</u> it produces through its operational speed and its development of extended sense systems. Technology <u>passifies</u> the body. Because technology so successfully mediates betweeen the body and the world, it disconnects the body from many of its functions. DISTRAUGHT AND DISCONNECTED, THE BODY CAN ONLY RESORT TO INTERFACE AND SYMBIOIS. The body may not yet surrender its <u>autonomy</u> but certainly its <u>mobility</u>. The body plugged into a machine network needs to be passified. In fact, to function in the future and to truly achieve a hybrid symbiosis the body will need to be increasingly anesthetized...

9. HYBRID HUMAN-MACHINE SYSTEMS. The problem with space travel is no longer with the precision and reliability of technology but with the vulnerability and durability of the human body. In fact, it is now time to REDESIGN HUMANS, TO MAKE THEM MORE COMPATIBLE TO THEIR MACHINES. It is not merely a matter of "mechanizing" the body. It becomes apparent in the zero G, frictionless and oxygen-free environment of outer-space that technology is even more durable and functions more efficiently than on Earth. It is the human component that has to be sustained and also protected from small changes of pressure, temperature and radiation. The issue is HOW TO MAINTAIN HUMAN PERFORMANCE OVER EXTENDED PERIODS OF TIME. Symbiotic systems seem the best strategy. Implanted components can energize and amplify developments; exoskeletons can power the body; robotic-structures can become hosts for a body insert. And with micro-miniaturized robots we will now be able to colonize the surface and internal tracts to augment the bacterial populations-to probe, monitor and protect the body.

10.- **TOWARDS HIGH-FIDELITY ILLUSION.** With teleoperation systems, it is possible to project human presence and perform physical actions in remote and extraterrestrial locations. A single operater could direct a colony of robots in different locations simultaneously or scattered human experts might collectively control a particular surrogate robot. Teleoperation systems would have to be more than hand-eye mechnisms. They would have to create kinesthetic feel, providing the sensation of orientation, motion and body tension. Robots would have to be semi-autonomous, capable of "intelligent disobedience." With teleautomation (Conway/Volz/Walker), forward simulation -with time and position clutches- assists in overcoming the problem of real time-delays, allowing prediction to improve performance. The experience of Telepresence (Minsky) becomes the high fidelity illusion of Tele-existence (Tachi). ELECTRONIC SPACE BECOMES A MEDIUM OF ACTION RATHER THAN INFORMATION. It meshes the body with its machines in ever-increasing complexity and interactiveness. The body's form is enhanced and its functions are extended. ITS PERFORMANCE PARAMETERS ARE NEITHER LIMITED BY ITS PHYSIOLOGY NOR ITS IMMEDIATE SPACE. Electronic space restructures the body's architecture and multiplies its operational possibilities.



Stelarc
"Handswriting"
writing one word simultaneously with 3 hands
photograph by A. Okada