Digital Image—Digital Cinema: The Work of Art in the Age of Post-Mechanical Reproduction

Roger F. Malina

ABSTRACT

Computers are transforming existing art forms and allowing new kinds of art forms to be developed. Because the computer is primarily a machine for processing information, not a machine for making objects, it provides a malleable medium that provides the artist with a large variety of tools for manipulating sense data. The work that contains the result of the artist's creativity is the software and the data, not any particular image or output produced using that software. The ultimate goal of artmaking using computers, in this light, is not to create art objects but to create dynamic art subjects, to produce families of aesthetically interesting outputs, or art performances, which are as different from each other as possible within the constraints of the software. This situates computer art within the larger context of the study and development of artificial life. To create significant artworks of this type, it will be necessary to improve the computer's capacity to be an autonomous artmaking subject; this will require the extension of the computer's senses, the expansion of its capabilities, and means for the computer to provide sensory inputs to the human nervous system and to other computers.

Digital computers are the most plastic medium ever to come under the hand of the artist. Yet computer art is often viewed by art theorists as unsuitable for significant artistic expression. In many scientific and commercial applications the immutability of digitally stored information or software is of course a desirable attribute; computer viruses that alter stored information are viewed as pests, not as agents for creative change. The perception of the inflexibility of computer art systems, and their unsuitability as tools for artistic expression, is perhaps reinforced by the widespread use of pre-packaged software, such as computer graphics 'paintbox' systems, and by the fact that most computer artists do not develop their own software.

Most digital data is in fact inherently malleable and changeable. The computer is foremost a machine for creating interactions, for symbol manipulation and for processing information or sense data; it is not primarily a machine for making objects or fixed representations. Digital information is inherently plastic because the way that it is stored allows it to be easily changed, and the computer provides many tools for making such changes. The unique computer tools available to the artist, such as those of image processing, visualization, simulation and network communication are tools for *changing, moving* and *transforming,* not for *fixing,* digital information. These processes are carried out by the computer under rules potentially controlled by the artist.

There is a second well-understood feature about computer art. In traditional plastic art forms, the artwork is embedded in the material itself and is directly accessible to the human senses. In computer arts the artwork itself, embedded in digital data and software, is not directly accessible to the human senses. The computer artwork must be projected or transformed into a form apprehensible by the human senses. The choice of output device, whether cathode ray tube or film or sound, is in itself an artistic choice that can be exercised. In a trivial sense this is also true of photography and film, since the artwork cannot be seen until projected onto a reflective screen; however, the range of choices of output modes for a film negative is very narrow. This aspect of computer art connects it to the time-based and performing arts, where the creative work is in the score or text [1].

These two facts—that digital, stored data and software are inherently malleable and that the software is the art—have a number of consequences that change the nature of the work of art in the age of post-mechanical reproduction.

The Impact of Computers on Pre-Existing Art Forms

We can notice two kinds of effects of the new computer technologies on artmaking. First, new kinds of art forms are enabled by the unique capabilities of the computer. I have argued in a previous article that the only significant kind of computer art, within the context of the history of art, will be the type that could not have been made *without* the computer [2].

Second, the introduction of the computer is affecting artmaking in pre-existing or traditional art forms. Just as the introduction of the technology of photography had multiple and profound effects on painting, so the computer is affecting pre-existing art forms. The computer is leading to change both in static art forms, such as painting, photography, sculpture, poetry and literature, and in time-based art forms, such as kinetic art, film, video, music, dance and theater.

The effect of the use of computers on pre-existing art forms is two-fold. First, computers are being used as labor-saving devices or cost-saving devices to achieve existing artistic goals of artists using pre-existing art forms. This is already evident in music where computer-driven sound synthesizers, samplers and sound mixers are now being widely used by contemporary composers to generate and manipulate sounds of traditional instruments. Second, the computer can be used as a 'sketch pad' for trying many variations of a composition or visual design very quickly. The artist then implements the final design in a traditional medium; for example, artist John Pearson executes charcoal drawings or paints canvases after exploring the design using a computer and selecting a computer-generated design as a

Roger F. Malina (astronomer, art journal editor), Box 75, 1442A Walnut, Berkeley, CA 94709, U.S.A.

This article is based in part on a paper presented at the panel "The Work of Art in the Age of Post-Mechanical Reproduction" hosted by the Australian Network for Art and Technology, Adelaide, Australia, March 1990.

starting point [3]. Computer graphics systems are now being widely used to generate simulated landscapes and scenes that are then displayed as photographs and judged as conventional photographic art.

Computers have been adopted with remarkable speed, within one generation of their widespread availability, by artists working in traditional art forms. Computer artists using computer graphics images are already creating work that either is indistinguishable from that made using painting techniques or is equally successful artistically and aesthetically. Similarly, computer animation films are now competitive with films made by traditional film animation techniques; the recent winning of an Academy of Motion Picture Arts and Sciences Award by a computer animation short is an example. Although these kinds of artworks are still often classified, exhibited and juried as computer artworks, it would be more appropriate to include them within more traditional art venues.

Widespread use of computers is also redefining and re-directing artmaking in pre-existing art media. For instance, computer techniques are introducing new visual vocabularies into painting. A trivial example is the fact that false color imaging, a common method of visual display for scientific data, has affected the visual vocabulary of some painters. Other examples are images created using fractal mathematics. In music, sampled sound has made available new kinds of sounds; for example, computers have been using sampled human voices to create songs that could not in fact be physically performed by live singers.

Film and television productions are beginning to exploit techniques such as the mixing of synthetic and real actors, the use of computer-generated scenery, and simultaneous display of multiple scenes on a split screen or in multiple windows. Digital television sets now available permit simultaneous viewing of two television stations on one television screen. We can anticipate new kinds of film scripts that exploit this capability by simultaneously presenting several linked film sequences. These kinds of technological developments represent the evolution of film technologies that has continued unabated since the introduction of cinema as an art form [4]. In dance, choreographers and artists such as John Sanborn [5] are developing new choreographic vocabularies that exploit editing techniques available in digital image processing (e.g. multiplication of images, reversal and inversion, scale changes, color manipulation). These new dance forms, marriages of video and traditional dance, could never be performed live but represent true extensions of dance as an art form.

One of the problems facing the artist using computers in pre-existing or traditional art forms is that the computer was not developed with the specific needs of artists in mind. The computer keyboard, mouse, digitizing tablet are all inferior tools for drawing compared to a piece of charcoal. The musician who is able to use two hands, two feet, breath and body motions, sometimes simultaneously, to control traditional musical instruments can be severely constrained if the only interface to the computer is a keyboard. State-of-the-art computer graphics systems still are not as flexible as a paintbrush and paints for producing realistic landscapes, and music-computer interfaces offer less control than a sliding trombone or violin bow. Development of computer-human interface technology is an area of key importance for computer artists.

One result of the lack of artists' involvement in directing the technological development of the computer is that the impact of the computer on existing art forms, although significant, has been short of revolutionary. Award-winning computer animation films have done little to advance the art of animation beyond the achievements of the 1920s and 1930s. The creators of abstract film and abstract art explored in detail most of the artistic issues being studied, at great expense, by many computer artists using expensive computer graphics. Surrealistic and photo-realist painters have already achieved the artistic goals being addressed by software simulating realistic landscapes and scenes. It is inappropriate to use the computer to address artistic issues that are better addressed using other technologies, except as training exercises for students.

New Art Forms Enabled by the Computer

Several lines of analysis are needed to elaborate the new kinds of art forms that are enabled by the computer. The first involves understanding the specific capabilities of the computer and creating art forms that exploit these. This approach, experimental and empirical, is being followed by many computer artists. As argued by John Berton [6] the concept 'tool first, application after' changes the way artists approach a tool. Berton argues that the motion picture camera shares with the computer a similar history of assimilation into artistic practice. Many computer artists not interested in learning to program the computer live within the constraints of software developed for other purposes, just as a painter is happy to leave the chemical formulation of paints to the paint manufacturer. These artists are assuming that the computer is a mature artistic technology. There are risks in this approach. Neither the steam engine nor the spreadsheet is a particularly useful tool for artmaking. Many artists creating kinetic artworks and applying new technology to art during the 1960s and 1970s failed to transcend the capabilities of the technology. The proponents of the empirical approach argue that until the artist has access to the technology, its potential for artmaking cannot be fully understood. A larger context for this argument is that, since contemporary culture is being driven by contemporary science and technology, one of the roles of the artist is as 'colonizer' of the technology for artistic ends. Some technologies, and some capabilities of computers, will not however prove hospitable hosts to the artist. I do not believe, for example, that copying machines or facsimile machines will prove to have significant, long-lasting value as art media.

If the computer is to be used as a starting point for artistic practice, it is wise to understand the change of worldview or paradigm that will ensue. The computer is of course not aesthetically neutral, since it enables certain kinds of artmaking in preference to others. Historians of science have documented in detail the impact of specific technologies on human affairs. The role of the technology of perspective in restructuring how humans viewed the world around them and their place in it has been extensively explored. As many have argued, the systems of perspective buttressed, if not gave birth to, the Renaissance belief that the individual was the center of his or her universe [7].

A recent study by Coleman argues that the technology of lens instruments—compound lens microscopes and telescopes—led to important epistemological effects, i.e. it reinforced the concept of the centrality of the ob-

server and the precept that visual observation (of natural phenomena and/or controlled experiments) was essential to scientific inquiry. These ideas underlay the philosophical ideas of the seventeenth-century Rationalist philosophers such as Descartes, Spinoza and Leibnitz.

There is a growing literature discussing the way the computer is becoming a new metaphor for explanations of physical and human phenomena. Sally Prior [8] has discussed the feminist analysis that questions the way in which the development of the computer is driven in the male-dominated computer industry; the dominance of war games in the computer-game industry is an obvious observation. Current metaphors based on the computer tend to connect to earlier metaphors of mind/body duality, rather than to emphasize the more holistic—and equally appropriate—metaphors of general systems theory.

Roy Ascott has discussed extensively how the use of computers and telematics system may change art practice. As he points out:

> There is no doubt though that telematic networks and computer systems, used merely as tools of production, will certainly and very effectively promote sterility and alienation in the culture . . . The principles of Socrates—critical reflection, personal development and sustained inquiry—must not be undermined in this new technological environment by the principles of Cato, which estimated everything by what it produced.

He cites for instance that

> the primary effect of creative interaction within computer networks is to render obsolete the distinction in absolute terms between the artist and viewer as producer and consumer, respectively [9].

Such an impact is of course incompatible with the whole foundation of the current commercial art market. This theoretical context of art made using the computer was well understood by the early pioneers of computer art. As early as 1968, Marc Adrian noted, "If in today's dealing in computer graphics the 'artist' is asked to sign a limited edition, then surely that is a concession to worn out conventions from which we will surely depart before too long" [10]. Yet a review of most of the art in computer art shows and computer graphics shows indicated that this 'convention' is still in force.

The Computer as a Technology Responding to an Existing Discursive Practice

An alternative analysis views the computer as a solution to pre-existing artistic ideas that could not be fully realized using prior technologies. The archeological method of French philosopher Michel Foucault, for instance, views the history of new technologies as beginning with the development of discursive desire and social imperatives. The development of a specific technology is then a response to this desire. One of Foucault's concerns was a critique of traditional historical ideas about inventions and beginnings:

> Archeology is not in search of inventions; and it remains unmoved at the moment (a very moving one, I admit) when for the first time someone was sure of some truth; it does not try to restore the light of those joyful mornings. But neither is it concerned with the average phenomena of opinion, with the dull grey of what everyone at a particular period might repeat. What it seeks . . . is not to draw up a list of founding saints; it is to uncover the regularity of a discursive practice [11].

Following Foucault, we need to shift from the context of current computer artmaking to the context of a larger regular discursive practice for which the computer is the desired object. One break in the discursive language of art occurred with the Constructivists early in this century. In 1966, Marshall McLuhan looking back at that period made the assessment, "The achievement of Constructivism was the abandonment of pictorial illusion in favor of multi-faceted and multi-dimensional art and can be seen as the rediscovery, after centuries of visual space and three dimensional pictorial space, of the whole human sensorium" [12]. The beginnings of practical technologies that allow the whole human sensorium to be addressed are now evident in multimedia and hypermedia workstations, virtual reality systems and technologies that allow direct connections to the human nervous system [13]. Included in this discursive practice are the long-standing artistic goals to create synaesthetic art forms that connect visual and sound art forms. There have been repeated experiments during the past 100 years to create various kinds of light organs, which can now be seen as precursors to multi-media computer works.

Within and preceding the Constructivist agenda is the long-standing search for prescriptive approaches to artmaking, a discourse that ranges from the Pythagorean school in early Greece to ongoing attempts to connect art and mathematics. These connections between art and mathematics are in a real sense fully realizable through the use of the computer. One example is the current applications of fractal mathematics for image making; there are numerous artists who have sought to create artworks that in some sense are examples of visual and experimental mathematics [14]. Max Bill made the following statement that makes this direction visible:

> I am of the opinion that it is possible to develop an art which is fundamentally based on a mathematical approach . . . The primordial element of all visual art is geometry, the correla tion of the divisions on a plane or in space . . . The mathematical approach in contemporary art is not mathemat ics in itself and hardly makes any use of what is known as exact mathématics. It is primarily a use of processes of logical thought towards the plastic of rhythms and relationships [15].

In recent years there have been a number of fertile areas of research, including the algorithmic aesthetics of, for example, James Gips and George Stiny, the generative aesthetics of Mihai adin or of Herbert Franke, and the current work in shape grammars by Ray Lauzzana and by Russell and Joan Kirsch. These research directions can be viewed as contained in a larger discursive practice that seeks to develop artificial intelligence, more recently extended to the general study and development of artificial life (the synthesis and simulation of living systems). The scientific study of artificial life has recently been the topic of two workshops at the Santa Fe Institute of New Mexico [16]; these workshops have made explicit the importance of this new science to the art of the future.

Christopher Langton defines 'Artificial Life' as

> the study of man-made systems that exhibit behaviors characteristic of natural living systems. It complements the traditional biological sciences concerned with the analysis of living or ganisms by attempting to synthesize life-like behaviors within computers and other artificial media. By extend ing the empirical foundation upon which biology is based beyond the

> carbon-chain life that has evolved on earth, artificial life can contribute to theoretical biology by locating life-as-we-know-it within the larger picture of life-as-it-could-be [17].

This agenda, locating art-as-we-know-it within the larger picture of art-as-it-could-be, is of course the agenda of the art 'avant-garde' in every period; the computer artist, working the agenda of the new field of artificial life, is defining the new art avant-garde (as the term has been applied in this century).

We can then identify one of the specific goals of the computer artist as that of developing an artistic or creative Other, an artistic Other that in turn elicits an aesthetic experience in the artist; the computer artist of the future will seek ways to break the perceived alienation of the individual in contemporary society and to create new connections to society and the surrounding world. The computer is a technology that responds to this need and to the discursive practice arising from it. Quoting Foucault again,

> I understand by the term 'apparatus' a sort of—shall we say—formation which has as its major function at a given historical moment of responding to an urgent need. The apparatus thus has a dominant strategic function . . . The apparatus is thus always inscribed in a play of power, but is always linked to certain coordinates of knowledge which issue from it but, to an equal degree, condition it. This is what the apparatus consists in: strategies of relations of forces supporting, and supported by, types of knowledge [18].

TECHNOLOGY

There are a number of attributes that could allow the computer to become a *creative art-making machine* rather than merely a significant artmaking tool. These attributes include the ability to have an in-built learning capability; the ability to connect to other computers or to people over short and large distances using various types of telecommunications technologies; the ability to collect information from the environment and to issue information through several sensory modes, many of them not directly available to the existing human senses; the ability to be used in real-time interactive display with humans or other devices; and the ability to create synaesthetic works.

These attributes can jn turn be viewed as the areas of key technological development that will allow the computer, as a component of an artificial life form, to carry out its own evolution and, through this intermediary, the evolution of the human organism. The technologies can be grouped into three areas, according to purpose. The first purpose is its use to extend or expand our information collecting systems; that is, our senses. Thus telescopes and microscopes and other light-collecting technologies extend the capability of our eyes to scales that our eyes cannot by themselves reach. These technologies also extend our visual range to include wavelengths of light to which our eyes are not sensitive. The telephone and other sound-collecting technologies allow us to extend the geographic and wavelength range of our hearing; the development of computer networks has been in response to this need to extend the sensory apparatus. An important impact of the extension of the computer through computer networks is to give credence to the concept of 'mind at large'. As argued by Gregory Bateson, the human plus the computer plus the environment can be viewed as constituting a thinking system, which today can be considered planetary in dimension. The current awareness of global environmental issues is one consequence of this perspective. Telecommunications artists, such as Eric Gidney, Carl Loeffler and Roy Ascott, then seek to create new kinds of artworks appropriate to this extended human organism.

Visualization tools—that is, computer-graphics tools—make up one of the most developed areas of computer technologies and are the fundamental technology usable to convert this expanded sensorium to a form that the human being can access. Virtual reality systems represent a major advance in providing new visualization environments. The development of new ways of connecting the environment directly to the human nervous system, bypassing the existing human senses, is one of the most important long-range agendas in this field; examples of artists working in this area are Stellarc, who has been working with a large variety of biomedical technologies, and composer David Rosenboom, who has been developing a direct musical interface to the composer's brain.

The second kind of purpose for technology is to amplify innate capabilities and functions. Thus storage devices, from books to photography to computer disks, allow us to increase both the size of our memory and the timescales over which information is collected. Machines extend the range and power of our limbs and our capability for locomotion and mechanical action. The development of robotic technologies and cybernetics is important for achieving future artistic goals; when viewed as an artistic Other, the computer needs to become mobile. Computer artists are working in a number of areas for this agenda. Australian dancer and computer scientist Don Herbison-Evans has for a number of years been developing basic software for computer choreology. Artist Margo Apostolos has been working with advanced robots in performance and artistic contexts. Workers in artificial life such as Randall Beer have been developing artificial insects, such as miniature robots capable of maneuvering around computer circuit boards to carry out circuit repairs. Artist Vernon Reed has been for some years creating cybernetic jewelry that can be viewed as a pre-cursor to cybernetic art insects.

The third kind of purpose for technology is to create artifacts—that is, to change our environment by creating objects, events or processes that in turn affect us. The technologies of art are used to create artifacts that affect our emotions and how we understand the world around us. The ability of computers to create interactions between the artist and the artwork situates the new artworks in a non-traditional format. Such formats would include the interactive environments of Myron Krueger, the interactive novels of Judy Malloy, and the global performance and interactive works such as *La Plissure du Texte* that were set up by Roy Ascott. It is very unlikely that the context of the commercial art market place, the gallery or the museum will be appropriate venues for this kind of art. These institutions derive from the needs of a prior, and exhausted, discursive practice. The computer artist is, by necessity, creating new exhibiting and displaying contexts and institutions appropriate to the new discursive practice. Paul Brown notes, "It is my opinion that practitioners should not waste their time trying to convince the arts mainstream of the value of their work. Our involvement in SIGGRAPH (1990 will mark the 10th anniversary of the SIGGRAPH Art Show), Ars Electronica, FISEA and other events constitutes the evolution of an international and interdisciplinary *Salon des Refusés*" [19].

The educational structure also needs to be responsive to the needs of the new discursive practice. A number of at-

tempts have been made to outline these new educational approaches, including Roy Ascott's call for a new Art Academy and Jurgen Claus's vision of an Electronic Bauhaus. Manfred Eisenbeis' New Art School in Cologne and the UNESCO programs to define new supporting structures for the arts in an electronic culture are promising signs that these institutions are indeed taking shape [20].

POST-MECHANICAL REPRODUCTION

The remaining question is that of *reproduction*. There are a large number of technological inventions that have allowed the production of mechanical copies from an original. The goal of mechanical reproduction is to produce copies that are indistinguishable from the original in as many ways as possible. In the case of many technologies, the goal of mechanical reproduction was embedded in a larger goal of representation. Thus Louis Daguerre stated, "In conclusion the *Daguerreotype* is not merely an instrument which serves to draw Nature; on the contrary it is a chemical and physical process which gives her the power to reproduce herself" [21]. The printing press, photography, xerography, telefacsimile, television, video, all allow the making of mechanical copies.

A different kind of reproduction is made possible by software—this is what I will call post-mechanical reproduction (although a more descriptive term such as 'generative reproduction' is needed). The goal of post mechanical reproduction is to make copies that are as different as possible from each other, but constrained by a set of initial rules. The prototypical type of post-mechanical reproduction is of course sexual and biological reproduction.

As noted by Marc Adrian, the reproductive capability of computers to produce copies of work is very different from that of photography. "The social consequences of the computer used in an artistic context lie rather in the fact that with each basic program, if it contains more than a minimum of aleatoric moments, a practically inexhaustible number of dissimilar realisations is possible" [22].

The computer is not just a useful tool for mechanical reproduction; rather it is the first tool available to the artist that is ideally suited for post-mechanical, or generative, reproduction. Artist Roman Verostko, in a recent *Leonardo* article, makes a compelling case that the art software should be viewed as genotype. He states

> This new artistic process, while hardly the same, is remarkably analogous to the biological process of epigenesis. The software . . . may be viewed as a genotype, because it is a code for how to make work. The software can make a family of works, each work being unique (one of a kind, yet familiar). The potential for crossing families of different artists opens the possibility of hybridization of form and eventually of a genealogy of form [23].

I believe that this argument is compelling and that we are seeing the birth of a new aesthetics appropriate to the new art forms. This aesthetic theory will require not only that we evaluate individual artworks, but also that we assess the art subject's ability to produce families of aesthetically interesting outputs, whether objects, events or processes, which are as different as possible from each other within the constraints of the software created by the artists. Not only is the software the art, but the behavior of that software constitutes the work of art in the age of post-mechanical reproduction.

AFTERTHOUGHTS

It is necessary to review the larger context and the desirability of creating artificial life forms. Paul Brown states:

> A tightly coupled man-machine symbiosis should lead to a close creative collaboration between man and machine. Eventually it's likely that we will see pure machine art—the product of what is essentially an alien intelligence—for the first time in human history. The potentials offered by interaction with these artificial and, once they pursue an independent evolutionary path, alien intelligences, will open up exciting new potentials for the creative artist [24].

As elaborated by Frank Dietrich,

> Previously, we had created art objects in which, by reflecting on them, we found echoes of ourselves. Now we are creating another subject, the Other that is not a mechanical contraption, such as in kinetic art, but a dynamic, autonomous entity capable of producing and understanding symbols—a machine capable of communication. This Other is really another subject which we cannot presume to be similar to us even though it can simulate a similarity that can make it indistinguishable from us. This Other manifests itself in a material-physicality that is not our flesh, and it possesses a mind that is not our mind [25].

One vision of this future is provided by cyberpunk author William Gibson in his descriptions of worlds connected by computer networks and populated by bionic humans and artificial intelligences. Gibson is reported to have been surprised by those who found his vision not uncomfortable: "It never occurred to me that it would be possible for anyone to read these books and ignore the levels of irony" [26].

To quote Paul Brown, discussing the problems facing our planet,

> Donald Michie has suggested that these problems are too complex for humans to understand and solve, and that our only hope is to develop artificial intelligence systems that can grasp the totality of the problem and so suggest viable paths of action. A dilemma here is that in order to create that technology, we need a level of industrialization that will, in the short term, increase pollution; by committing ourselves to this particular solution we also guarantee its need [27].

It is surely one of the roles of the artist to question not only the discursive practice leading to the need for the computer, but also the epistemological consequences of accepting the technology. There is need to make evident the nature of the underlying discursive practice, determine its desirability, and ensure that appropriate technologies are used. As noted by Sally Prior, in her presentation in Adelaide, we need to understand whether the discursive practice also leads to a technology for artificial compassion.

Acknowledgments

This paper is based on a talk given during the Adelaide Festival at the Center for Experimental Art, March 1990. The talk was given at a panel session organized by Virginia Barratt of the Australian Network for Art and Technology. The panel was titled "The Work of Art in the Age of Post-Mechanical Reproduction". Barratt chose this title not only in ironic reference to the phrase coined by Walter Benjamin, but as a satirical comment on the other panels at the festival—panels that dealt at great length with currently fashionable French philosophers. The other panelists were Sally Prior and Paul Brown. This final version of this paper is strongly influenced by their presentations at the panel.

References and Notes

1. Herbert W. Franke, *Computer Graphics—Computer Art* (London: Phaidon, 1971) p. 122. Franke pointed out that intellectual property rights for computer art will need to be protected by copyrights similar to those used for music and literature.

2. Roger F. Malina, "Computer Art in the Context of the Journal *Leonardo*", *Leonardo* Supplemental Issue *Computer Art in Context* (1989) p. 67.

3. John Pearson, "The Computer: Liberator or Jailer of the Creative Spirit", *Leonardo* Supplemental Issue *Electronic Art* (1988) p. 73.

4. See John Andrew Berton, Jr., "Film Theory for

the Digital World: Connecting the Masters to the ew Digital Cinema", in this issue.

5. Manfred Eisenbeis, ed., "Synthesis: The Visual Arts in the Electronic Age", *Proceedings of UNESCO Workshop* (1989) p. 146.

6. Berton [4].

7. Pierre Descargues, *Perspective: History, Evolution, Techniques* (New York: Van Nostrand Reinhold, 1982) p. 10.

8. Sally Prior, presentation to the panel The Work of Art in the Age of Post-Mechanical Reproduction, Adelaide, Australia, March 1990.

9. Roy Ascott, "Art and Education in the Telematic Culture", *Leonardo* Supplemental Issue *Electronic Art* (1989) p. 7.

10. Marc Adrian in 1969, as cited in Franke [1] p. 119.

11. Michel Foucault, *The Archeology of Knowledge*, A. M. Sheridan Smith, trans. (New York: Pantheon Books, 1969) p. 144.

12. An Interview with Marshall McLuhan, *The Structurist,* Special Issue on Art and Technology, No. 6 (1969) p. 61.

13. David Rosenboom, *Extended Musical Interface with the Human Nervous System, Leonardo* Monograph No. 1 (1990).

14. Frank J. Malina, ed., *Visual Art, Mathematics and Computers* (Oxford: Pergamon Press, 1979).

15. Quoted by George Rickey in *Structure,* 3rd Series, No. 2 (1961).

16. Christopher G. Langton, ed., *Artificial Life,* Santa Fe Institute Studies in the Sciences of Complexity, Vol. 6 (Reading, MA: Addison-Wesley, 1989).

17. Langton [16] p. 1.

18. Foucault [11] p. 195.

19. Paul Brown, "Beyond Art", paper presented to the panel The Work of Art in the Age of Post-Mechanical Reproduction, Adelaide, Australia, March 1990.

20. Eisenbeis [5] p. 13.

21. Louis Daguerre (c. 1939) as quoted in Helmut and Alison Gernsheim, L. J. M. Daguerre, *The History of the Diorama and The Daguerrotype* (New York: Dover, 1968) p. 81.

22. Franke [1] p. 119.

23 Roman Verostko, "Epigenetic Painting: Software as Genotype", *Leonardo* **23**, No. 1 (1990) p. 17.

24. Brown [19] p. 6.

25. Frank Dietrich, "The Computer: A Tool for Thought Experiments", *Leonardo* **20**, No. 4 (1987) p. 325.

26. Brown [19] p. 1.