The Wizard of Ethereal Pictures and Virtual Places

Timothy Binkley

ABSTRACT

Renaissance artists constructed pictorial space using algorithms based on Euclidean geometry. Computer artists use algorithms based on the analytic geometry of Descartes to compute pictures as well as the subjects in them. An examination of the workings of these two different types of algorithm reveals that the computer offers a radical new approach to making art, which is not yet well understood. Postmodern algorithms for picturemaking are more evanescent than their Renaissance counterparts because computers process information conceptually instead of storing it physically. The computer is neither a passive medium nor a pliant tool, but an active creative partner.

. . *the computer is a 'metaphysical machine'* [1].

—Sherry Turkle

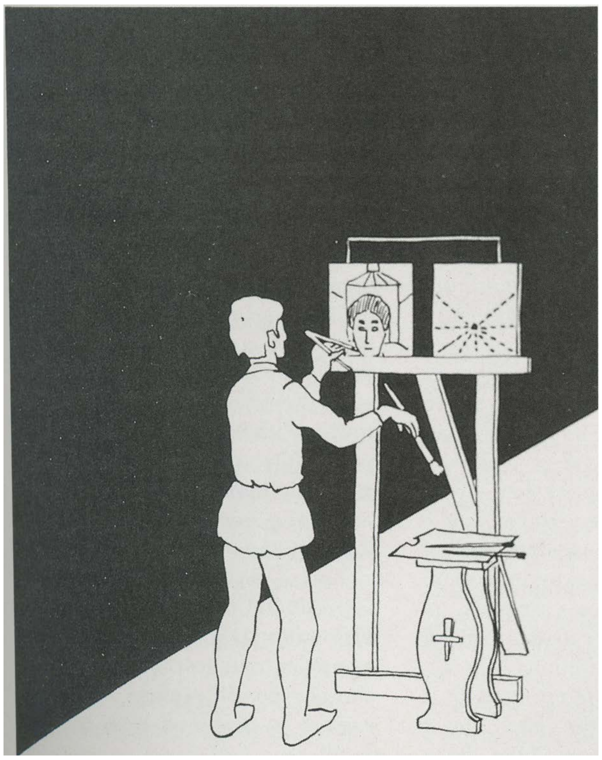
THE ARTISTIC COMPUTER: A PROTEAN ENIGMA

Computers are protean. Gamboling from the churning high seas of Postmodernism, they disturb the cultural waters even further with their enigmatic and plastic visages. Like the Greek god of the sea, they are facile with disparate guises—pretending to be now a pencil, then a spreadsheet, a design studio, an airplane, a chess partner, a paintbrush, a raconteur, and most certainly a sorcerer—all the while remaining nothing other than hyperactive dervishes spinning out myriad illusions by proficiently manipulating numbers. Add to this that their sometimes obstreperous mischief makes them seem more demons than deities, and it is no wonder that critics and the artgoing public alike are suspicious of computer art in addition to being baffled by it. What is the computer's role in art? Does it have a legitimate claim to artistic respect? Or is it simply a technological charlatan, recalcitrant to acculturation and slippery as Proteus when we try to grasp its essence?

Efforts to navigate these troubled waters sometimes liken the computer to a medium as a way of explaining its role in art [2]. But upon examination, I believe we will find the concept of the computer as a medium to be more misleading than useful. Computer art will be better understood and more readily accepted by a skeptical artworld if we acknowledge how different it is from traditional tools. The computer is an extension of the mind, not of the hand or eye, and, unlike cinema or photography, it does not simply add a new medium to the artist's repertoire, based on a new technology. The role of media in artmaking is fundamentally altered by 'thinking machines'.

It will help clarify the confusing rubric 'Computer Art', which congregates a multitude of disparate objects and events, by looking at the art-historical context. Let us begin by studying differences between picturing techniques used by Renaissance artists and those employed more recently by computer artists. By comparing the alternative ways perspective drawings are rendered, we can begin to understand in a familiar context the radical new approach to artmaking introduced by computers. The computer does much more than assist imagemaking, but once we understand its novel approach in familiar territory, we will be better able to chart its wild and woolly antics. So, taking a lesson from the old myth, let us grasp this protean creature relentlessly until it gives us some answers.

Fig. 1. Samuel Edgerton's rendition (from Ref. [3]) of how Brunelleschi constructed his first perspective picture. The Baptistry is situated behind the artist. The easel holds a mirror on the left and a painted panel on the right. Measurements are taken from the mirror by caliper and then transferred to the panel.



CONSTRUCTIVE ALGORITHMS: THE TRANSPARENT WINDOW

Circa 1425 A.D., Filippo di Ser Brunellescho made a revolutionary pilgrimage to the Baptistry of Florence to develop what we now call an 'algorithm' for making pictures. His

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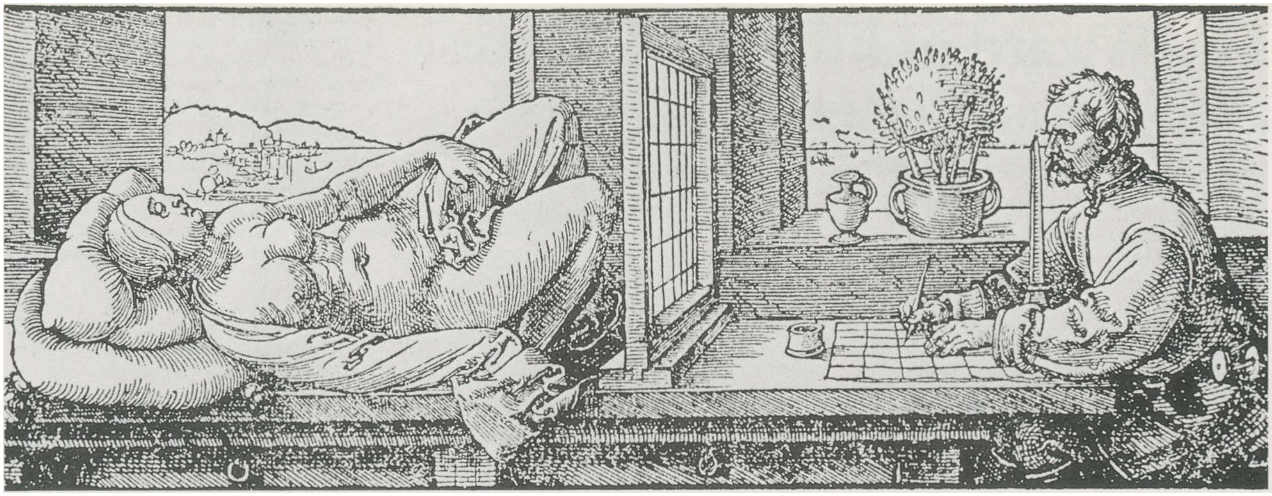


Fig. 2. Albrecht Dürer, *The Designer of the Lying Woman.* In this version of the Constructive Algorithm, the point of view is fixed by a small obelisk marking the place where the artist moves his eye to take readings. The picture plane is the framed grid of strings. A matching grid is drawn on the paper and used to transfer points from the picture plane.

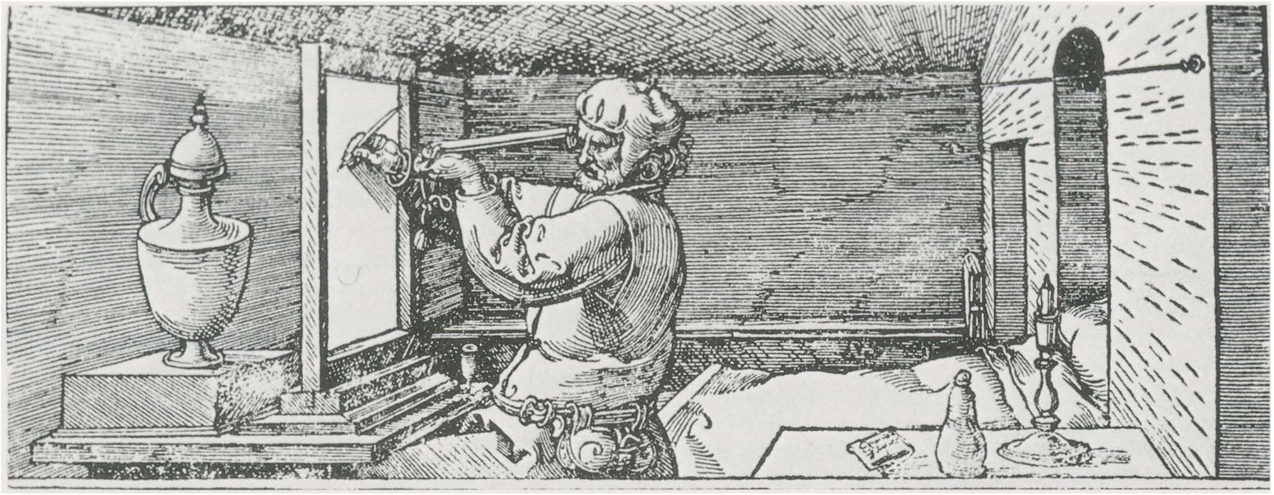


Fig. 3. Albrecht Dürer, *The Designer of the Can.* In this version of the Constructive Algorithm, the artist draws directly on the picture plane, which is transparent.

achievement changed the history of art. Perspective had apparently been used in ancient times, but there existed no records of any formulae that might be applied systematically to construct a perspective picture. By using a mirror to ascertain picture elements, Brunelleschi essentially delineated a process that can be described with a set of step-by-step instructions for transferring the appearance of the everyday three-dimensional world to a convincing two-dimensional image on a panel [3]. According to Samuel Edgerton's hypothesis (Fig. 1), the artist placed a mirror on an easel next to the panel to be painted. With his back toward the Baptistry and his own reflection partially obscuring the view, Brunelleschi transferred magnitudes of reflections in the mirror onto the panel by means of a caliper. His algorithm spawned others that were codified by Alberti 10 years later and were embraced by many artists of the Renaissance who used them to create spectacular works of art with heretofore unseen depth and startling points of view [4]. The illusionary panoramas these algorithms produce have become so much a part of our culture that we no longer feel the astonishment they provoked in fifteenth-century Florentines.

Brunelleschi's algorithm, like its progeny, is based on the constructive geometry of Euclid. Its essential parameters are fixed in the pictured setting: a *point*—the point of view—from where the scene is seen, and a *plane*—the picture plane—determining where the image will be cast onto a surface [5]. These elements are more apparent as well as easier to use in one of Albrecht Dürer's renditions (Fig. 2), where the point is determined by a small obelisk and the plane by a framed grid of strings. Like many great discoveries, Brunelleschi's seemed obvious once articulated, and the rules of the algorithm are simple to follow. Its purpose is to correlate points on the image with points in the represented setting. This is done by repeatedly connecting the point of view to points in the scene (using light rays in Figs 1 and 2 and a taut string in Fig. 3). Lines so constructed will intersect the picture plane at a point that represents the corresponding point in the world. With this sort of algorithm, the perspective picture is actually *constructed* following Euclid's classic principles of geometric construction with straightedge and compass. The conviction of the apparition so fabricated is grounded in Euclid's Twenty-First Proposition (Fig. 4), which guarantees by similar triangles that proportions in the picture will preserve those in its subject as perceived from the viewpoint.

Once his algorithm became known, industrious artists found many ways of implementing and modifying Brunelleschi's insight. Dürer made a number of woodcuts depicting different methods. In yet another of his constructive algorithms (see Fig. 3), the artist again fixed the point of view with a screw eye mounted on a wall, but the picture plane was a transparent sheet and the lines of sight were intersected with the picture plane by aiming them through a viewing tube attached to a string tied to the screw eye. All of these algorithms involved geometrical constructions that are accomplished with manual tools such as pens, strings, rulers and calipers and were carried out in the actual presence of the depicted setting. Related techniques were developed by Alberti and subsequently by others for designing perspective images of simple geometrical shapes without needing a real physical subject to work from. The *locus classicus* of strictly two-dimensional constructive algorithms is the checkerboard ground plane Alberti used as his paradigm (Fig. 5). By turning the line of sight 90 degrees, one can place it in the same plane as the picture and, with a straightedge, construct the receding horizontal lines. Although capable of assisting the construction of pictures of imaginary settings by adumbrating geometrical outlines, even these methods require the manipulation of real physical tools on a desktop, tools that constitute the necessary hardware for any geometrical construction. The achievements of Renaissance artists promoted the development of an abstract theoretical branch of mathematics called Projective Geometry, but the applications of its theorems to picture-making always rely upon the concrete manipulations of constructive geometry.

Brunelleschi's ingenious insight has been likened to cutting a window in the Medieval fresco wall [6]. His predecessors used a motley assortment of practical rules of thumb to indicate depth; these had been gradually worked out over the centuries, including such principles as occlusion, foreshortening, terracing, and locally convergent lines in architecture, which were usually developed in response to particular types of subject matter. Artists of the Middle Ages struggled to make plaster and pigment adhere to a wall while amalgamating dissimilar methodologies in an effort to concoct a convincing representation of what was outside. Brunelleschi and his peers broke through the barrier of the wall and instituted a completely systematic method of projecting three dimensions into two to reveal a pictured world so clear and refined that it appears as if viewed through an open window. Easel painting was born on moveable framed panels.

Computational Algorithms: The Luminous Screen

Two hundred years after Brunelleschi's discovery, Descartes built the foundation for a rather different kind of picturing algorithm based on analytic geometry. Although such algorithms were not widely used until the advent of computers, they can be described without any reference to hardware. Instead of working directly with manual tools in the real world, a computational algorithm relies upon algebra applied in an abstract coordinate system. It is an example of the kind of problem treated in a new branch of mathematics that has recently been christened 'Computational Geometry'.

Computational algorithms for picturing do not require placement in any real setting; indeed if one wants to depict an actual object, the first step is to abstract its shape from the real world and place it in the imaginary world of a selected coordinate space (see Fig. 6). The object must be described using numbers to fix its characteristics ($X0$, $Y0$, $Z0$). The picture plane is similarly determined with points or an equation ($z = ZP$), and the point of view simply becomes an ordered triple (XV, YV, ZV). A computational algorithm functions not by manually or optically tracing out lines connecting an object to a point, but rather by using equations to calculate algebraically the depicting points of intersection in the picture plane. Once the points are calculated, they need to be reified in some medium to make an actual image out of them. As such algorithms are used today, this medium is typically the screen of a video monitor connected to a computer that performs the calculations and sends the results to a cathode ray tube (CRT).

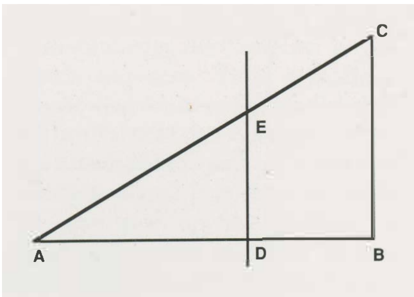
Before examining the computer's contribution, let us look more closely at how the two types of picturing algorithms differ.

The underlying frameworks are similar: beginning with an object, a plane, and a point, we create a representation of the object in the plane by scrutinizing lines connecting the object and the point. Perspective projections using the two algorithms may sometimes have similar appearances, but they are quite different and can yield rather different-looking results. In order to highlight their differences, let us step up to the easel beside Brunelleschi and compare 'manual' executions of both.

As Brunelleschi deftly gleans the outlines of his picture by casting glances at his mirror, we laboriously begin setting up a coordinate system by arbitrarily (but we hope conveniently) locating an origin and three perpendicular axes. The next step is to use a tape measure to take readings of the positions of the main features of the Baptistry and record them as coordinate triples in reference to our axes. Similar readings are taken for the picture plane and the point of view. So far, we are doing only preparatory work. Brunelleschi has probably already completed at least a sketch of his picture before we even finish taking readings.

Brunelleschi must use his algorithm while standing in the square before his subject, whereas the real work on ours begins after we leave the site. As we slowly sift through our data and process them, a piece of graph paper is kept on the side where the axes of an appropriate 2-D coordinate system have been registered to represent the picture plane. Each time a projected point is calculated, it is marked on the paper, and a picture slowly begins to take shape. Once abstracted and

Fig. 4. Euclid's Proposition 21 states that, given a triangle, *ABC*, and a line, *DE*, intersecting two of its sides, *AB* and *AC*, and parallel to the third, *BC*, then the smaller triangle, *ADE*, is similar to the larger one, *ABC*. This theorem assures the preservation of proportions in perspective projections.

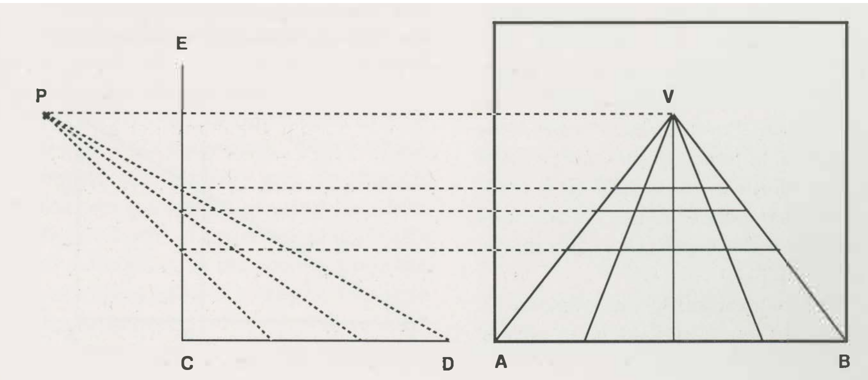


processed, the information arising from the depicted setting needs to be reconcretized to convert it into a pictorial—as opposed to merely a numerical—format. The image surface has become once again opaque, like a Medieval fresco wall, and we never have the sense of making an image by peering through a window.

Recent technological developments turn the picture plane of computational algorithms into the luminous screen of a CRT, which replaces the Renaissance window and emanates a vibrant image after it has been quickly calculated by a computer. Despite its comparatively humble appearance, the computer is actually more critical than the vibrant screen to a successful career for the new algorithms, since our thought experiment clearly demonstrates the impracticality of trying to execute them 'by hand'. Yet maybe we should say 'by brain' since mental processes are more important then manual ones in executing computational algorithms. The practical difference is one of the first things that strikes us about the two algorithms: one can be executed manually, the other cannot. But the reason for this goes deeper than matters of convenience, since the two algorithms manipulate different kinds of entity and take place in quite different realms. The former works with objects in the real world; the latter works with concepts in an imaginary one [7]. One I do primarily with my hands, the other primarily with my mind (although I do, of course, use both mind and hand in either case). The reason the computer revolutionizes picturing by computation is because of its speed and precision in performing calculations. But this is a mental, not a physical, prowess.

It is important to notice what happens at the onset and culmination of the computational algorithm. At both ends conversions occur, from concrete to abstract and back again. These transformations are unnecessary in constructive algorithms since their execution stays concrete from beginning to end. In constructions, information is taken from the world and processed in an *analog* format. It is continuous, smooth and transferred directly from the world to the picture by physical processes using physical magnitudes. The computational algorithm, on the other hand, processes information as numbers whose magnitudes are indicated not by physical size but by symbols in a conceptual framework. It treats information in a *digital* format, which is discontinuous, discrete, and extracted from the real world by an indirect process that converts physical magnitudes into numbers. The tape measure is a primitive analog-to-digital converter that delivers numbers for computation, and graph paper is a crude digital-to-analog converter that turns numbers into physical magnitudes on paper. Both are grounded in a Cartesian coordinate system that supplies the frame of reference for making the conversions. Thus, while constructive algorithms are bound to record information from the real world, computational algorithms can be used to generate pictures of fantasy worlds just as readily: coordinates do not by themselves betray whether they represent any real object or event.

Fig. 5. One of Alberti's methods for constructing, entirely on paper, a perspective picture of a checkerboard floor. A side view of the projection is drawn on the same piece of paper as the picture, adjacent and aligned. The principal vanishing point, *V*, is located in the picture, and lengths of the floor tiles are marked off along the line, *AB*, where the ground plane and picture plane intersect. Receding lines in the floor are constructed by connecting *V* with the points marked on *AB*. The lateral floor lines, which are more difficult to position and came later historically, need to be constructed in reference to the side view. Lengths of the floor tiles are again marked, but this time on line *CD* in the side view. Line *CE* is the side view of the picture plane. By connecting the point of view, *P*, to the points on *CD*, the correct position of the orthogonal floorlines can be found at the intersections with *CE*.



The major difference between the two types of algorithm lies not in technology, but in ontology. Constructive algorithms have been automated as well—by cameras, which can often take pictures quicker than computers can make them. But cameras cannot take pictures of fantasies since they automate manual chores, not mental ones. Computers using computational algorithms, on the other hand, can conjure up images of any world that is mathematically describable. This is because the computer is an extension of the mind, not of the eye or hand.

Because they deal with numbers instead of objects, computational algorithms can encompass a greater breadth of information than their constructive counterparts. The original Renaissance algorithms projected only shape and location; there were no resources for dealing with color, lighting, transparency, elasticity and a host of other parameters that are grist for the computational mill. Even cameras, which often do a good job with color, do not permit independent control of variables and cannot depart from what is presented by the panoramas and laws of nature.

One algorithm works with physical tools and materials, the other with conceptual structures and numbers that have no preferred or canonical material expression. Nowhere is this distinction more apparent than when we look at dimensions greater than three. Although constructive algorithms can be used to project three dimensions into two, there is simply no way to stretch a string into the fourth dimension to construct a projection of its inscrutable denizens. Computational algorithms, on the other hand, can readily be devised to project images from higher dimensions into the lower ones we inhabit. The work of Thomas Banchoff and his colleagues at Brown University offers unprecedented glimpses into the fourth dimension that help us visualize what it is like, much more vividly than we are able to do simply by thinking about it or making sketches by hand. Our understanding of the hypercube (a four-dimensional analog of the cube) is greatly increased by viewing his animated film that shows different views of it as it rotates. This is accomplished by calculating the projections from four- into three-dimensional space and then from three-dimensional space into the two-dimensional space of the film. Just as the constructive algorithm gave rise to projective geometry, the computational algorithm is opening up vistas on new mathematical worlds. It is a boon to mathematics and science, as well as art, because it yields to our purview a wide variety of rich new abstract worlds including such things as cellular automata, chaos and fractals.

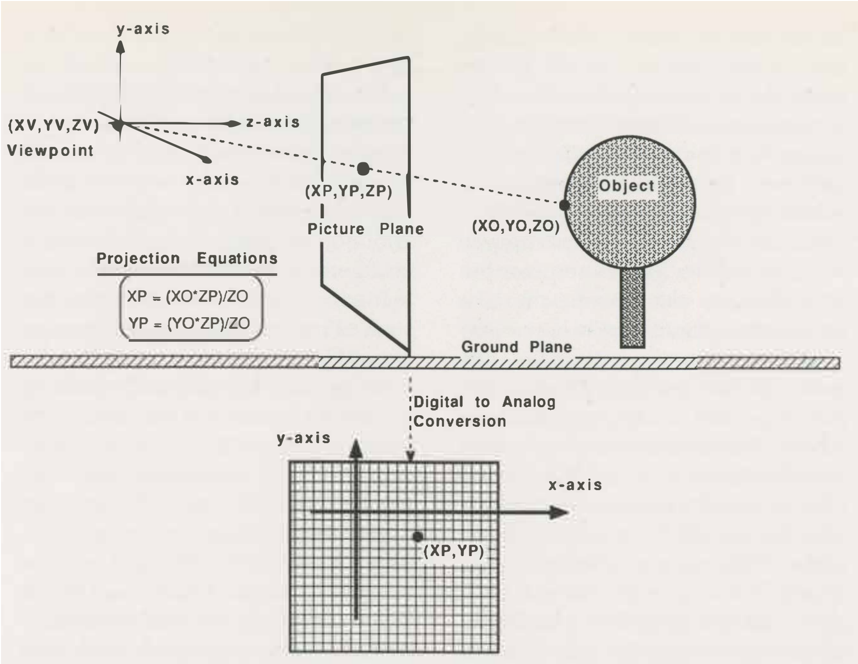


Fig. 6. The Computational Algorithm. Projected points, such as (X_p, Y_p), are calculated using equations. Once their values are determined, they can be plotted on graph paper representing the plane of the picture.

THE COMPUTER'S ROLE: CREATIVE PARTNERING

Let us first consider the role of a medium in constructive algorithms. In a Renaissance painting, the medium of paint serves several functions. (1) It is the physical repository of pictorial information. The projection is constructed in the plane of the painting. (2) It passively embodies this information in an analog format existing in an inseparable union with paint. It is deposited directly on the canvas, so to speak, and does not exist in another form that can be freely moved from one medium to another. (3) It is the locus defined by a set of manual tools and techniques for articulating imagery. In order to make a constructed picture, the artist manipulates a physical material and hence must learn how to do such things as mix paint and wield a brush. (4) It is a channel for communicating cultural information from one person to another. We learn of Renaissance art by looking at paintings made at that time or by looking at reasonable photographic facsimiles of them. (5) This channel is culturally defined. It is according to a set of cultural conventions that the artistic message is read from the front of the painting and not the back, or that it stops where the frame begins and does not continue onto the adjacent wall.

The artist stands amidst media creativity. One element the artist contributes, which is not part of the medium per se, is the imaginative thinking that gets expressed in the work of art. This thinking activity is absolutely essential in order to construct a picture: the artist figures it out using manual tools, but without the mental process nothing happens. So the artist's mind is allied with the physical material of a medium to procure the creative result.

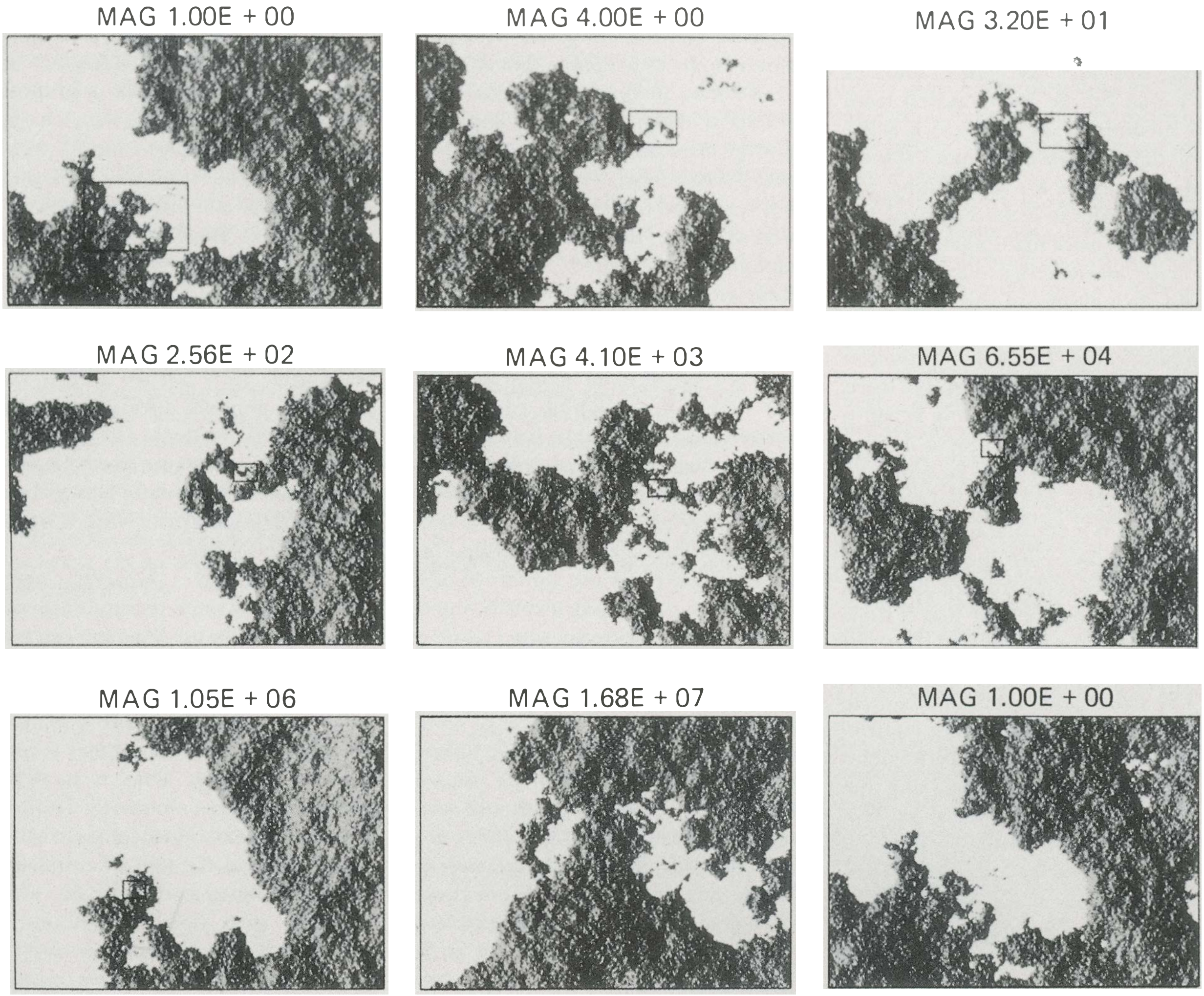
Now if we look at what a computer does for computational algorithms, it appears that its function is much closer to the conceptual contribution of the artist than to the physical contribution of the medium. Computers diverge from media on each of the five points listed above. (1) Computers are not very good places to store information since they do not have very large memories and tend to forget everything when turned off. Furthermore, stored information is conceptually coded in a digital format, not physically embodied in an analog one; this (2) makes the machine capable of actively manipulating it. It is immaterial to digital pictorial information whether a computer is made of silicon chips or vacuum tubes since these substances are not constitutive of that information the way the substance of a medium is. (3) Mental dexterity supercedes manual dexterity when using a computer, and no fixed tool-based skills are prescribed. (4) Computers are not themselves channels of communication, although they are linked to such channels in much the way we are. (5) The computer deals with concepts, numbers, and bits, which are not culturally defined and dependent in the way a medium is. From these considerations, I think it is apparent that the role of a computer in art is more that of an active creative partner than a passive medium [8]. Comparing the benefits of a computer to a pencil is not like comparing the advantages of a backhoe to a shovel when one is searching for buried treasure. Rather like a seismic detector, the computer does not promise to shovel more dirt faster to get to the rich nuggets of creative insight more quickly but rather avails itself of a little intelligence to obviate the need to move a mountain to find a pot of gold. In computational algorithms executed by computer, some of the thinking burden carried by the artist using a constructive algorithm is shifted to the computer. Here we see clearly that what the computer does is quite unlike what a medium does. The computer 'thinks'—it calculates. Media cannot do this since they are physical and passive; the computer can since it is conceptual and active.

The computer, however, needs media for the same reason our brains need sense organs. A person can execute a computational algorithm in the mind, but it requires eyes and hands to convert the data into a picture. Without media, the computer is completely impotent. Thus it is always functioning in a symbiotic relationship with at least one medium to which it is interfaced through an automated analog-to-digital converter. So, while we may give up the medium of graphite for page layout in desktop publishing, we nevertheless transfer its function to another medium, the laser printer. Computers are so integrally bound up with media that they are starting to be built into the tools of media, such as cameras and videotape recorders. Putting them closer to the media they work with is a trend likely to continue and intensify as computers grow smaller and more powerful. This may be one reason why it is tempting to assimilate computers into media and try to win a place for computer art in the gallery alongside paintings and sculptures. But this strategy is dangerous since it obscures the computer's true role and is more likely to put off than to convince critics who are skeptical that the computer has any valid role to play in making art. The promiscuity with which a computer can interface with a variety of media underscores the fact that it is not one of them. If we hope the computer will eventually become accepted as a new medium, we may have a long wait.

Although it must use media, the computer is not best understood as a new medium tool, whether it is in the gallery as an interactive installation or in the studio as a creative partner. It is a metamedium and a mental tool. It can add intelligence to tools by working cooperatively with them. Its contribution is made by establishing a relationship between hardware and software that does not exist for the tools of media. The computer is more versatile than a camera, but it can do nothing without software to guide its cognition. A camera is not directed by software because it is 'hardwired' to do one job only; it is physically based and cannot think for itself [9]. Software supplies the computer's affect, its 'personality', which is what makes these machines able to interact and think. The computer is not a single-minded tool: it can be taught new tricks with new software. It can 'learn', unlike traditional media-based tools that are unable to modify the structure of their behavior based on any software fed into them. Even though a video cassette recorder can play any tape, it can do nothing other than play it out (unless, of course, it has a little computer inside).

In his renowned essay, "The Work of Art in the Age of Mechanical Reproduction", Walter Benjamin claims that mechanical technologies remove the aura from one-of-a-kind artworks produced using traditional methods [10]. The *Mona Lisa* loses some of her mystery when the image of Leonardo's painting is subjected to profligate replication in books, magazines, posters and post cards. The computer can reproduce imagery even more faithfully than mechanical devices can, since it processes information digitally; but its effect on art is unlikely to be similar. Its information technology is more metaphysical than mechanical, which makes it capable of generating novelty and responding uniquely to different situations. Its legacy need not be the impersonal tedium of assembly-line culture emanated from physical dynamos conceived in the Industrial

Fig. 7. A sequence of zooms into a fractal landscape by Richard Voss. Magnification ranges from 1 to more than 16 million.



Revolution. Although the computer will never reclaim the lost aura of art from an earlier age, it does invite new personality onto the art scene.

The Myth of Resolution: Metaphysical Imagery

Some artists are drawn to the computer (or repulsed by it) because of what they perceive to be a characteristic look of the art created with it. This is, however, just another byproduct of the effort to domesticate these intractable machines by assimilating them into media. Even a cursory examination of the varied work in exhibitions reveals that computer art in itself has no representative physiognomy. Computers are bound to media, but to no particular one, and hence work done with them can project all the different appearances of media currently in use. The myth of the look is fostered by the fact that, due to historical circumstances, the canonical medium for working with computers has been the CRT connected to image memory in frame buffers that have until recently been rather limited in size. Yet since their role is conceptual, not perceptual, any new appearances that computers introduce must reside in the structure of their interfaces to media, and not in the substance of media, in the way that certain looks are characteristic of watercolors, oil, pastels or charcoal.

One of the paradigmatic differences between computers and media is that the former usually process information in digital form while the latter store it in analog form. Because of this difference, imagery created with computers can still look discrete when interfaced to an analog medium and give the impression that the computer has its own peculiar 'digital' look. Yet in the process of converting digital computer information into analog medium information through an interface with an analog-to-digital converter, the discreteness of digital information can be hidden and completely assimilated into the analog medium.

One feature that has until recently been commonly associated with computer art is the low resolution for which it was often ridiculed in its infancy. But it is important to recognize that the computer per se is resolution-independent in a way no medium can be. This is at first difficult to comprehend, since we constantly talk about the resolution of computer graphics systems and compare them on this basis. Yet this concept of resolution has more to do with interfaced media than with digital information. Media has resolution; computers do not. The resolution of video or film is rather apparent, based on the number of scan lines of a video system or the size of grains on film. Even paints and pencils have a definite resolution, refined although it may be. The computer, on the other hand, does its calculations with numbers whose results can be delivered to an output device at any desired resolution. The precision of floating point arithmetic does impose limits, but these limits are flexible and permit the reiterated zooms of Richard Voss (Fig. 7), which would produce grainy pictures very quickly if done photographically. Even a tunnelling electron microscope possesses a quite definite—albeit extremely high—resolution, while computerized magnifications of virtual worlds can seem to go on forever without losing definition. Resolution is not defined by the computer, but by the output device—a medium.

Interaction in a Postmodern World: Experiencing Virtual Reality

The era of Modernism was the age of new media: photography, cinema, video, acrylic paint and fiberglass sculpture. The self-conscious exploration of artistic expression that was characteristic of Modernism provided the spawning ground for new media as artists experimented with newness and highlighted the foundations of their expressive channels. Banners of the avant-garde charted a progressive course through exhaustive investigations of the possibilities of media.

Conceptual art marked a watershed between the progress of Modern art and the pluralism of Postmodernism [11].

Due to its conceptual orientation, the computer should not, I believe, be placed in a Modernist context as a new medium, but rather in the context of an increasingly conceptual Postmodern art that, while reverting to the use of media, remains aloof from them. The computer is Postmodern not only temporally but theoretically. By working with formal properties, computers can simulate anything specifiable with numbers or mathematical formulas. They thereby demonstrate something of Proteus' prescience by being able to foretell the future—or at least play it out—in a virtual world. These computer simulations should be allied with the Postmodern work of such artists as Sherry Levine or Michael Graves and not with the media they sometimes simulate. The recent history of art has witnessed the breakdown of distinctions between traditional media, and artworks have become generally less media bound (happenings, performance art, multi-media, conceptual art, etc). It is retrogressive to try to justify computer art as the advent of yet another medium when in fact its real import is much more closely allied with the conceptual thrust of recent art than the physically based media delimited in the past as separate disciplines. Even when it emulates them and uses them, the computer etherealizes media and makes them evanesce in the spirit of a tradition inspired by Marcel Duchamp's readymades. Although his amusing work *In Advance of a Broken Arm* is a physical object (a snow shovel), its artistic meaning is not expressed in physical material the way a sculpture by Rodin or Calder is. The import of the computer as a creative partner is similarly conceptual. The computer is more than a fancy picture maker; its powers are versatile enough to carry us into the virtual worlds it conjures up with its computational algorithms. The window of Renaissance perspective is a barrier keeping us away from the depicted world at the same time it unveils it to us. But the luminous screen under computer control can transport us—like Alice through the looking glass—into the virtual worlds it displays. We can, in a sense, live in these created environments and interact with them.

The unique element computers add to art is interactivity. This happens in two stages. First, the computer transcends the passive physicality of media to become conceptually active. The art itself has assumed the ability to manipulate conceptual objects; this has heretofore been the exclusive domain of the artist. The second step takes place as the artwork becomes almost anthropomorphized so that we can interact with it. It is not simply active, putting on a performance of entertaining wizardry, but it recognizes us as sentient beings with whom dialogue is possible. The paradigm by which to comprehend computer art is not the medium or the medium simulation, but the interlocutor. The computer rises from the sea of Postmodern culture not as a new Venus promising more beautiful art, but as a wily sorcerer taunting us with its cleverness. This wizard is not easy to work with [12], but commands an intriguing repertoire of artistic resources.

References and Notes

1. Sherry Turkle, *The Second Self* (New York: Simon & Schuster, 1984) p. 16.

2. See, for example, Arielle Emmett, "Computer and Fine Arts", *Computer Graphics World* (October 1988) pp. 68–75. See also Cynthia Goodman, *Digital Visions* (New York: Abrams, 1988). Her book and the exhibition "Computers and Art", on which it is based, provide ample documentation of the diversity of art created with computers. Other examples of the medium paradigm can be found in *The Art of David Em* (New York: Abrams, 1988) and Stephen Wilson, *Using Computers to Create Art* (Englewood Cliffs, NJ: Prentice Hall, 1986). Wilson does admit, however, that "it is a concept . . . that may have outlived its usefulness" (p. 21).

3. Brunelleschi left no record of the precise rules he followed, but Samuel Y. Edgerton, Jr. has done an admirable job of reconstructing them in his book *The Renaissance Rediscovery of Linear Perspective* (New York: Basic Books, 1975).

4. Leon Battista Alberti, *Della Pittura*, L. Mallè, ed. (Firenze, 1950).

5. Edgerton [3]. See also my article "Computed Space", *Proceedings of the National Computer Graphics Association* (1987) pp. 643–652.

6. Edgerton [3]. See also John White, *The Birth and Rebirth of Pictorial Space* (New York: Harper & Row, 1972) and Dan Pedoe, *Geometry and the Liberal Arts* (New York: St Martin's, 1976).

7. Jean Baudrillard dubs this computational realm 'hyperreality' to distinguish it from the real world of constructions. See his *Simulations* (New York: Semiotext(e), 1983).

8. Arguments for this view are presented more fully in my essay "The Computer Is Not a Medium", *Philosophic Exchange*, forthcoming. See also "Medium Nor Tool?", *Computer Graphics World* (February 1989).

9. I explore some of the differences between ways cameras and computers make pictures in "Camera Fantasia", *Millennium* **20/21** (Fall/Winter 1988/1989).

10. Walter Benjamin, "The Work of Art in the Age of Mechanical Reproduction", in *Illuminations* (New York: Schoken Books, 1969).

11. Some background for these views is presented in my article "Piece: Contra Aesthetics", *Journal of Aesthetics and Art Criticism* **23** (1977) pp. 265–277, reprinted in *Philosophy Looks at the Arts*, Joseph Margolis, ed. (Philadelphia: Temple University Press, 1987). See also "Conceptual Art: Appearance and Reality", in *Culture and Art*, A. Balis, L. Aagaard-Mogensen, R. Pinxten, and F. Vandamme, eds. (Gent, 1985). Relevant examples and discussions of conceptual art can be found in Lucy Lippard, *Six Years: The Dematerialization of the Art Object from 1966 to 1972* (New York: Praeger, 1973); Gregory Battcock, *Idea Art* (New York: Dutton, 1973); and Ursula Meyer, *Conceptual Art* (New York: Dutton, 1972). Relevant discussions of Postmodernism can be found in Brian Wallis, ed., *Art After Modernism: Rethinking Representation* (New York: New Museum of Contemporary Art, 1984).

12. I discuss some of the unique problems attendant upon efforts to create art with a computer in "Does Art Computer?: The Myths, the Madness, and the Magic", *Art and Academe* **1** (1988) pp. 90–99.