COMPUTER GRAPHICS AND ART

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COMPUTER GRAPHICS AND ART

COMPUTER GRAPHICS and ART is a new international quarterly of interdisciplinary graphics for graphics people and computer artists. This new periodical is aimed at students, teachers, people from undergraduate and graduate institutions, researchers, and individuals working professionally in graphics. Its topical coverage is broad, embracing a variety of fields. It is useful, informative, entertaining, and current.

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This periodical is aimed at students, teachers, people from undergraduate and graduate institutions, researchers -- and individuals working in graphics. Its topical coverage is broad, embracing a variety of fields. It is useful, informative, and current.

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ABOVE: "Wernher von Braun" by E. T. Manning. MEDIUM: Photo of output of optical processor for spatial quantization. The original shown in the ART OF THE SPACE ERA EXHIBITION is in color. The latter is 24" x 18", in proportions of 4:3.

SPATIALLY QUANTIZED IMAGES

by E. T. Manning
Watson-Manning Incorporated
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Stratford, Connecticut 06497

This picture is a spatially quantized transform of an ordinary color photograph of Wernher von Braun. It was made by photographing the output display of an optical processor that I built, on whose input face the original photograph had been projected.

It has often been observed, and probably quite correctly, that the computer is another (and magnificent) tool for the artist. The digital computer certainly opened the way to the intriguing art form of the spatially quantized image.

The artist is quick to shape his tools to his needs. If he enjoys the long way around the block, he can install a small digital computer on the passenger's seat of his automobile to provide a constant calculation of the amount of gas left in his tank -- or he can glance at the gasoline gauge which is a somewhat specialized (albeit very simple) computer that gives him the same information.

Just as it is simpler to use the gasoline gauge to measure how much gas is in the tank, it's simpler to use a specialized optical processor to prepare a spatially quantized image.

The simple term "optical processor" disguises an assemblage of instrumentation somewhat more complex than the gasoline gauge. In the same sense that a gas gauge can be defined as a specialized computer, the optical processor is a specialized computer. It has a tremendous advantage in its speed of operation. Coupled to a digital computer through proper sensory equipment, the optical processor can be a powerful tool in the areas of automatic recognition, gross sieving of data, investigation of fuzzy sub-sets and combinatorial mathematics. Used alone, it provides intriguing images that not only titillate the retinae and amuse the psyche, but provide deep insights into the processes of perception and recognition.

THE SIGN OF TOMORROW

by Manfred Mohr
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75007, Paris, France

The fundamental view that machines should not be considered as a challenge to humanity, but like McLuhan predicted, as an extension of ourselves is the basic philosophy when becoming involved with technology.

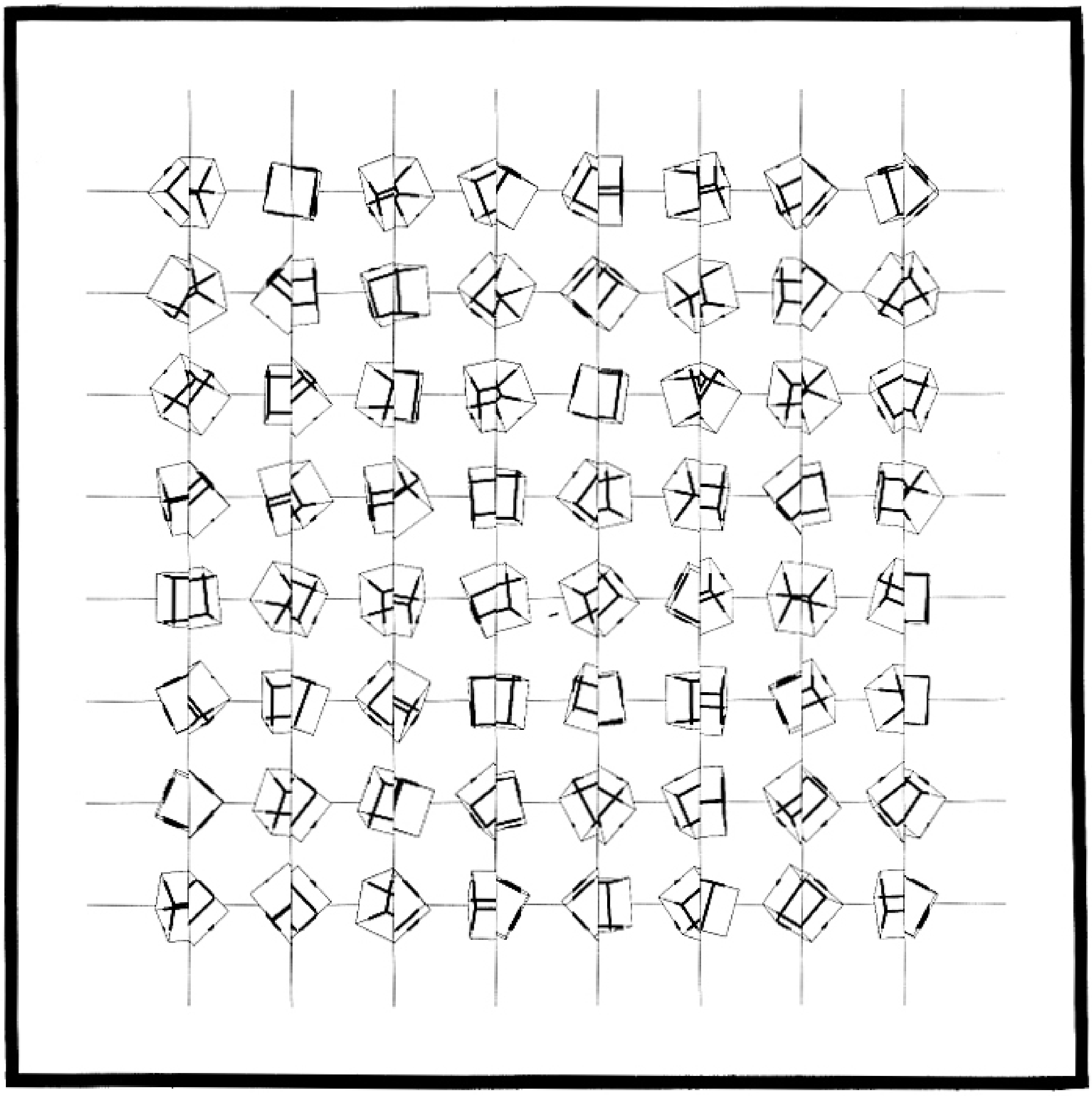
A technology which "functions" has to be integrated in our lives like a physical extension -- a necessity of our body and our mind. We are living now in an era of enormous technological transitions, where so many misunderstandings in human-machine relationships are created by lack of knowledge and the categorical refusal to learn by most individuals. A quasi-mystical fear of an incomprehensible technology is still omnipresent.

Breakthroughs in human development are always accompanied by radical changes of attitude towards the so-called human values. It is, for example, from a practical (and philosophical) point of view evident that one should simply be ready to leave the most possible part of a work to a machine when it becomes clear that in this way the desired solution may be better and more reliably achieved. It is also true that human thought can be "amplified" by machines, raising our consciousness to a higher level of comprehension.

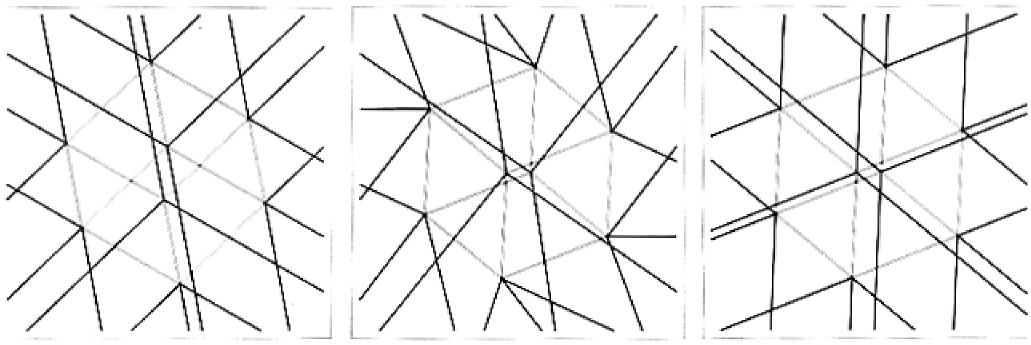
To apply methods of this kind in science is obvious, and generally considered as basic. To use similar methods in aesthetical research is, in my opinion, a possible and nevertheless historical consequence. Aesthetical research runs, for this point at least, parallel to scientific research, and together they make our human developments more comprehensible.

In this context I consider the computer as a legitimate amplifier for our intellectual and visual experiences.

BELOW: "P-197A" by Manfred Mohr, 60 x 60 cm. MEDIUM: Heliogravure.



BELOW: Portion of "P211 A" by Manfred Mohr, a series of seven related works.



Through detailed programming analysis, one is able to visualize logical and abstract models of human thinking, which lead deep into the understanding of creative processing. Creative processes are mental processes having a priori an associative character, where associations are defined as interactions and/or transversal connections (Querverbindungen) of thoughts in a Time-Space neighbourhood relationship.

Unifying those divergent or intersecting data from memory in order to form new meanings is called imagination or the facility of creating free associations. Most adults have been taught to think in a way which does not allow them to play with free associations. This "cliche" thinking of so many people is radically opposed to imaginative thinking. To create new and perhaps important aesthetical information, it is necessary to operate with free associations. This does not necessarily involve a talent, but a training which has to be practised.

A computer, however, is (at least until today) not able to process in an associative way, even though it is a self-supervising machine. The computer is not conscious of what it is doing and can only execute orders from outside: from us! That means: a computer itself cannot create or invent anything. We do not have to ask: what can the computer do?, but reverse the question by asking ourselves: what do we want to do? and then consider whether the help of a machine could be useful for our purpose. If the answer is positive, we have to find ways of asking the machine the right questions in order to get reasonable results, amplifying our thoughts and intentions. Proceeding in this way is an important step towards a systematic approach of aesthetical problems. Abraham Moles once said: "La machine ne pense pas, elle nous fait penser."

A SYSTEMATIC APPROACH OF AESTHETICAL PROBLEMS

There are several ways of approaching the computer for this purpose:

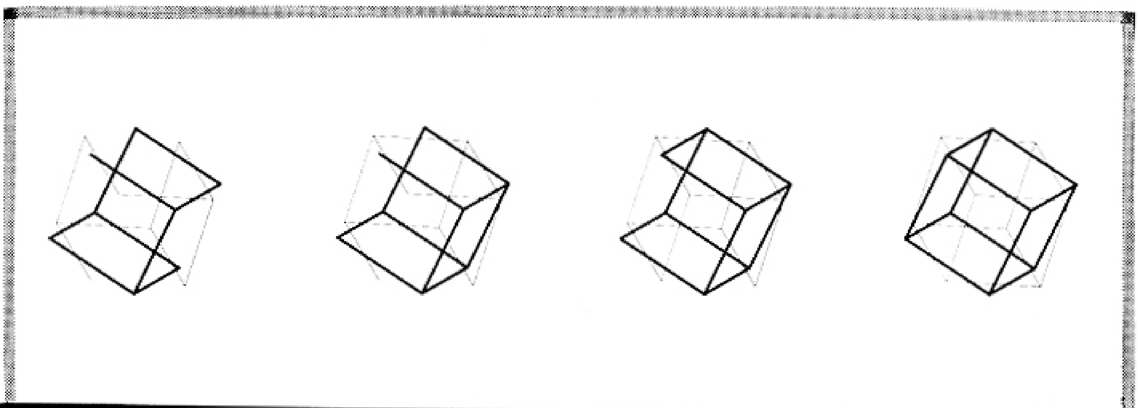
1. A Visual-Concrete Procedure

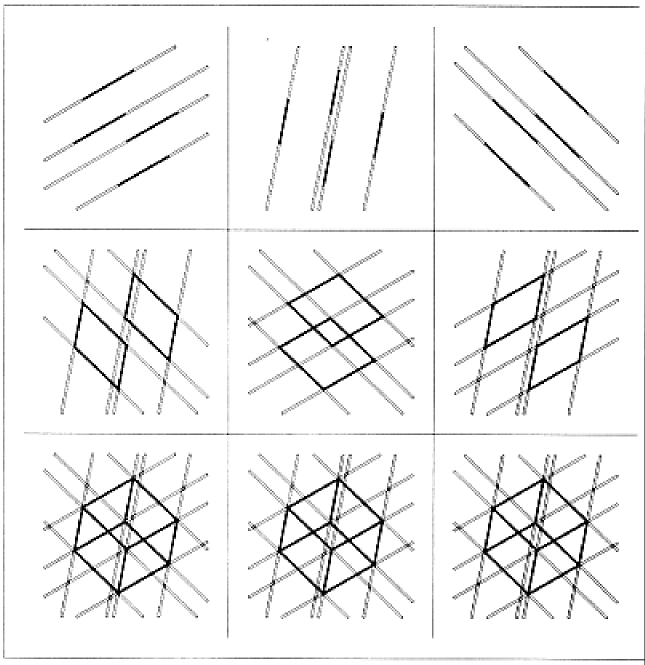
An existing visual image is dissected into its basic elements. Each element can represent an algorithm. One can operate in various ways with these elements. The experience is: visual image -> process -> visual image.

2. A Statistical-Flexible Procedure

An existing or invented abstract logic is the basic algorithm and no visual image, or only a vague one, can be predicted. The importance of this approach lies in the applied rules, which are, at least, in their conception, a new way of approaching a visual experience. The experience is: abstract logic -> visual image.

BELOW: Four examples from the "Signs and Co-Signs" series, P193B, by Manfred Mohr. This particular series contains 26 related works.





ABOVE: "P210 A" by Manfred Mohr, 35 x 35 cm. The work is a series of two designs. Part 2 is shown below.

Statistical-flexible procedures deviate into two distinct directions:

A. The Visualization of Mathematical Formulas

Without doubt very interesting results can appear which have never been seen before. For long-term artistic interest, however, the resulting aesthetical information of a mathematical formula is in itself limited and therefore a closed system.

B. The Research to Find or Invent Individual Rules as a Means of Artistic Expression

The individual impact of human behavior, filtered and reformed through the inherent peculiarities of a computer, will lead directly to an interesting and overall coherent open system. Of course mathematics are used, but in this case only as a technical help, and not as the sole purpose. The logical construction of a programming language forces us, on the one hand, to concentrate with an almost maniacal precision of formulation (the instructions), but opens, on the other hand, new dimensions for a wider and statistical thinking.

THE DIALOGUE WITH THE COMPUTER

New operation models appear:

- Precision as part of aesthetical expression.
- High speed of execution and therefore multiplicity and comparativity of the works.
- The fact that hundreds of imposed orders and statistical considerations can be easily carried out by a computer instead of by the human mind, which is incapable of retaining them over a period of time, for example during plotting time (calculation time).
- The continuous feedback during a man-machine dialogue involves a learning process on the side of the human being, resulting in a clearer image of the creator's thinking and intentions.

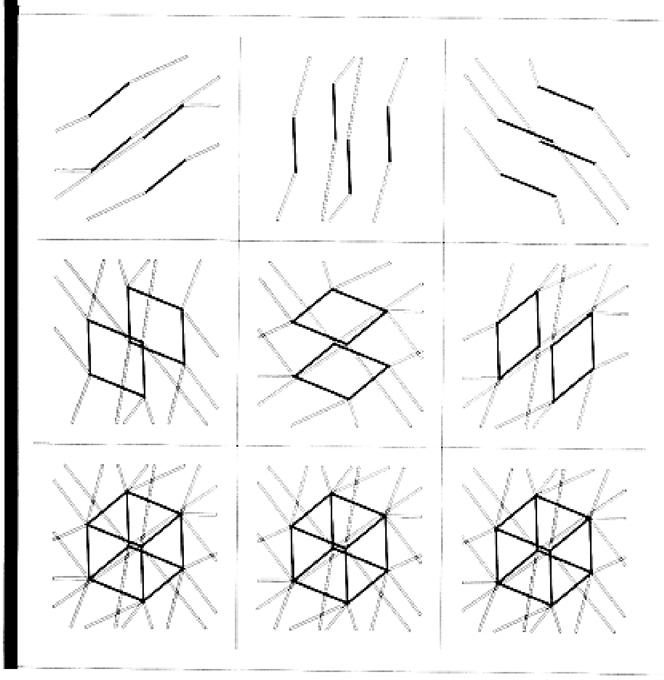
The dialogue with the computer implies also that results (graphics, etc.) and their visual expression have to be judged under completely new aspects. It is evident that one should not create single forms and judge them by a traditional and subjective aesthetic, but build sets of form where the basic parameters are relationships between forms with no aesthetical value associated to any particular form in the set. It is possible within this context to ignore the former "good" and "bad", now allowing aesthetical decisions to be based on statistical and "wertfreie" procedures, where the totality represents a quality of a quantity.

This procedure may lead to different and perhaps more interesting answers, lying of course outside one's normal behaviour but not outside the imposed logic. The above postulated conception becomes part of a conditioned aesthetical information.

COMPUTER ART AND THE FUTURE

Computer-aided art is too young a phenomenon for one to foresee all its influence on the arts. It is most probable that the importance of an art thus created might lie essentially in its subtle and rational way of proceeding, which means that not only the "what" but also the "how" of the change will have fundamental consequences for the future.

BELOW: Part 2 of the "P210 A" series by Manfred Mohr.



The world will not be changed from the outside but from the inside, and aesthetical decisions will be more and more based on knowledge rather than on irrelevance. The shift from uncontrollable metaphysics to a systematic and logical constructivism may well be the sign of tomorrow.
(From the ART OF THE SPACE ERA EXHIBITION, copyright, Manfred Mohr.)

NOTE: The following technical comments are taken from a recent publication titled "Generative Drawings" by Manfred Mohr, Part II, Travaux de 1975-1977, from a showing of new work at the Galerie Weiller, Paris, October-November, 1977. The comments below are copyright by Manfred Mohr.

CUBIC LIMIT II RESEARCH

In my present publication, Cubic Limit II, I extend this search by three new procedures:

1. ADDITIVE

The signs are used as visual-numerical elements, thus adding up through superposition, to complete cubes.

A. Overlapping of the signs in regular or different sized matrices on the surface of a torus, or on a flat surface. All signs are of the same rotational location.

B. Superposition of signs, which are not of the same rotational location.

2. RESTRICTION

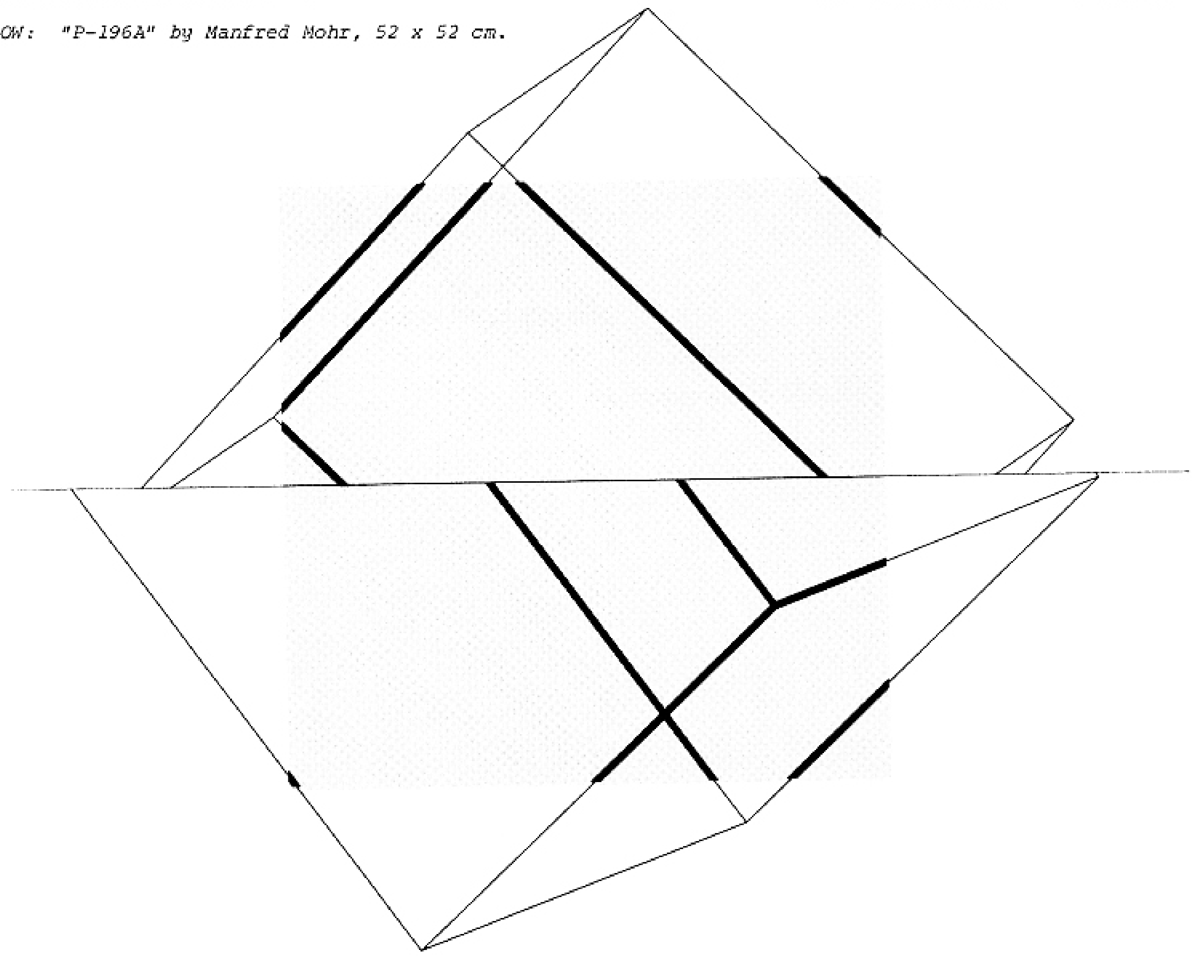
A cube is cut through its centerpoint into two half cubes which can be rotated separately around this common point. Both parts create independent signs and their visual aspects change when seen under different angular projections.

A boundary is imposed by the two-dimensional representation of the initial spatial location (frontal view) of the cube at (0,0,0) degrees, thus forming a square window, which defines an inside and an outside. This is graphically represented by different line widths.

3. EXTENSION

As an inverse procedure to restriction, all 12 lines of the cube are extended through their endpoints, to a determined length. The cube itself is the subject of rotational operations while all the endpoints of the extended lines are kept fixed at their last rotational location.

BELOW: "P-196A" by Manfred Mohr, 52 x 52 cm.



COMPUTER SYNTHESIS OF ANAMORPHIC PROJECTION SYSTEMS

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DEFINITIONS, EXAMPLES

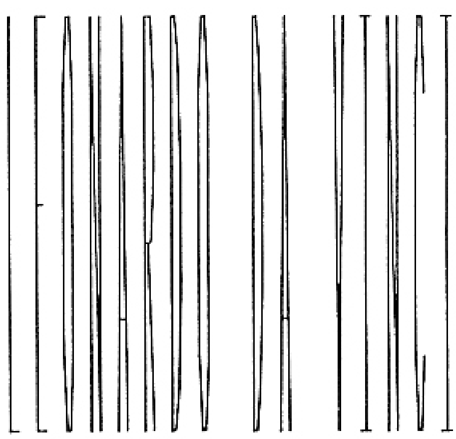
Anamorphic images are those which, when viewed objectively, seem to contain extreme distortions. These distortions become meaningful, however, when the image is viewed subjectively, as from a predetermined vantage point, or when it is reflected in a special mirror. An effective analogy can be drawn to the familiar fun-house mirrors which produce severely distorted reflections. The reflection of normal human torsos in these devices usually appears alternately fat, thin, and curvilinear.

An anamorphic human figure, which might objectively appear distorted to an observer, would then have a reflection that would appear quite normal. Another, somewhat less sophisticated example of an anamorphic image is the word, AMBULANCE, which often appears on the front of such emergency vehicles. The objective message makes little sense, but when viewed by an automobile driver through a rear-view mirror, the subjective message is quite clear.

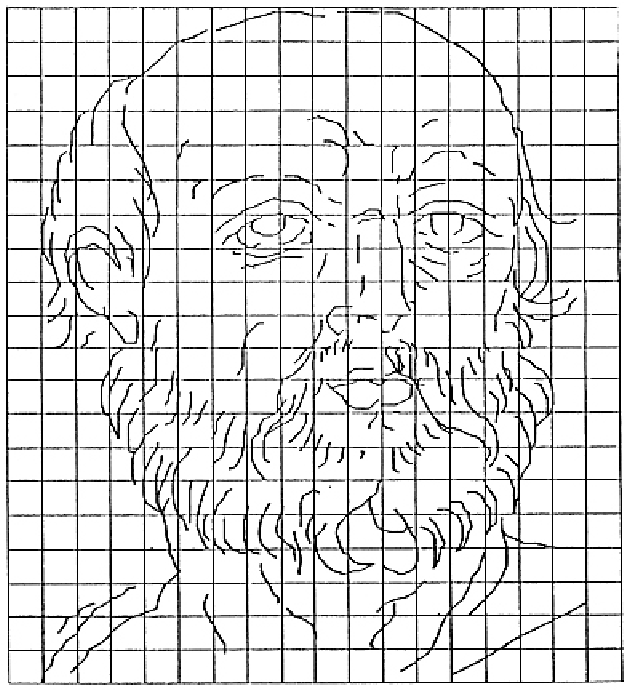
HISTORICAL BACKGROUND

One of the earliest documented studies of anamorphic images and anamorphic projection systems was conducted by Leonardo da Vinci. His sketches reveal that he investigated the properties of images projected on oblique surfaces. Such images, when viewed from a point perpendicular to their plane, are often unrecognizable. However, when the angle between the observer and image plane becomes very small (5 degrees or less), the substance of the form is coherent. (Figure 1.)

NOTE: Tilt the anamorphic illustrations for a less distorted view--Below: The name of Leonardo.



ABOVE: Figure 1 -- (View from 5° horizontal)

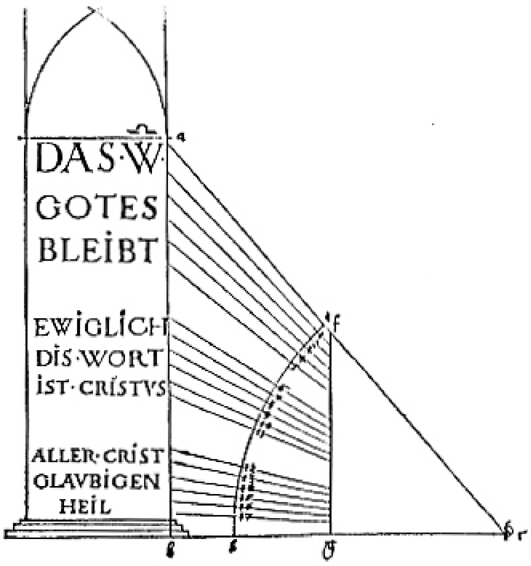


ABOVE: Undistorted portrait of a man on a grid. This source drawing is later revealed within varied projections throughout this paper.

The study of perspective drawing techniques received a great deal of attention during the Italian Renaissance. Alberti, among others, sought to quantify and describe the principles and techniques surrounding perspective drawing. His treatise, "De Pictura", developed many theories of perspective foreshortening based on the angle of vision subtended in the eye by the object being viewed.

Later, Durer expanded this concept to the conclusion that: equal angles of vision = apparently equal size of objects being viewed. An example of this is the apparent size of a dime held at arm's length and the full moon -- they both appear to be the same size. It is only the presence of familiar objects in a visual scene that permits accurate interpretation. Accordingly, Durer presented a scheme for placing inscriptions on high walls: the size of the letters increase as they are placed upward on the wall. When viewed from a point near the base of the wall, all the letters subtend the same angle of vision and therefore appear to be the same size. (Figure 2.)

(See Figure 2 on the next page.)

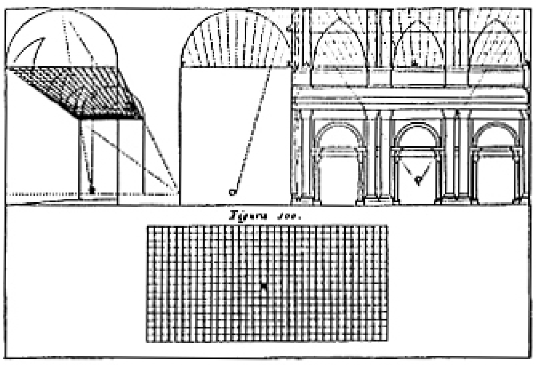


ABOVE: Figure 2 -- Wall Lettering (Durer)

The understanding of angles of vision and the concurrent concept of visual rays (imaginary rays which carry the image to the eye), was the most important concept in the development of anamorphic images. The realization was made that, if these visual rays could carry an image forward to the eye, then one might also extend them backward, away from the observer, to an intersection with any form of surface. Then, using the visual rays as a guide, the image can be transferred to this back surface. Objectively, the projected image will most probably appear quite distorted. However, when viewed from the original point used for the construction, it will regain its natural form. The explanation is simply that, from this point, the two images (original and projected), are identical in terms of visual rays and angles of vision subtended.*

CONSTRUCTING ANAMORPHIC IMAGES

The concept of constructing such images is simple enough, but the practical implementation becomes more complex, especially since the main component, visual rays, are imaginary. The problems surrounding the implementation of this procedure were overcome by Andrea Pozzo and described fully in his treatise, "Perspectivae Pictorum atque Architectorum", which appeared in 1693. The technique described by Pozzo, which related to painting on architectural domes and vaults, is called "Quadratura". (Figure 3)



ABOVE: Figure 3 -- Quadrature (by Andrea Pozzo)

A rectangular grid of ropes or strings is placed across the base of the vault or dome. This network corresponds to another grid which has been placed on a sketch of the desired painting. Then, strings are stretched from a central viewing point through the intersection of the grid and continued to the surface of the vault. In this manner, the grid was transferred to the curved surface, and, the sketch was copied over square by square to the distorted grid. Similar techniques were also used in the production of frescoes on oblique surfaces. The end results were images which seemed to float free of their surfaces and so served to visually extend the limits of the architectural space.

During the seventeenth century a number of French mathematicians expanded on this knowledge of projection systems and added to it the newly discovered principles of optics. The net result was the development of complex systems for anamorphoses utilizing, among other things, the reflecting cone and cylinder. The principal work on this subject, entitled "La Perspective Curieuse", was published in 1638 by Jean-Francois Niceron. This document presented the geometrical basis for the construction of these anamorphoses and was quickly assimulated by both artists and mathematicians. As a result, the next hundred years enjoyed a vogue of anamorphic engravings and paintings, during which a number of interesting, if not artistic, works evolved.

ANAMORPHIC IMAGES VIA A DIGITAL COMPUTER

This paper presents some of the techniques relating to the construction of anamorphic images and the implementation of those techniques on a digital computer. The various forms of anamorphic images mentioned above have been classified by this author into three categories to simplify their explanations in this paper. These categories are:

1. PROJECTION, for those images which require only observation from a predetermined point to appear normal;

2. REFLECTION, for those images which require specially shaped mirrors in which their reflection appears normal; and

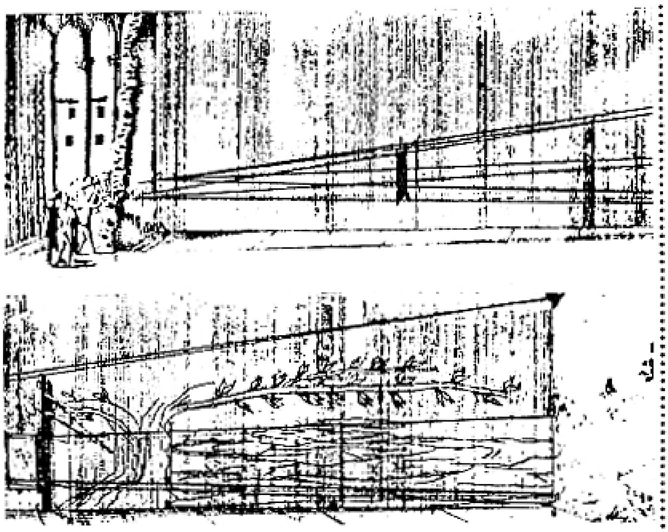
3. CONSTRUCTION, for those images which must be transferred to the surface of a constructed solid to appear natural.

In many respects, the CONSTRUCTION category is a subset of the PROJECTION category. In the following pages the various types of anamorphic projection systems will be presented and analyzed in approximate chronological order based on their initial development and use.

PROJECTION ANAMORPHOSES -- PLANAR SURFACES

One of the most interesting projection anamorphoses was painted on a wall in the Monastery of SS. Trinita dei Monti, in Rome, by Maignan in 1642. Figure 4 is an original engraving by the artist illustrating the technique that he used in the construction.

**Subtend - Sub + tendere, from the Latin, to stretch; to extend under, to be opposite to, as each side of a triangle subtends opposite angles.*



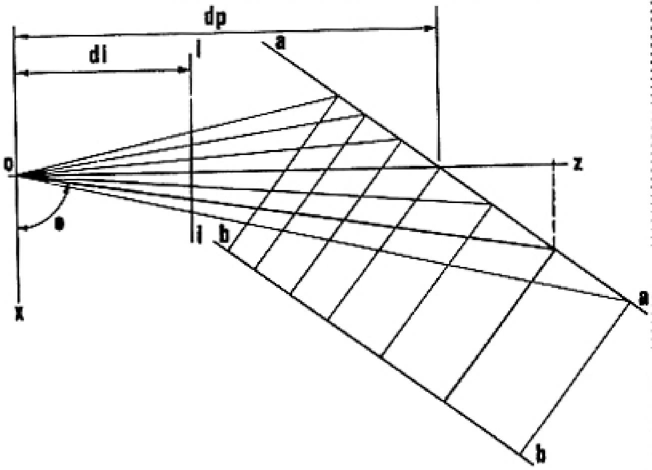
ABOVE: Figure 4 -- St. Francis of Paola (Maignan)

The painting, St. Francis of Paola, is located on a corridor wall, and appears quite normal when viewed from the end of the corridor. However, as one proceeds down the corridor, the image becomes increasingly distorted until, when viewed from a point perpendicular to the wall, it is unrecognizable.

Figure 5 (below) illustrates the geometry of this construction. Plane I-I contains the image which is to be painted on surface A-A. In order for the painted image to appear normal to an observer at point "O", it must be constructed according to the linear distortions exhibited on plane B-B. The concept is this: since objects which are more distant from an observer naturally appear smaller (through perspective foreshortening), they must be made larger if they are to appear the same size as closer objects. This construction is very elementary for the computer.

For simplicity, we consider the observer to be located at the origin of a three-dimensional set of cartesian coordinates. Figure 5 is displaying this construction, which is being viewed looking down from the positive y-axis. Then, any visual ray connecting the observer and a point of the source image plane has the equation: $Y = M1X$ where M1, the slope, equals the distance separating the observer and the image divided by any image x-coordinate. The surface on which the image is to be projected makes a known (specified) angle with the z-axis at a distance (DP) which is also specified.

BELOW: Figure 5 -- Geometry of Planar Projection



The equation for this line is in the form: $Z = M2X + B$, where M2 is the known angle and B is the DP distance. Then, through simple analytic geometry:

visual ray: $Z = M1X$
projection surface: $Z = M2X + DP$

the intersection:

$$M1X = M2X + DP$$

and, the common x-coordinate:

$$Xc = 1.0 / ((M1 - M2) / - DP)$$

The y-coordinate, of course, rarely lies in the plane used for this construction. Its value is determined through a system of similar triangles.

The projection of the point on the z-axis:

$$Z = \tan(\theta) * Xc,\text{ or,}$$
$$Z = (DI / \text{any x-coordinate}) * Xc$$

The ratio of similar triangles is:

$$(\text{any image y-coordinate} / DI) = (\text{the projected y-coordinate} / Z)$$

or, simply:

$$Yc = (\text{any image y-coordinate} * Z) / DI$$

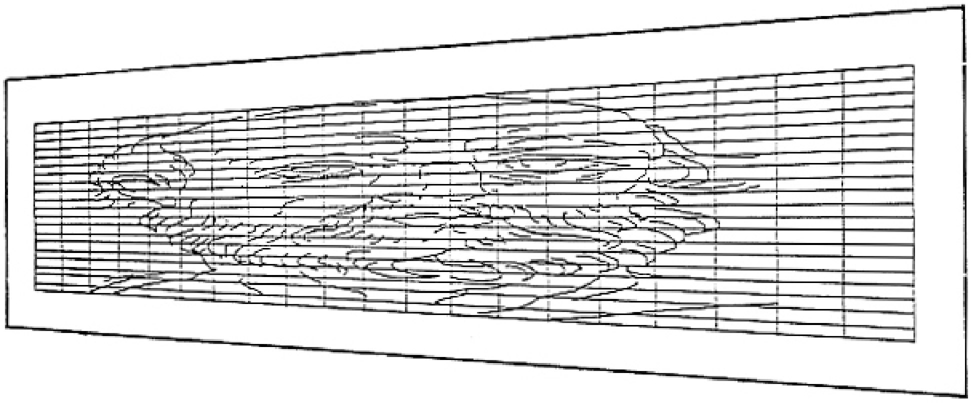
Finally, in order to correctly plot the anamorphic image, it must appear as on plane B-B. This is done by substituting the distance from the z-axis along the projection surface to the visual ray intersection for the x-coordinate, with careful attention to the appropriate sign of the coordinate. This procedure allows for the option of a second projection surface at any specified angle, and oriented in the negative x-direction.

Figures 6 and 7 (see next page) are examples of plotted output from this program illustrating projections on one and two surfaces respectively.

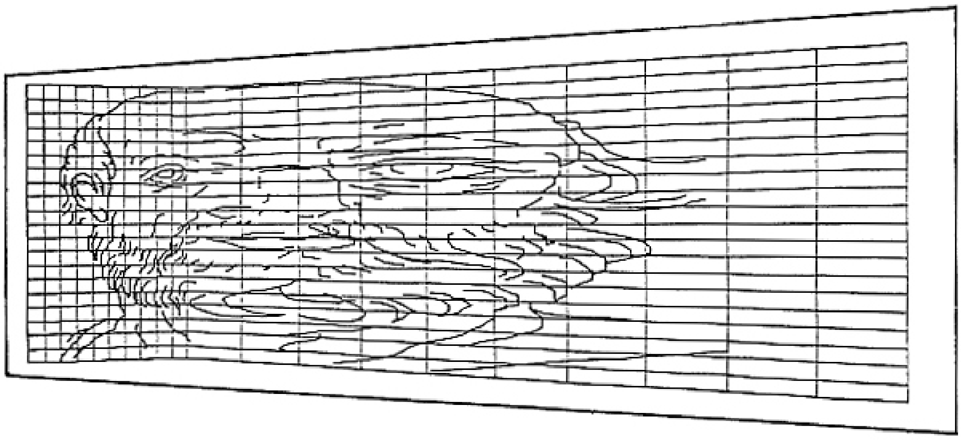
PROJECTION ANAMORPHOSES -- CURVILINEAR SURFACES

There are many examples of this type of anamorphic projection. Paintings and frescoes on vaulted surfaces have been common architectural elements since the forms first emerged. The most successful of these images as illusions of extended architectural space have, as their foundation, the techniques developed by Andrea Pozzo. These techniques, or "quadratura", as previously discussed, were elaborate manual constructions for projecting a rectangular grid onto curvilinear surfaces utilizing a system for simulating visual rays. The projected, distorted grid then became the basis for copying the desired image which had been previously subdivided by an undistorted grid to facilitate the transfer.

(See page 13 for figures 6 and 7.)



AT LEFT: Figure 6 -- Computer Planar Projection: One Surface



AT RIGHT: Figure 7 -- Computer Planar Projection: Two Surfaces

IMPLEMENTING COMPUTATIONAL PROJECTION TECHNIQUES

The computational implementation of this technique is no more complex than the intersection of a line and a circle. The line is the equivalent of any visual ray, and, the circle is equivalent to the vaulted form. Since this process usually yields two points of intersection, it is possible to calculate anamorphoses for both concave and convex surfaces. In the actual implementation of this procedure, it was also possible to include the option of two curvilinear projection surfaces, each either concave or convex, and tangent to each other at the central visual ray.

The intersection of a line and a circle can be solved in many ways. The procedure utilized in this study is based on analytic geometry, and, specifically the Law of Sines. Figure 8 (at right) illustrates schematically the most important aspects of this technique.

The observer is considered to be located at the origin of a cartesian coordinate system. The vaulted surface appears with its center located on the z-axis and is DC units distant from the observer. As before, the diagram in Figure 8 is displayed as viewed from the y-axis. The angle at the observer between the central visual ray (CVR) and any visual ray can be determined by the slope of any line having the end-points of (0,0) and any set of image plane coordinates. The relationship defined by the Law of Sines, which is the radius of the vaulted form divided by the sine of this angle, becomes the important factor for projecting the image point.

Factor = Radius / Sin (ang)

Since: A / Sin (a) = B / Sin (b) (The Law of Sines)

Then, this Factor is also equal to the following:

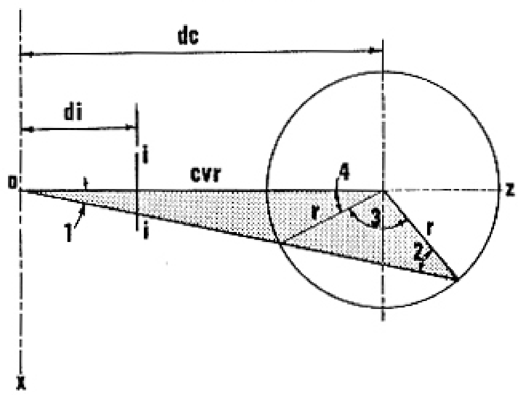
Factor = Dist. to circle center / Sin(ang2)

or,

Sin (ang2) = dist. to circle center / Factor

Ang2 is the interior angle where the visual ray intersects the circumference of the circle. Ang3, which is at the center of the circle, is the

BELOW: Figure 8 -- Geometry of Curvilinear Projection



supplement of Ang and Ang2. The length of the visual ray from the observer to its intersection with the circle, is determined by a similar relationship:

Factor = Length / Sin (ang3), or,
Length = Factor * Sin (ang3)

If, for some reason, the desired projection surface is convex (the opposite curvature of most vaulted forms), the length of the visual ray must be reduced by the hypotenuse of the interior triangle in Figure 8. This is an easy task since all the angles and two sides (radii) are known.

PLOTTING PROJECTED POINTS

The process of plotting this projected point on a flat surface is to theoretically unroll the circular surface by substituting the circumferential distance along the arc for the x-coordinate. This is done by first determining the angle CA in Figure 8, which is either the supplement of Ang3, or, the difference between Ang3 and Ang4, depending upon the curvature of the surface (concave or convex). The ratio of this angle to 360 degrees is also the ratio of the desired circumferential distance to the total circumference. Then, the y-coordinate of the point may be determined by a process of similar triangles:

Y(image) / DI = Y(plot) / dist. to intersection

or,

y(plot) = (Y(image)*dist. to intersection) / DI

This is a process for determining the end-points of a line to be projected onto a circular surface. However, if one is to simply project and plot end-points, the resulting segment will be a chord (relative to Figure 8) and not a true circular projection.

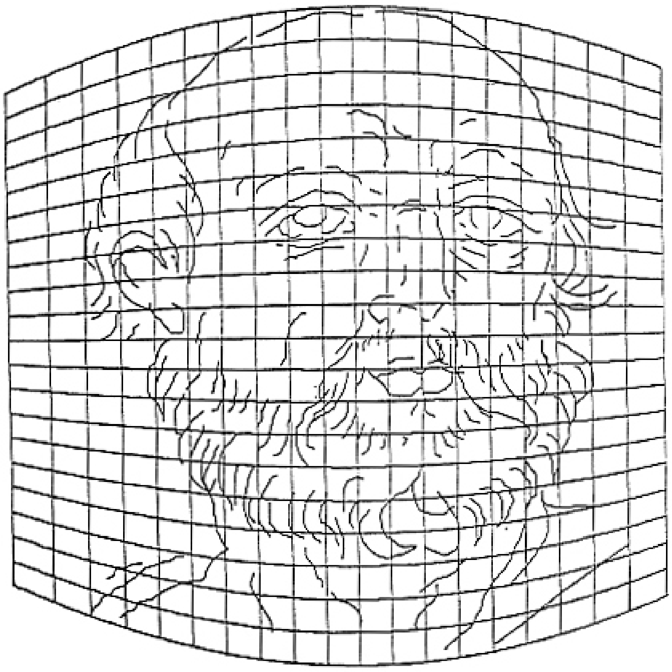


Figure 9 --
Computer Curvilinear Projection: Concave

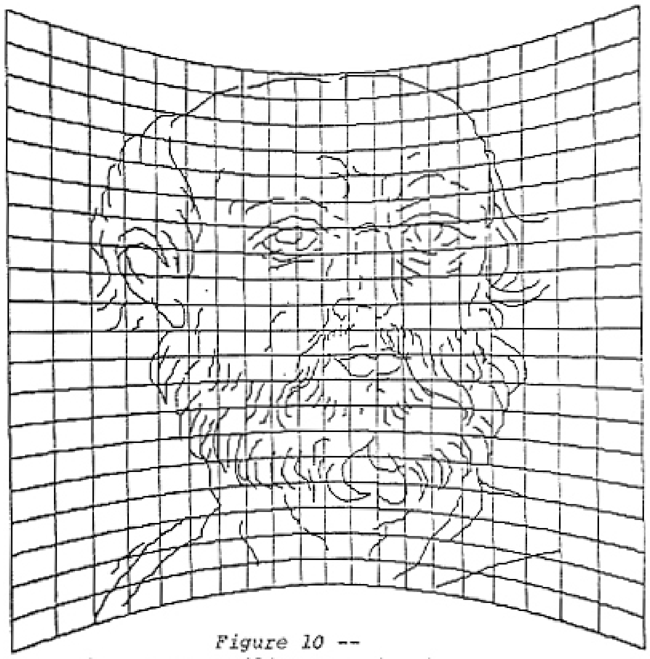


Figure 10 --
Computer Curvilinear Projection: Convex

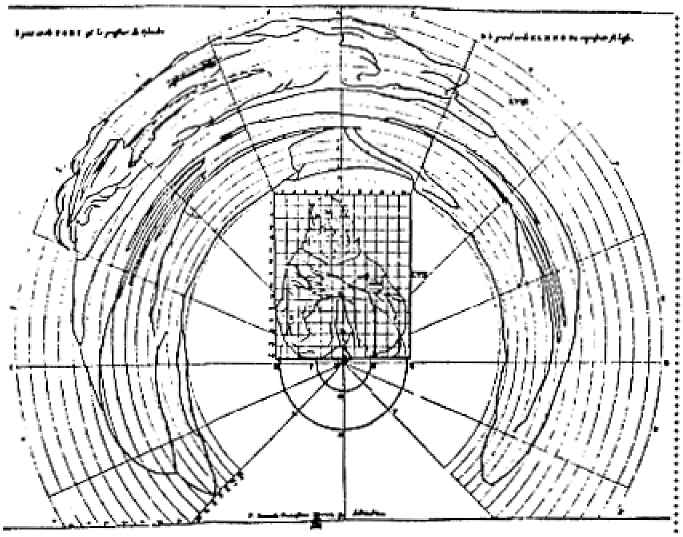
Therefore, in order to approximate a true circular projection, the line to be projected should first be subdivided into many small segments which, when projected individually, will closely approximate the desired results. This subdivision is best accomplished by calculating the angle between the visual rays connecting the observer and the end-points of the line to be projected. This angle is then divided into one-sixth of a degree intervals which are used to calculate the intermediate coordinates in the divided line.

This method is superior to the arbitrary subdivision of each line into a fixed number of segments. Using it, short lines will have few segments and long lines will have many, and, no lines will be subdivided beyond the point of visual relevancy. Three-dimensional angles do not have to be computed for this process because the vaulted surface is only curvilinear in two dimensions.

Figures 9 (bottom, left) and 10 (top, right) illustrate some typical plotted output from this program displaying sample anamorphoses for concave and convex surfaces respectively (the illustrations may be bent toward or away from the observer in an appropriate cylinder to remove the distortion).

REFLECTION ANAMORPHOSES

"La Perspective Curieuse", published by Niceron in 1638, is considered to be the most important documentation of the techniques of reflection anamorphoses. The work was republished in a more extensive form with the title, "Thaumaturgus Opticus", after Niceron's death in 1646. These documents, as well as some earlier and many later ones, notably "Perspective Cylindrique et Conique", by Vaulezard, in 1630, and "La Perspective Pratique", by DuBreuil, in 1649, are primarily responsible for the great vogue of cylinder and cone anamorphoses which followed during the next hundred years.



ABOVE: Figure 11 -- Reflecting Cylinder Anamorphosis (Niceron)

Although some oils were executed by Niceron, the principal anamorphic works for the first half of this period were engravings. These were produced in great quantities and rapidly spread through Europe and England. These engravings supplied the inspiration and the technique for the many anamorphic paintings which began to appear during the early and mid-eighteenth century, notably in the Netherlands and in England, where the works of Henry Kettle are among the best remaining examples of this technique.

REFLECTION ANAMORPHOSES -- THE CYLINDER

Figure 11 (above) is an illustration used by Niceron in his "La Perspective Curieuse". The grid which is superimposed on the portrait assists in communicating the techniques of creating the anamorphosis. The vertical lines seem to become radial, and the horizontal lines seem to become somewhat concentric. Close inspection of the anamorphoses of the horizontal will reveal, however, that they are not circular, but somewhat elliptical. An official geometric description of this shape could be the Limacon of Pascal. The equation for this form is:

$$R = B - (A * \cos(\theta))$$

where:

B is greater than or equal to 2 * A

In this application it is probably more accurate to express this shape as the locus of all points equidistant from a single point via a reflection off a circular form (Figure 12 at right). The single point corresponds to the observer, the circular form is the reflecting cylinder and the locus points occur equidistantly along visual rays defined by the position of the observer and the source image. Another look at Figure 11 (above) should also reveal that the spacing between the projected horizontal lines increases with the distance it is from the center of the cylinder. This relationship is illustrated in more detail in Figure 13 (see next page), where it may be observed that the top of the source image defines visual rays which must travel a longer distance to the anamorphic surface and thus exhibit a greater divergence.

The process of calculating a reflecting-cylinder anamorphosis by computer is somewhat more complicated than the ones previously described for projection, but, readily decomposes into a number of simple and distinct operations.

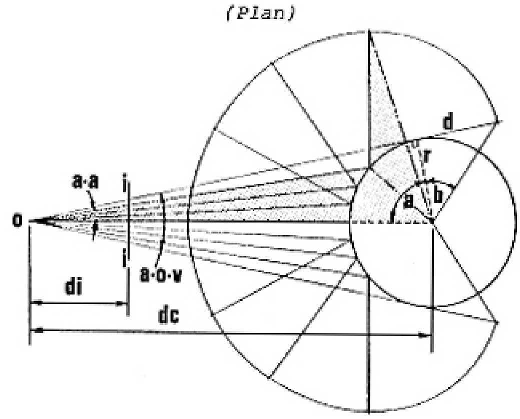
The most obvious approach to pursue after inspecting Niceron's engraving is to somehow express the anamorphic image in terms of polar coodinates relative to the center of the reflecting cylinder. This would require an unusual relationship between the rectangular coordinates of the source image and the desired anamorphic polar coordinates. Instead of normal transformation equations, this approach requires that the x-coordinate of the source image be related in terms of an angle, theta, and that the y-coordinate be expressed in terms of a distance or radius to the cylinder center. The procedure to accomplish this has a number of steps.

First, it is necessary to solve for the total angle of vision of the observer (noted in Figure 12). The right triangle containing the angle "A" is well-defined and all angles and sides can be rapidly calculated. The total distance from the observer to any point on the anamorphic image has to be the same for the construction to work. This distance is an important factor since it controls the reflected angle of vision and the portion of the cylinder's surface which will be utilized by the reflection. An experimental value equal to twice the distance separating the observer and the surface of the cylinder seems to achieve optimal results. Theoretically, any value between one and infinity times this distance would also work. Lower values will decrease the angle of vision and the area of the cylinder surface used to produce the reflection. A value of one is the limit; if used, the cylinder becomes mathematically planar, and the reflection becomes a line.

Once this quantity is chosen, the distance from the observer to the point of tangency between the visual ray and the cylinder may be subtracted to yield the value of "D" in Figure 12. Then, the angle "B" can be calculated, and, twice the sum of angles "A" and "B" yields the total angle of vision relative to the reflection. The next operation is to normalize the range of the x-coordinate on the source image to this angular range. This operation is performed so that an angle of ninety degrees corresponds to an x-value of zero. The extremes of this range then become:

-Xmax = 90 - (Total / 2.0), and,
+Xmax = 90 + (Total / 2.0)

BELOW: Figure 12 -- Reflecting Cylinder Geometry (Plan)



Thus, every x-coordinate on the source image will have a corresponding angle, theta, which will be used in plotting the anamorphic image.

The second half of this process is the determination of the required radius expression for the polar coordinates. This quantity corresponds to the y-coordinate values on the source image. At first glance, the considerations of three-dimensional angles and distances might seem a bit overpowering. Fortunately, reflections, by their very nature, yield a family of similar triangles. Additionally, since all three-dimensional distances for a visual ray bear the same ratio to their plan projections, it is possible to confine the construction to only these two-dimensional projections. The process then becomes much simplified and results in equally correct anamorphic images.

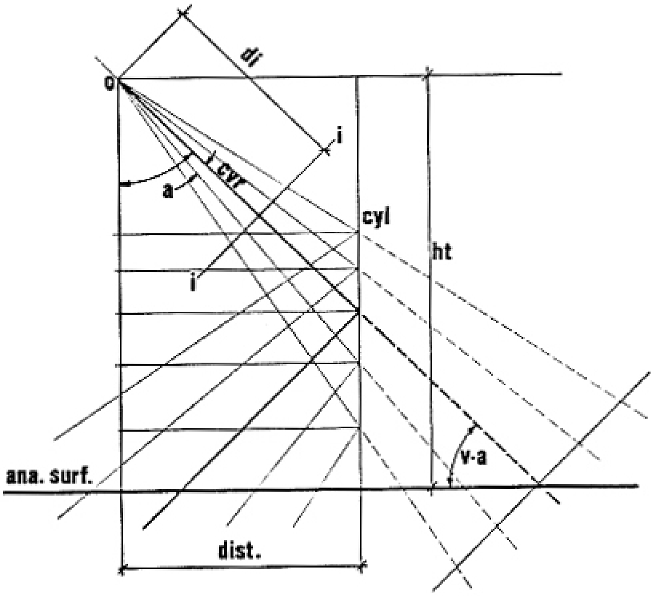
Figure 13 (right) also illustrates that the plan distances from the edge of the reflecting cylinder to the intersection of any visual ray with the anamorphic surface is the same distance which would occur with a transparent cylinder. This concept becomes very helpful in the construction. The plan projection of any visual ray may be determined in the following manner:

First, the vertical angle between the central visual ray and other visual ray is calculated and then appropriately added or subtracted from the angle between the central visual ray and the anamorphic surface.

Next, the tangent of this angle multiplied by the height of the observer will yield the total plan projection of this ray.

The following steps are concerned only with the plan prolections of the visual rays as they appear in Figure 12. (See preceding page.) The intersection of any visual ray with the surface is the next priority operation. This is accomplished by constructing a triangle with vertices at the observer, the intersection of the visual ray and the cylinder, and, the center of the cylinder. The apex angle of this triangle at the observer is the same as the horizontal angle defined by the image plane coordinates. Knowing this angle, the distance to the cylinder center and the radius of the cylinder, it is an easy matter to solve for the remaining sides and angles by applying the Law of Sines. Some care must be taken to account for the two intersections which occur with a line and a circle and to choose the appropriate one. The difference between total plan lengths of the ray and the side of this triangle from the observer to the intersection will be the plan projection of the reflected visual ray. Knowing this length, the radius of the cylinder and the angle between the two (which, by the definition of reflection, is equal to the angle of the previously-solved triangle at the common radius-leg), the Law of Cosines may be applied to yield the required radius-distance to complete the necessary information for the anamorphoses.

As before, the line segments on the source image are subdivided to approximate the true curvilinear character of the cylinder anamorphoses. This subdivision is only necessary in the x-direction (horizontally) because the cylinder is only curvilinear in two dimensions. Figure 14 is an example of typical plotted output calculated by



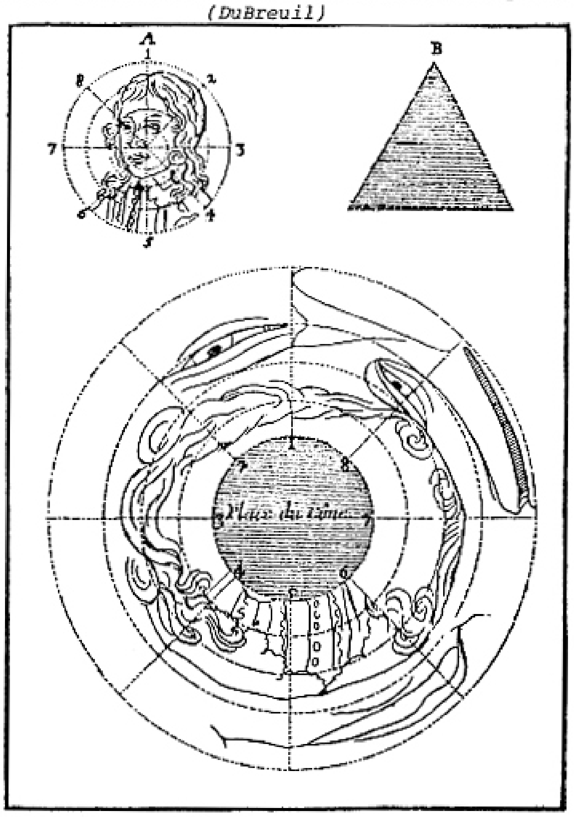
ABOVE: Figure 13 -- Reflecting Cylinder Geometry (Elevation)

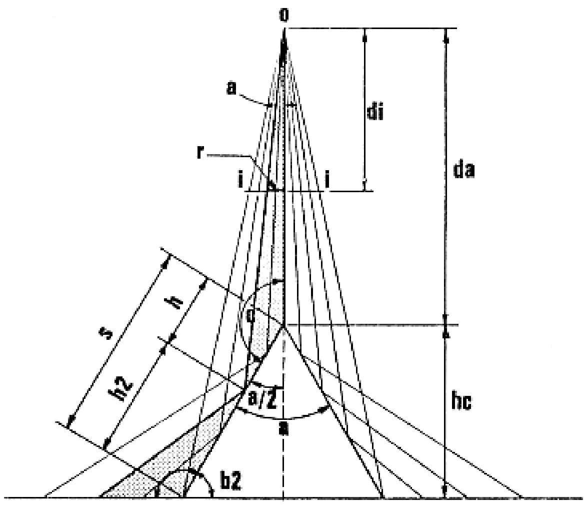
this program. (See the next page for Figure 14.)

REFLECTION ANAMORPHOSES -- THE CONE

Figure 15 is an engraving from "La Perspective Pratique...", published in 1649 by DuBreuil, who was one of Niceron's followers. As one may observe, the process involves inverting and expanding the original image.

BELOW: Figure 15 -- Reflecting Cone Anamorphosis (DuBreuil)





ABOVE: Figure 16 - Reflecting Cone Geometry

(For discussion of Figure 16, see text at right.)

Figure 16 (at left) is a geometric diagram of this process, and, illustrates that the solution is of low difficulty. If the angles of the cone are known as well as the various distances separating the observer, source image and cone, then the calculation of the intersection of the visual ray with the anamorphic surface is relatively simple. There are, however, some important considerations which must not be overlooked in implementing this procedure in a computer program. These are:

1. Visual rays which project directly on the apex of the cone do not reflect. This condition must be checked, and if it occurs, the ray must be moved a small fraction off the apex.

2. Because the reflection surface is curvilinear, the source image lines must be subdivided as before. However, since the anamorphic image is inverted and expanded, lines which occur close to the center of the source image must contain more subdivisions than lines which occur at the extremities. This problem can be overcome by utilizing a sliding scale of subdivision tolerance which ranges from

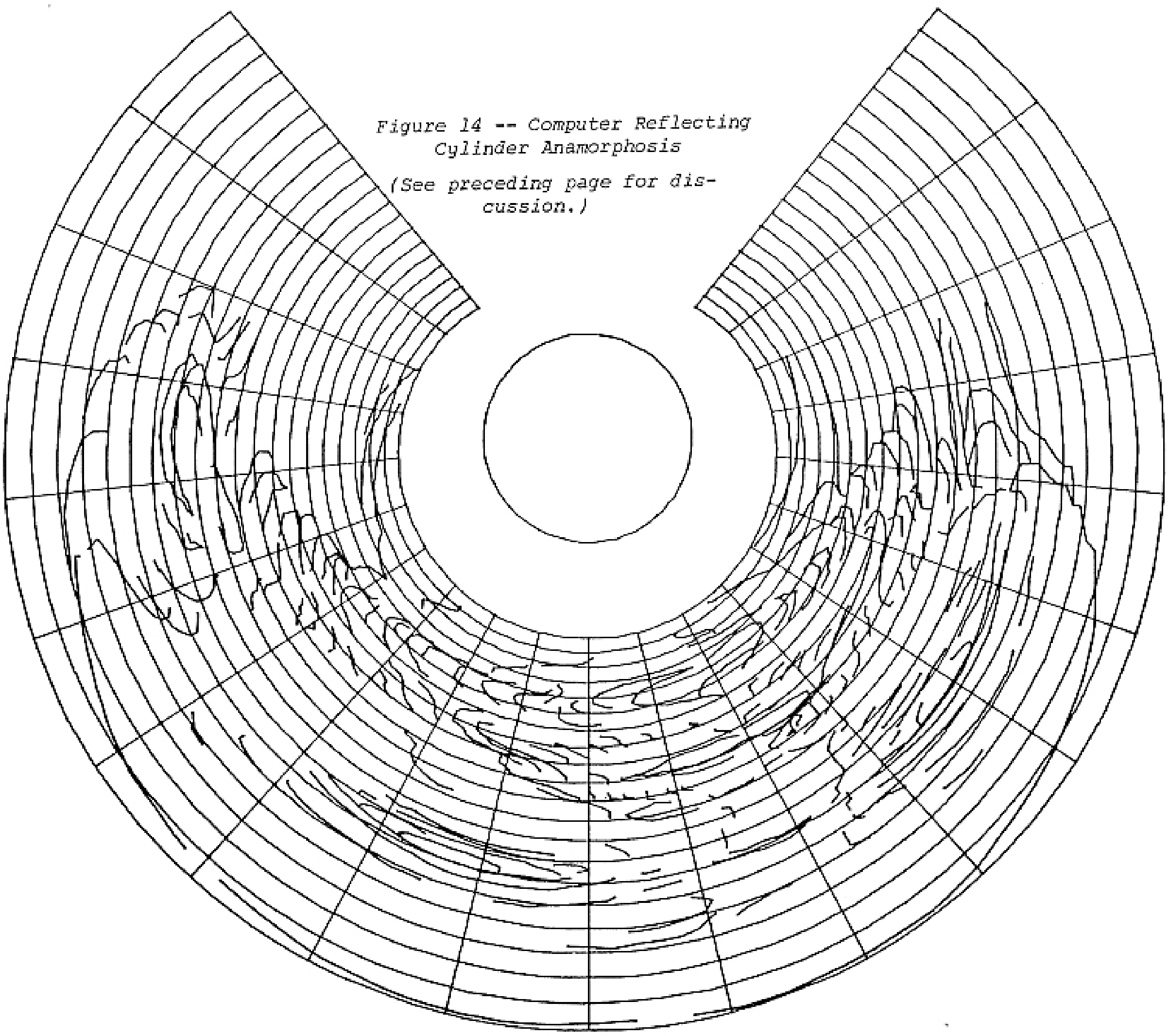


Figure 14 -- Computer Reflecting Cylinder Anamorphosis

(See preceding page for discussion.)

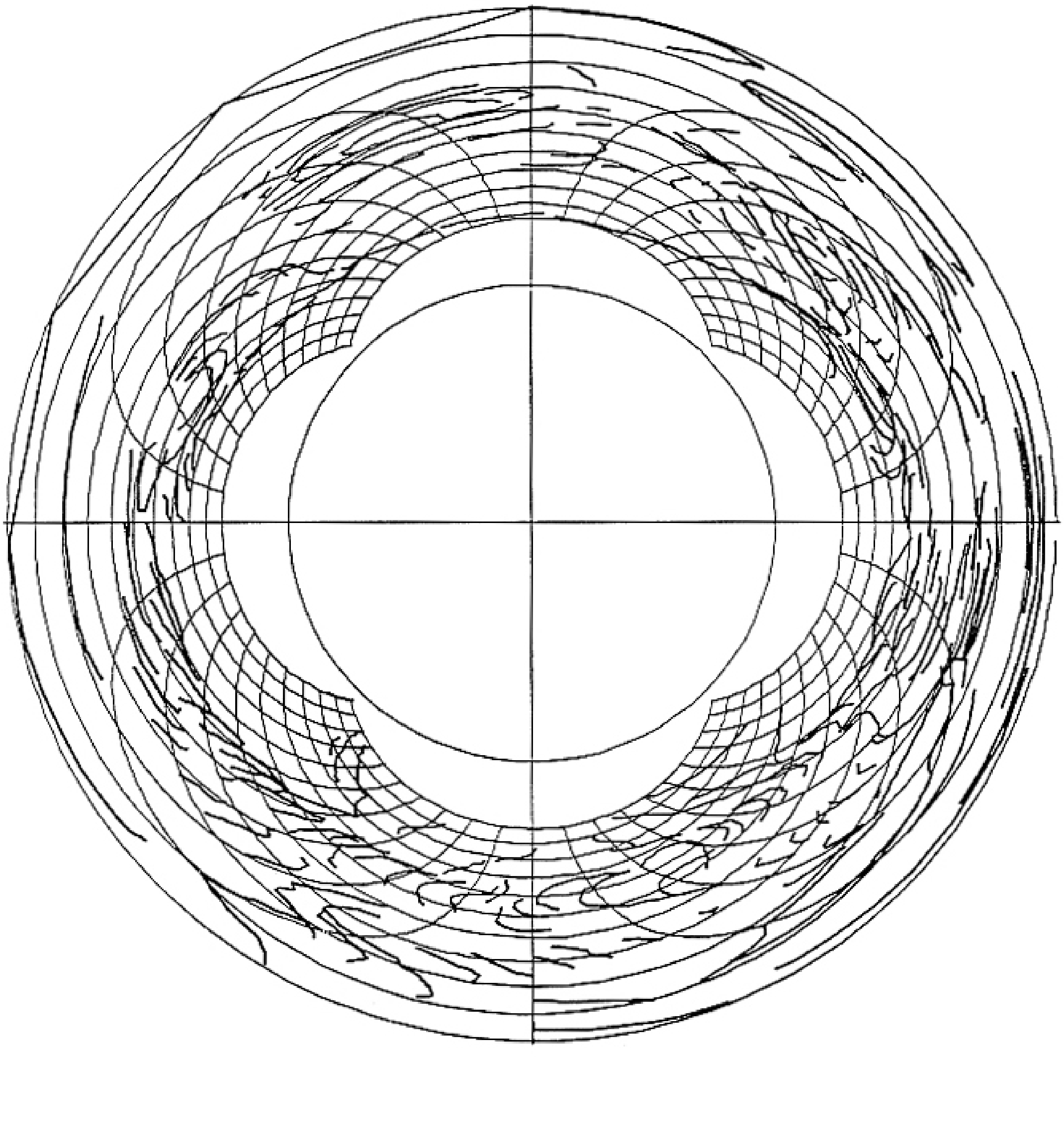
one-sixth of a degree at the extremities to one-sixtieth of a degree at the center. The most logical way to implement this seems to be a binary subdivision process where each line segment on the source image is progressively halved until the remaining segment subtends the appropriate angle for the portion of the image in which it occurs.

The technique utilized in programming the cone anamorphoses proved to be quite efficient. First, the coordinates of the line segments on the source image are converted from rectangular to polar. Then, the radius of each point is used to calculate the angle occurring at the observer between the central visual ray and the visual ray passing through this point (see Figure 16 on the preceding page). Once this angle is known simple techniques of complement, supplement and reflection are used to determine all the angles required by the construction. Some of the lengths of these triangles are known (the distance from the observer to the apex of the cone and the height of the cone). Once again, the Law of Sines is used to calculate the remaining unknown lengths, especially the length of the base projection of the visual ray on the anamorphic surface. The length of this projection is then used as the radius in a new set of polar coordinates which describes the anamorphosis. The angle in this coordinate set is the same one which was calculated for the original point on the source image. Finally these new polar coordinates are reconverted to rectangular for plotting. Figure 17 (below) represents a typical output plot from this program.

CONSTRUCTION ANAMORPHOSES -- THE CONE

The conic-construction anamorphosis is one of the easiest to calculate on a computer. Working on user specifications of cone height and apex angle, it is relatively simple to calculate and plot a planar shape which, when cut out and rolled, will form the desired cone. The radius of this planar shape will be the length of the cone side from apex to base, and the central angle of the wedge-like form will be that angle which subtends an arc of the same length as the base circumference of the cone.

BELOW: Figure 17 -- Computer Reflecting Cone Anamorphosis



As in the cone-reflection anamorphosis just described, the source image coordinates are converted from rectangular to polar, and, the same techniques are utilized to determine the intersection of each visual ray with the side of the cone. The distance from the apex of the cone to this intersection then becomes the radius of the polar coordinate anamorphosis. The angular part of this coordinate is, once again, the original angle of the source coordinates, with the range having been normalized from the original three-hundred and sixty degrees to the value of the central angle which was calculated for the planar cut-out. Figure 18 is an example of the plotted output from this program. If the shape is cut out, rolled into a cone, and, viewed from a point directly above the apex, the image will regain its natural form.

WORK IN PROGRESS

The research presented in this paper represents the preliminary results of a project which is continually expanding. Some of the remaining work, in progress or anticipated, is concerned with the following areas:

- Construction anamorphoses for the pyramid and other common geometric shapes;
- Reflection anamorphoses in which the anamorphic image is non-planar;
- Reflection anamorphoses for sphere and other solid forms;
- Investigations into "transmittance" anamorphoses which will require special optical lenses (curvilinear or faceted) to view the anamorphic image.

SOME APPLICATIONS

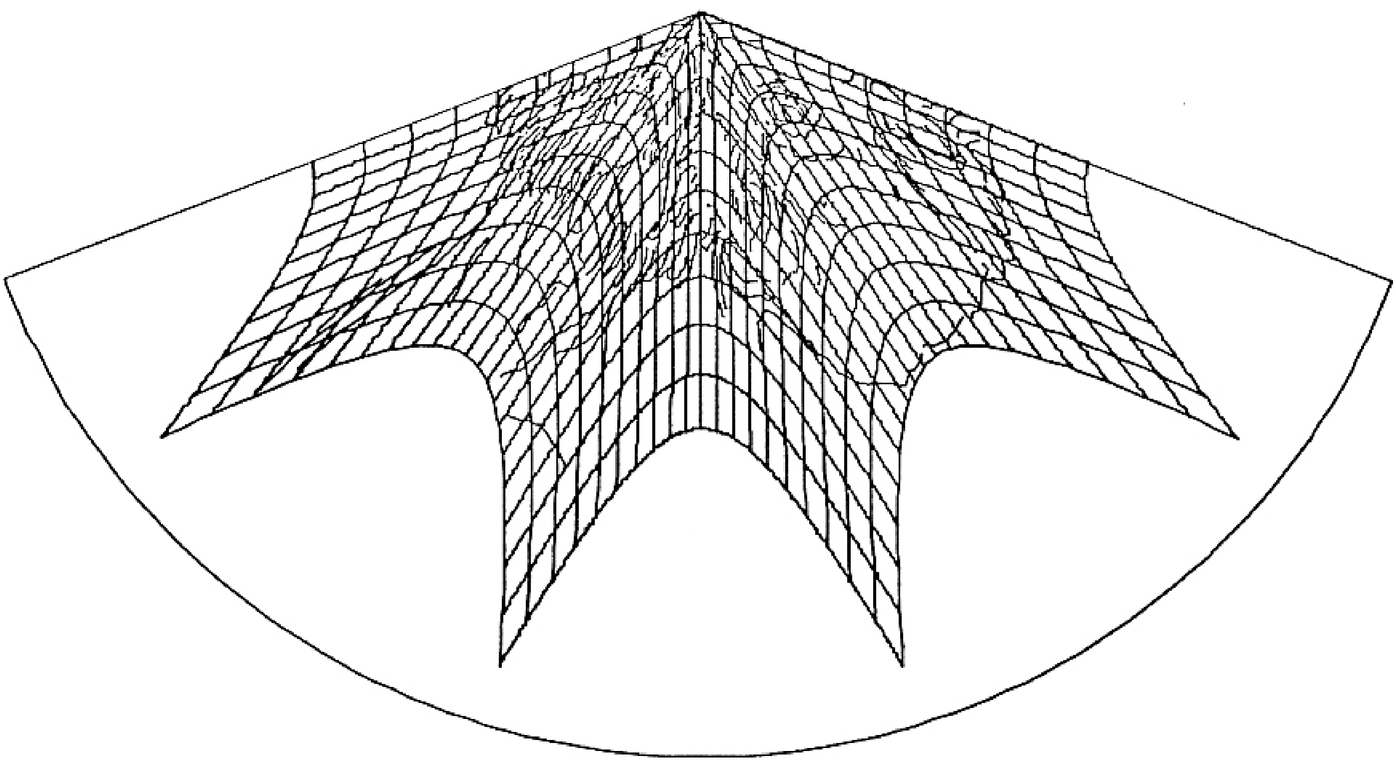
Apart from their artistic value and curious novelty, some of the techniques of anamorphoses presented in this paper have had some practical applications in the area of theatre sets. The anamorphic image of the desired scene is plotted and, if necessary, manually colored. The image is photographed onto a slide, which can then be projected at an oblique angle (from the stage wings) onto a backdrop curtain. Because of the extreme angle of the projection, the image regains its natural desired form and provides the appropriate set.

ACKNOWLEDGMENTS

The following illustrations which appear in this paper were reproduced from the book, "Hidden Images", by Leeman, Elffers and Schuyt with the kind permission of the publisher, Harry N. Abrams, Inc., New York: Figures 2, 3, 4, 11, and 15. This book also provided the seed for this project, and I am indebted to the authors and the publisher for its existence.

ABOVE: Detail, "Beauty Adorns Virtue" by Leonardo.

BELOW: Figure 18 -- Computer Cone Construction Anamorphosis



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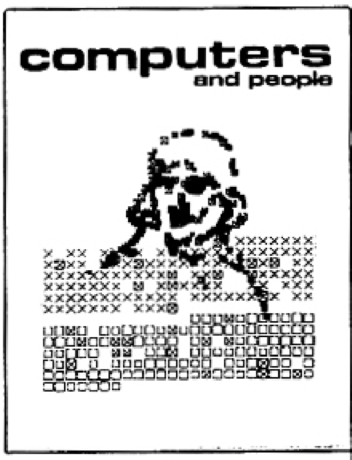

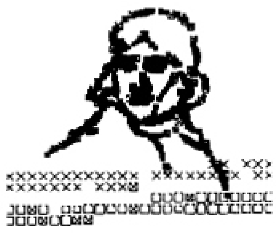

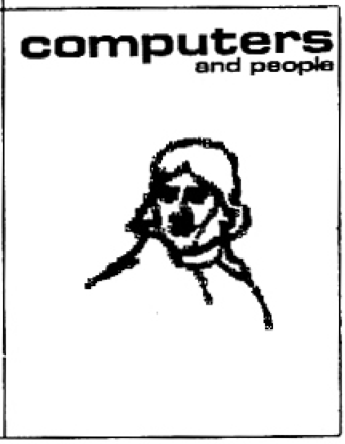

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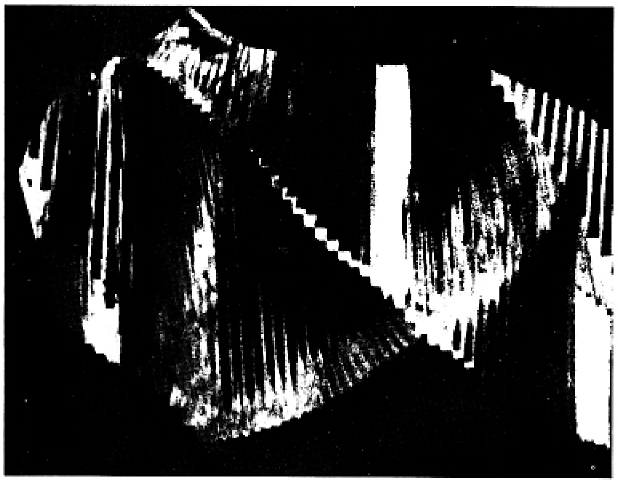
THE ARTIST AS TRANSLATOR AND INTERPRETER



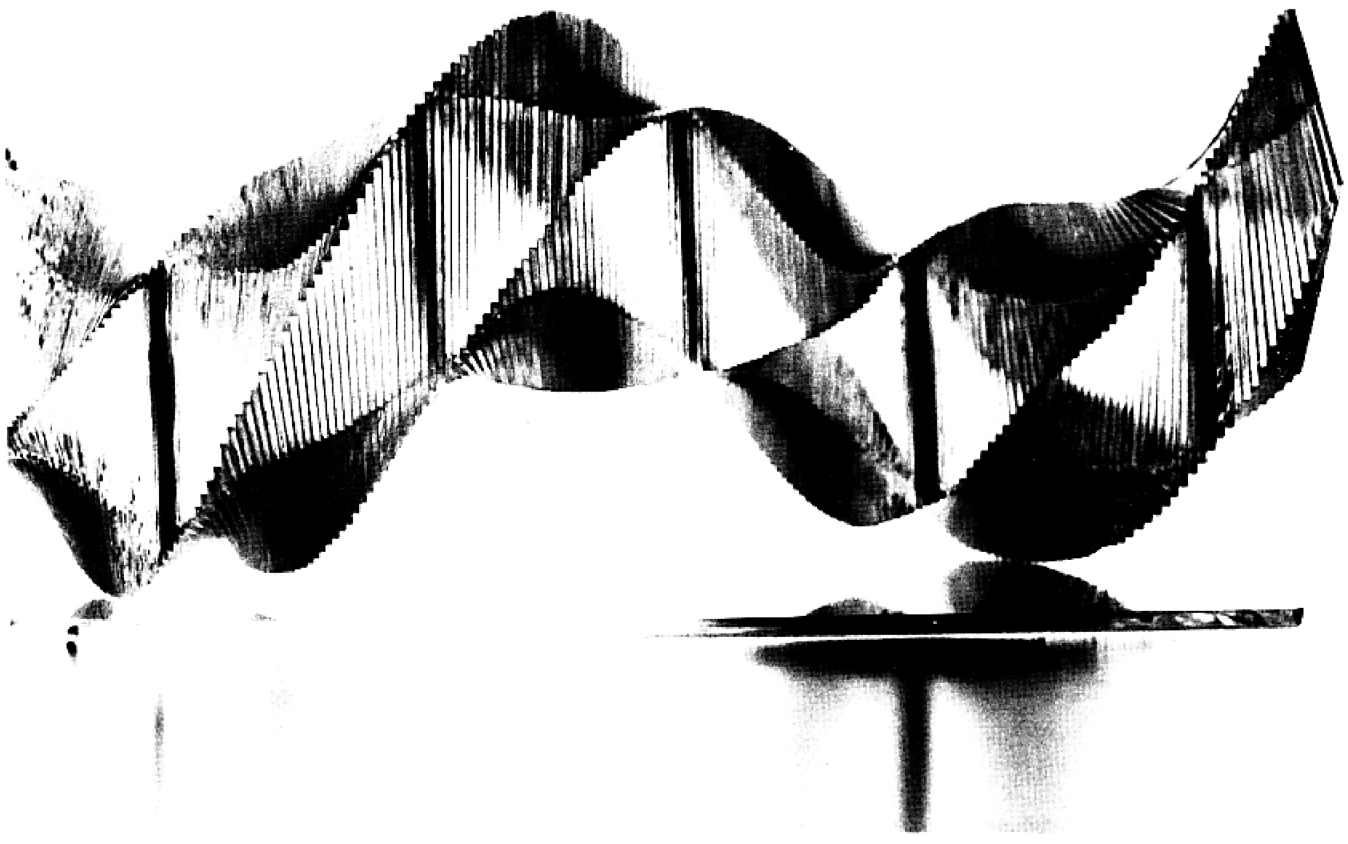
by James C. Ver Hague
88 East Main Street
LeRoy, New York 14482

As a mathematician I was involved with computers and space technology for several years. In my research I discovered the endless, fascinating forms that the computer was capable of generating. Their intrinsic beauty and potential as art led me to the formal study of art and design and a career as a teacher of Communication Design.

I feel that certain aspects of computer methodology and art are very closely related, because both are symbolic interpretations and visualizations of abstract mental concepts. However, that which we call Art must go beyond mere utilization of technology. For people to respond to an artist's work and have it touch them in a meaningful way, the artist must do more than program the machine. He must act as Translator and Interpreter by adding something of his own spirit and understanding in developing the final form of each piece. For me the computer is a source of ideas and a tool in the creative process rather than an end in itself.

My own work is in a constant state of evolution and has taken many directions. One series of plexiglas sculptures (the latest of which is shown here) is a result of my interest in the possibilities of using simple geometric shapes to generate complex forms through rotations and translations about points which are themselves moving along a prescribed path. The sculptures are extrapolations of computer-aided designs into 3 dimensions such that structure becomes the form, creating physical rhythms with harmonic proportions that are classical yet contemporary.

BELOW: "Voluta" by James Ver Hague, from the ART OF THE SPACE ERA EXHIBITION. AT RIGHT, ABOVE: Detail of the sculpture, double-exposed, in negative form, revealing the organic quality of James Ver Hague's work.



ON BEING CREATIVE WITH COMPUTER AIDED DESIGN

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Computer-aided design is currently enjoying a move into useful application. However, this new productivity is marked by a complete disregard for the notion of creativity. In fact, current CAD systems are not conducive to it.

Following introductions to the history of the paper, theories about creativity, and computer graphics, the paper presents four settings for the computer as a wholesale slave, a virtuoso, a creativogenic tolerance, and a place. They progress from a compliant and partitioned system to well-disposed and redundant surround.

The paper concludes cheerfully with some of the ingredients for highly personalized design systems, so-called idiosyncreatic systems. This is hyperbolized in the concept of the return of the Sunday painter.

1. HISTORY OF THIS PAPER

The following monograph is a complaint. It laments the absence of any effort to amplify creativity through computer-aided design. Current systems attest to this deficiency by offering no precedent of a person using a computer to be creative, let alone to be more creative than he or she would be without it. In fact, quite to the contrary, we find numerous examples of cases in which computer-aided design deprives us of those dimensions of design that account for its joy and richness. Computers have helped the implementation and execution of designs, as measured by yardsticks of time, of cost, and, on occasion, of quality. But, design *per se* is done off-line, on the backs of envelopes, in the privacy of a daydream, during a walk in the park, through the spontaneity of *cameraderie*.

According to Merejkowski, [35] Leonardo da Vinci, an enthusiast for systems, devised one consisting of little spoons with which different colors were to be used, thus creating an automatic harmony. One of da Vinci's pupils, after trying in vain to use this system, in despair asked one of his colleagues how the master himself used the invention. The colleague replied: "The master never uses it at all."

Such is the state of CAD. Our creative energies as computer scientists are concentrated on the making of better design systems which, while often focused on advancing the comfort and scope of the user, always presume a well-defined task that the unfortunate user must view as a job to be done. We can explain this in part as a cultural phenomenon in the presence of a general American apathy toward creativity; we are indeed a country of doers. We can account for it with the subtleties of human thought and discourse, for example: humor. However, in large measure, we can blame our personal attitudes, frequently selfish and self-serving, toward problem solving, computer graphics, data bases, and the like, which has often overshadowed the more long-range goal of amplifying creativity.

I feel intimately involved with and no less guilty about this state of affairs. Consequently, the following pages are written very much in the first person singular, in the full knowledge that I too shall continue to work on the manageable details of computer graphics and computer-aided design.

The reason I begin with a section on the history of this paper, is that it follows a development that has seemingly (but not in fact) been concerned with the creative use of computers. In 1968 I wrote, [44] "The dialogue of human and machine would be so intimate - even exclusive - that only mutual persuasion and compromise would bring about ideas, ideas, ideas unrealizable by either conversant alone." In 1972 I followed with, [40] "The intimacy of a dialogue can be in some sense measured by the ability of each person to recognize the intentions of the other." But this time, baroque language was accompanied by pragmatic research and modest developments, namely, in sketch recognition.

Sketch recognition is as much a metaphor as a fact. It is illustrative of an interest in those areas of design marked by vagary, inconsistency, and ambiguity. While these characteristics are the anathema of algorithms, they are the essence of design. The recognition of hand-drawn sketches has been reported on by me and other, [42, 64, 22] but the reader should not wander to that literature hoping to find the problem solved. Instead, it describes an important step toward personalized computing. I coined the term "idiosyncratic system" [37, 39] to distinguish a personal computer from a personalized computer, one that knows its user intimately and can accordingly invoke all the necessary inferences to handle vagaries, inconsistencies, and ambiguities. I offered the following hypothetical scenario as an example:

> Okay, where did you hide it?
> Hide what?
> You know.
> Where do you think?
> Oh.

The pursuit of personalized design aids is stymied by a complete lack of input from the work and literature of exerpimental psychologist, who are far too engrossed in normative behaviors. Only when an idiosyncracy goes too far, i.e., deviancy, [14] does it get attention, and then usually from psychiatry. A notable exception is the work of Pask [48, 49].

Historically, Arthur Koestler [25] offers the following anecdotal example of the first recognition and application of an idiosyncratic system. Apparently, in 1796 a minor scandal occured at the Greenwich Observatory: the astronomer Maskelyne dismissed one of his assistants because the latter's observations differed from his own by half a second to a whole second. Ten years later the German astronomer Bessel read about this, puzzled over the frequency of similar timing mistakes, and initiated a ten year comparison of his own records. Bessel was able to prove that there existed systematic and consistent differences between the spread with which each astronomer reacted to observed events and he succeeded in establishing the characteristic reaction time - which he called "the personal equation" - of several of his colleagues.

More recently, Williams and Rimland [73] have underscored "individuality" from the point of view of psychiatry, neurology, and psychoanalysis.

Turning to creativity, I find a larger volume of literature, populated by a larger number of disciplines. The following pages deal with areas of intersection between part of this literature and my own experiences with computer graphics and computer-aided design.

2. VIEWS ON CREATIVITY

Writings on creativity are numerous. Silvano Arieti's recent book *Creativity, The Magic Syntheses* [1] has 384 entries in the bibliography. Gordon's famous *Synectics, The Development of Creative Capacity* [20] has 351. Only 13 entries on the subject appear in both! This illustrates a dramatic lack of common reference to and common postures toward creativity and, in some sense, characterizes a lack of consensus which surrounds the topic. As a newcomer, I take license to classify these theories, somewhat according to their age, as philosophical, psychoanalytic, psychological, and industrial (for lack of a better word). I am purposely avoiding (for the moment) the alternate taxonomy, ordered by discipline - art, science, engineering, and the like.

Philosophical positions on the topic of creativity are distinguished by being venerable, but not particularly useful. According to Vincent Tomas [67], when one asks the philosophical question, what do we mean by creativity, we are not looking for historical information about the habits of great artists; nor for the personal and social conditions most conducive; nor for the psychological explanation. Rather, he argues, "one is asking for a clarification or analysis of the *concept* of creativity" (the italics are his). The classics offer us very little on the topic. Only the accidental is new in the world of Aristotle; it is no wonder that he had to reduce creativity to imitation. [18]

Psychoanalytic theories of creativity understandably start with Freud's contribution of the importance of unconscious processes, especially of unconscious motivation. However, Freud was almost exclusively concerned with motivation in creativity as opposed to the essence of creative behavior itself. Only much later did his primary processes gain the attention of psychiatrists, particularly in regard to creativity as the product of the preconscious and not the unconscious. [26, 27] Arieti [2] introduces the notion of a tertiary process to designate the special combination of primary and secondary mechanisms of strict Freudian doctrine. He further introduces and coins both the term "endocept" to title the nonrepresentational activity of the psyche and the term "paleologic" to describe a seemingly illogical form of thinking; two concepts important to creativity. The following sections on the setting for using CAD as a creative tool owe a great deal to that particular author, especially to the notion of a creativogenic (his adjective) machine. However, my perusal of this literature leaves me with an uncomfortable (but understandable) sense of correlation between creativity and insanity. [31, 24, 28, 54]

A more sanguine attitude can be found in psychological theories. Joseph Wallas [69] is held to be one of the first to give the creative process attention. He advanced a four-stage process of preparation, incubation, illumination, and verification, which received both confirmation [51, 42, 53] and elaboration. [58, 66, 64] However, many authors, for example Beloff [3] and Westland [70], agree that the turning point was J. P. Guilford's presidential address to the American Psychological Association in 1950, titled *Creativity*. Guilford emphasizes divergent thinking and advances the hypothesis that creativity as a cognitive function is to be distinguished from intelligence (the tests for which have consisted almost entirely of items which measure the ability to think convergently).

Finally, what I call the "industrial" attitude toward creativity borders on application-dependancy. It is meant to distinguish a body of literature pertaining to neither the fine arts nor the academies of science, but to more routine endeavors, frequently called "problem solving." Paradoxically, it is this body of literature which most overtly relates to design, notably Osborn's [46] *Brainstorming* and Gordon's [20] *Synectics*. I say "paradoxically" on three counts. For one, I contend that design is not problem solving, but is what several authors (including myself, [44]) have called problem worrying. For another, the examples from this fourth category of literature dwell on group processes, which in some endeavors are unthinkable; for example, we cannot imagine Michelangelo's *David* or Picasso's *Guernica* as the result of teamwork. Finally, aloneness is the first condition for the cultivation of creativity considered by Arienti, [11] whereas CAD is a team (of at least man and machine) by definition.

On certain issues, there is agreement among these writers, namely on the Jekyll-and-Hyde nature of judgment and imagination, which demands that the critical mind be suspended lest it hinder the production of ideas. This involves, one is told, the merging of disparate contexts, making the strange familiar and the familiar strange. In a celebrated lecture to the Societe de Psychologie in Paris (quoted in Ghiselin [17]) Henri Poincare states: "Among chosen combinations the most fertile will often be those formed of elements drawn from domains which are far apart .... Most combinations so formed would be entirely sterile; but certain among them, very rare, are the most fruitful of all."

Another area of agreement truly violated by current design systems is the need for tranquility and lack of disturbance. One author goes as far as to postulate that the "conditions for poetic creation are also the optimal conditions for scientific creation." [72]

3. COMPUTER GRAPHICS

This section is limited to those specifics of computer graphics that can be viewed as both metaphors and facts. The detailing of a current swing away from a dismal past, particularly away from a static graphics, is reported elsewhere. [40] Computer graphics originated with considerable ambitions [11] of bringing the act of design into the realm of computer aids. However, even the most enthusiastic user of CAD will not argue that we have arrived yet at that point. Instead, almost to the contrary, we are increasingly locked into a paradigm of automation which services the details of graphics and data management in the name of liberating the designer to design.

Computer graphics offers a rather lopsided augmentation of our vision and gestures. Certain aspects of innovation provide design aids hitherto unimaginable, while others do not even approximate the richness of pencil and paper. For example, the dynamic, and even static, embodiment of a three-dimensional construct allows us to view designs as never seen before. On the other hand, the gentle and inquiring texture of graphite on paper is unavailable to us. Too often we disregard these anomolies of automation, in favor of saturating our senses with new perspectives. But note that "many creative persons want to be removed from excessive stimuli." [1] I will contend that those stimuli present must be in concert with both the nature of the involvement and the nature of the person.

An example I have used over and over can be found in the dimension of color. Color is increasingly removed from our lives, notably by printing costs and office copying machines. (An important exception is television. A current trend is television-based graphics [37] which, among other advantages offers color at almost no cost.) My example has to do more specifically with the endeavor of writing. At home I compose a document on an old electric typewriter (as I never handwrite), the kind that looks much like a 1950s Buick and has a red/black cloth ribbon. When carried away by something even as dull as a memorandum, I may type particular words in red, to bring them to the attention of the reader, even at a glance. Subsequently, at the office, this is transcribed with a fancy, correcting, 15-inch platen Selectric with carbon ribbon. Carbon ribbons only come in black. The result is the substitution of an underscore, change in type, or some graphical ploy. My point is not to bemoan the removal of the dimension, but to claim that I would have written the document differently in the absence of color, perhaps surrounding the important words with heated adjectives.

Similarly, in computer graphics we are constantly driven, sometimes unconsciously, to consider those aspects of a problem which lend themselves to the various and circumstantial dimensions of the hardware at hand. This is particularly noticeable in graphic design, where page layout systems (until recently) could not display high-quality text or photographic material. Consequently, the market has offered hyphenation and justification (the infamous H&J) packages for the production of proof in a most conventional, off-line manner.

As a final note to this section, I will question the well-entrenched notion in computer graphics of a "window." The inception of the idea stems directly from the physical size of cathode ray tubes and indirectly from their poor to modest resolution. The idea simply considers the display to be a porthole into a sea of data which can be translated and scaled, bringing various amounts of grpahical information into view. In a very real sense, the user chauffeurs himself about his graphical space, in more complex systems with a three-space. I have likened this to the blinders worn by horses which pull anachronistic carriages down Fifth Avenue. The failing is threefold. One, you have to know where you are going to get there. Two, the panorama, mostly in the fovial vision, is composed of an *a priori* signal-to-noise ratio. Three, the framing in a physical sense is a true cramp.

Later sections will offer alternatives, specifically, the concepts of ambient information, graphical place, and sensory pruning. Instead of considering our design aids as peepholes into computers, I suggest we think more spatially, filtering data in manners not cartesian. I am reminded of seeing a familiar city for the first time at night or, in reverse, a ski resort during the summer.

4. THE MACHINE AS A WHOLESALE SLAVE

In discussing computer graphics, Coons [10] refers to "an idiot-slave model of a fast draftsman who doesn't eat." This simple metaphor is the facade of a very complex paradigm of man-machine interaction, to which most of us ascribe, whether or not we admit it. It is a mascot for those who dispute the advisability or feasibility of developing an artificial intelligence. It is the common denominator of current CAD.

More speculative approaches to CAD include commitments to machine intelligence, yet to be fulfilled, and consequently vulnerable to criticism. The purpose of this section is not to champion a current cause, but to contrast it with the concept of a slave. Important concepts for amplifying creativity are found in the distinction between manipulating ideas as though they were things. [36] The machine as a wholesale slave lends itself to many aspects of thing-manipulation, but not to critical tasks of generating, evaluating, and, most importantly, understanding ideas. Instead of pursuing the large epistemological problems of these concepts (that has been done eloquently by Pask [49, 48]), I will dwell on two particular details of the slave paradigm in CAD, namely, that of *partition* and that of *compliance*. I see these as the two most important deterrants to the creative use of CAD.

The idea of a well-formed partition between what the human does and what the machine does can be traced to cocktail chatter: "Let the machine do what it is good at doing and let the human do what he or she is good at doing." We recurrently find example examples: observe how few of us can recite the alphabet backwards or how no machine can distinguish Der Fliegende Frankfurter from an airborne sausage. Horman [23] gives some account of this in her paper *A Man-Machine Synergistic Approach to Planning and Creative Problem Solving*. My concern about the partition is caused by the lack of redundancy of tasks. When each party is doing that and only that in which he, or she, or it, is expert; a premature sense of completeness arises, and a premature critical judgement is invoked.

I am thinking in particular of graphical exactness. My position is exemplified in problems of graphical input, where I will claim that the wobbliness of lines in a sketch have an important gestalt in relation to one's current thinking about the design of which that sketch is a representation. Further, hand-movements and hestitations, before stylus hits paper, reveal senses of completeness, certainty, transciency, and the like. In contrast, in CAD we are forced to think with an expert draftsman, on occasion with insidious rubber-band lines. What this does is to create a false sense of exactitude and consummation, which in turn discourages the bantering of alternate strategies. Ironically, CAD was supposed to allow for the study of more design alternatives. Instead we find a more rapid zeroing in upon one.

We have seen in section 2 that a major consensus prevails regarding the desirability of suspending critical judgment during the time of incubation and production of ideas. This suspension is exceptionally difficult when one is presented with a contradiction to a "fact of life," at least a seeming one. For example, in a well-partitioned system we could never live with a machine-aided mathematics, using the term; "lowest common denominator." The term is a blatant contradiction in that what we mean is the highest common denominator (but we all know that in a large set of numbers, it is usually low). In other words, the wrong idea is in some sense right, and in this example, has even assumed cultural

Turning to the notion of cultural compliance - maybe better termed acquiescence - we find a host of trite examples of machines that blindly execute stupid commands, all of which require one of two extremes, either an "understanding" or a special-purpose trap in order to be avoided. I am less concerned about the kind of compliance that may cause robots to jump out of windows when told then I am in the strategic singlemindedness that goes hand in hand with it. By this I mean the ability to view a problem in different ways even though there is a brute force, an eminently "do-able" way that does not require any "effort" or originality. Consider the following example by Karl Dunker [13]:

Two trains are a hundred miles apart, separated by a straight stretch of track. They start moving toward each other at twenty miles per hour. At the same time, a bird perched on one of the trains for some unknown reason starts flying toward the other, at thirty miles per hour. Upon reaching the advancing train, it turns around and flies back to the first, whereupon it reverses its direction, back and forth, and so on. The question is: how much distance did the bird cover, flying back and forth, until the trains met?

A compliant computer will grind out the sum of the series and, yet worse, probably will not interact with the user in any manner except to expedite this sum. A more creative solution to the problem is to take it out of the contest of *space* and put it into *time*. Obviously, or not-so-obviously, the trains required two and a half hours to meet. We see at once that the bird must have also flown for two and a half hours and hence covered a total of seventy-five miles.

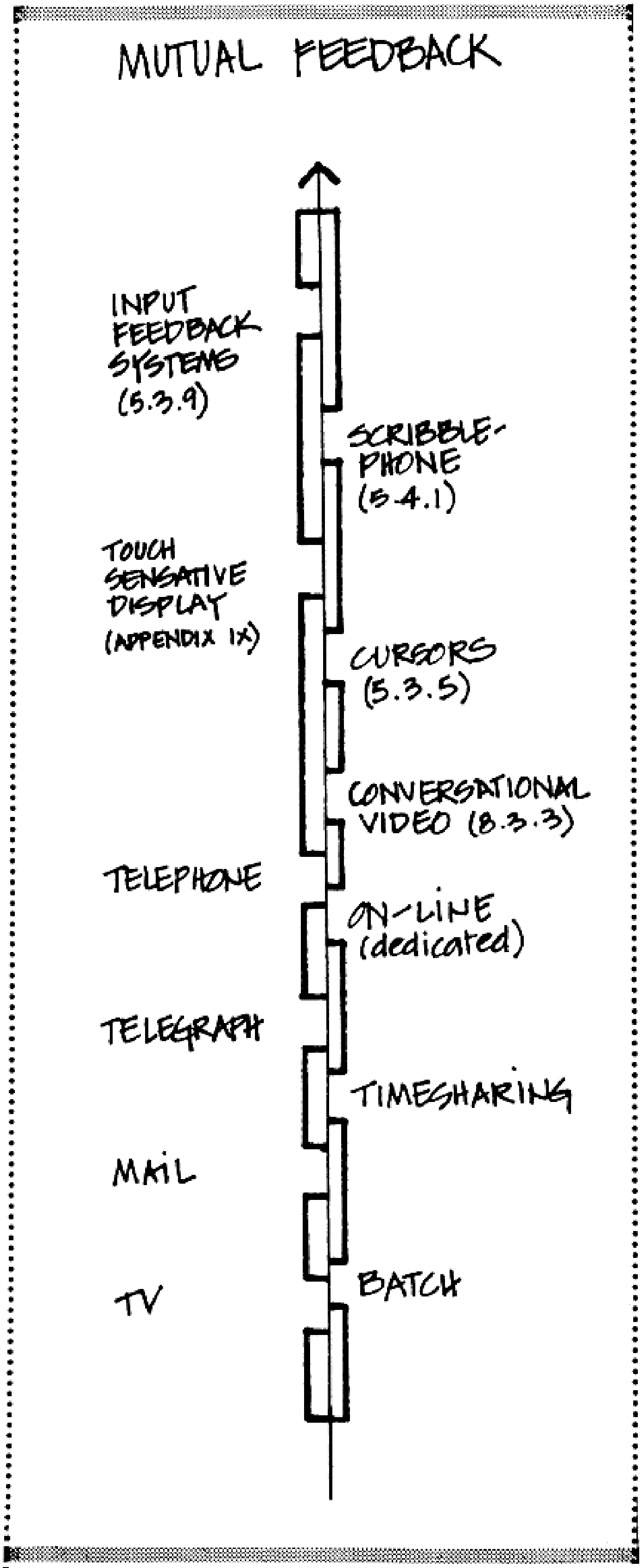
5. THE MACHINE AS VIRTUOSO

Consider the notion of the Renaissance machine.

Leibniz is said to be the last person to know everything. However, Arieti [1] (who, out of 487 references to authors, artists, scientists, luminaries, never mentions him) makes a case that such people do not exist. He argues that the notion of a Renaissance man is vacuous. For example, Leonardo da Vinci's life as a scientist and engineer is filled more with frustration than accomplishment. His airplanes, submarines and diverting of the Arno river were undertakings that failed, especially in comparison to the Mona Lisa or The Last Supper. Similarly, Alberti reached his greatness in architecture, even though skilled in music, painting, poetry, Latin, and philosophy.

The question of this section (mostly unanswered), in complete contrast to the preceding, is simply: in what ways is creativity enhanced or subdued in the presence of a machine posed as an incontrovertable savant? I am reminded of my father's painting, which suffered more than benefited from my critiques based on the minutiae of perspective construction.

Two seemingly debilitating personal characteristics are attributed to the creative personality: gullibility and, for lack of a single word, the tendency to jump to conclusions with insistence but without proof. Rothbart [59] expands the former in the context of engineering. Polya [56] states: "When you have satisfied yourself that the theorem is true, you start proving it." The English anatomist Harvey and the Russian chemist Mendeleev are examples. Harvey postulated the existence of capillaries (before the microscope was developed into a serviceable tool), but could not prove it. Thirty-three years after the publication of Harvey's book (in 1628) his explanation of the circulation of the blood was proved by Marcello Malpighi (who discovered capillaries in the lungs of a frog). Similarly, Mendeleev was successful in the design of his Periodic Table of Elements (announced in 1869) by virtue of not being deterred by serious shortcomings. When he could not place an element in his table he was content to leave the entry blank and to predict the future discovery of an appropriate entry. In less than thirty years his prediction came true with the discovery of gallium, scandium and germanium.

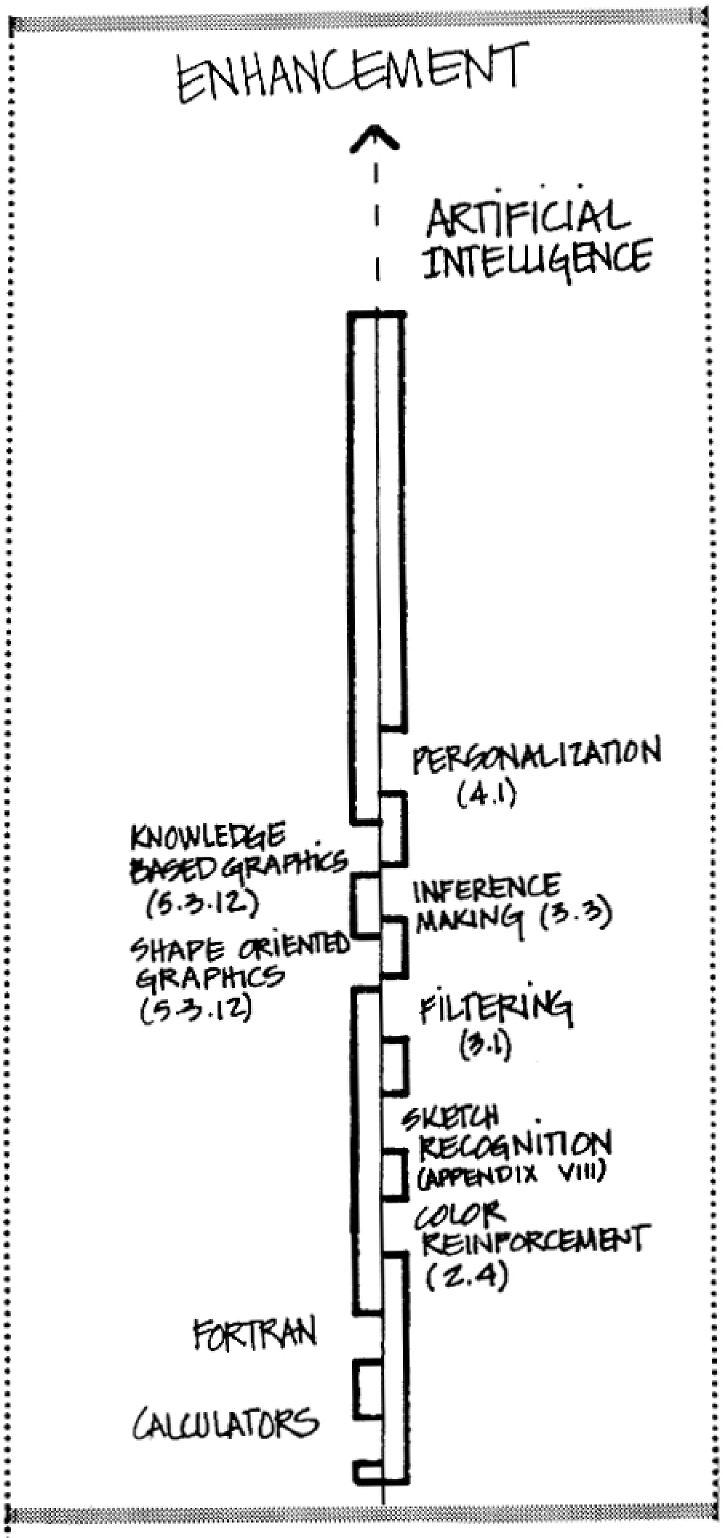


If we view the problem as the amplification of creativity in design, a revealing distinction is found in the difference between a hunch and a hint. According to Platt and Baker [55]; (I cannot find a more current reference to this topic): "A hunch springs from a wide knowledge of facts but is essentially a leap of the imagination, in that it goes beyond a mere necessary conclusion which any reasonable man must draw from the data at hand." A hint, meanwhile, is the caricature of paternalism and accordingly demeaning.

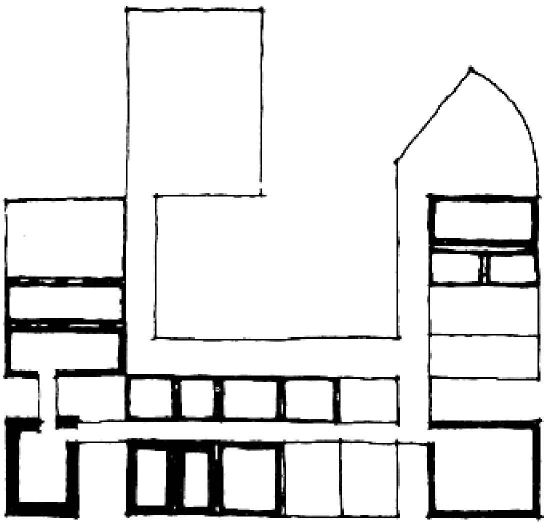
Most computer-aided design systems are more like hint-giving systems than hunch amplifiers. The notion of an *incompatibility*, even of my own design, [45] is vulnerable to this hint-giving paradigm. "In the ideal situation, the communication language could be so informal, that is, so natural, that the computer-aided designer would not have to learn it .... If an *incompatibility* is found, the designer concerned would be informed." [21] The italics are my own. Maybe that is not so ideal. My concern stems from three problems with CAD systems: that of timing, which can be managed; that of thwarting the "creative leap," which may not be manageable; that of paternalism, which might be a built-in contradiction to the intention of using CAD for creative purposes.

The timing of a remark is frequently more important than the remark itself. Subsequent sections will argue that such timing is aided by an intimate acacquaintance with the designer. Here I am more concerned about the propriety of keeping quiet. Three important references to the influence of timing are found in Maier and Burke, [33] Burke, Maier and Hoffman, [9] and Burke. [8] Some of their conclusions include: the behavior engaged in at the time a hint is received will determine the way in which the hint will be interpreted and used; when the ongoing behavior is at odds with the information provided, the individual will attempt to find a new approach that is compatible; the timing of the hint does not influence subsequent problem-solving activity. It is the last that is most disturbing. The explanation may be that the problem-solving approaches in this body of literature may be oriented toward exercises of ingenuity, as opposed to creativity.

For example, consider the so-called Hat Rack problem. The task is to design a structure sufficiently stable to support an overcoat, using two sticks (1" x 1" x 60" and 1" x 1" x 43") and a 2" C-clamp. In this example, hints are used to overcome faulty presumptions like: a hat rack is a vertical structure that rests on the floor, or, the coat must be hung from one of the sticks. This is because the only stable solution consists of clamping the two sticks together so that they may be wedged between the floor and ceiling, using the clamp handle as a coat hook. Are not the more creative solutions in complete contradiction with the fabric of such an experiment, that is, to dwell upon overcoming the limitation, in some sense breaking the rules, (maybe even the sticks)? It is, in fact, in these violations of the given that one finds the framework for creative leaps.



I have implicitly likened a hint to a machine constraint. More explicitly, hints presume a know-better, as do constraint resolvers of one kind or another, which determine and post conflicts or incompatabilities. In the environment of the virtuoso machine, one need only remember (and worry about) one of the few domains of consensus about creativity, namely, the suspension of critical judgment in moments of collaborative effort to find that for which you do not know you are looking. Osborn [46] argues strongly that the premature intrusion of judgement (note the issue of timing) aborts the ideas which could prove to be most valuable. I am worried that the machine as a virtuoso is prone to such intrusions, at least as a metaphor for one style of work on CAD.



This last question, that of paternalism, cannot be solved, only broached. It is a riddle with paradoxes, as much emotional as rational. I am reminded of a formidable PL/1 compiler that concluded a bugfull compilation with a list of errors of the sort, "semi-colon missing following ELSE of the third nested DO on line 36, column 18." At first one is irritated by the exhibitionism and wonders why such cleverness cannot simply be deployed to fix the bug automatically. Then one worries about the occasions when the compiler is wrong. And finally one despairs at having to use such a denatured language in the first place.

As a concluding example, I submit a very delicate problem inherent in one of our current research projects: Architecture-by-Yourself. [15,70] The problem is to build a computer-aided design system for a future homeowner, presumably (though not necessarily) in a high-density setting. The problem is to avoid railroading the user into decisions and to act only as an early warning system. This is achieved with a very passive computer, asking few questions, tallying the consumption of energy, materials, dollars, and the like. How does one encourage new ideas and broaden insights without paternalistically inducing solutions that are in no way a reflection of the user's needs? I do not know. But I do know that question-and-answer lobbying is not the correct solution. I offer the following as an example of the virtuoso machine doing damage [57]:

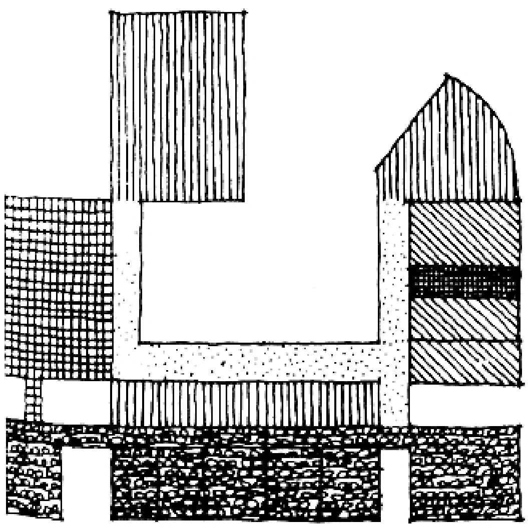
Computer:	Shall we discuss the dining areas?
User:	Yes.
Computer:	Who does most of the cooking in your family?
User:	Carol.
Computer:	I would suggest that the dining area for your everyday meals be in the same room as the cooking area so that everyone can socialize while meals are being prepared and Carol won't be isolated in the kitchen. Don't you agree?
User:	Yes.
Computer:	How often do you want these occasions to be formal (that is, other than casually joining you for dinner) in times per year?
User:	Twelve.
Computer:	Keeping these answers in mind, do you feel that you need a separate dining area for more formal occasions?
User:	No.

6. THE MACHINE AS A CREATIVOGENIC TOLERANCE

Coons [10] states about CAD: "The central issue seems to be how to endow the machine with that undefinable capacity called *"understanding."* The evidence of *"understanding"* in humans as well as machines is some intelligent response that is *"meaningful"* and pertinent; although not necessarily *"right."* I am reminded of a child's explanation of the wind. His theory was the the trees waved their leaves and caused the wind. However *"wrong"* this is, it would be wonderful to have a machine intelligent enough to invent such an essentially logical idea."

Such ideas are not only the delight and fancy of children, but frequently the origins of important theories. One need only consider Aristotelian physics, which lasted until the Renaissance, sustaining such explanations as, stones fall to earth because it is their natural home, and, flames rise upward because their home is in the sky. Arthur Koestler [25] recounts an example of a situation in which "correct" ideas were not tolerated. The incident involves the Viennese doctor Ignaz Semmelweiss, who discovered that certain infections were caused and carried by the unwashed hands of surgeons and medical students. Consequently, he introduced the strict rule of washing in chlorinated water, which dropped the death rate first from one in eight to one in thirty, then one in a hundred. Subsequently Semmelweiss was hounded out of Vienna by the medical profession for daring to suggest that they carried death on their hands. Exiled to Budapest, he denounced his opponents as murderers. Receiving little attention, he became raving mad, was put in a straitjacket, and died in an asylum.

While it is hard to liken a computer system to the Viennese medical profession in 1850, it is easy to parallel a momentous intolerance, for "right" as well as "wrong" ideas. I can remember numerous occasions of feeling frustrated by an uncompromising, inflexible, dumb computer. Intolerance for typographic inaccuracy is in itself sufficient to illustrate the complete opposite of a creativogenic environment. I have frequently wondered how many people have been driven crazy, not quite to the extreme of Semmelweiss, by the substitution of a lowercase "L" for a one, something we have done all our lives with typewriters and something for which there is no convention like slashing a "0". (I admittedly can never remember whether Ø is a zero or an O.)

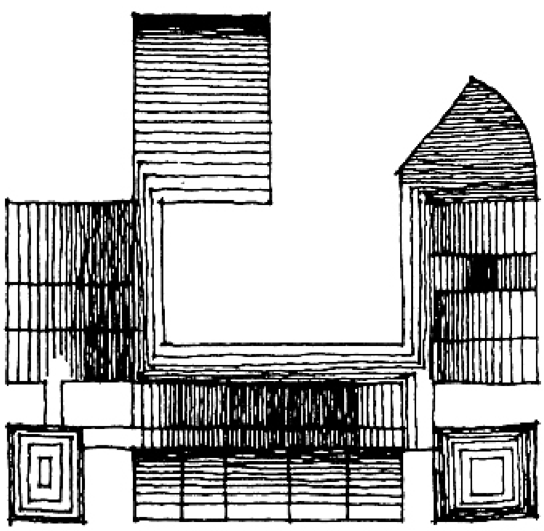


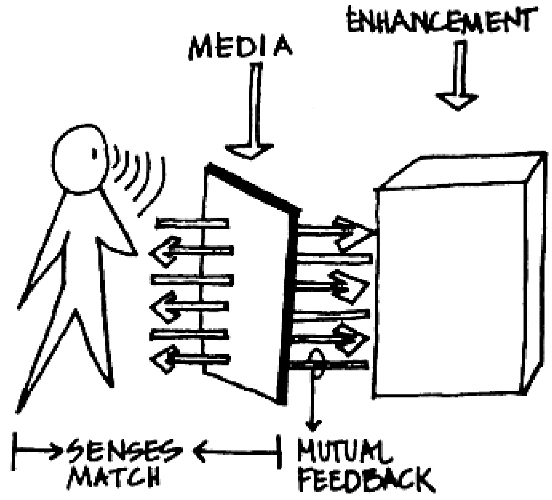
Very few authors study creativity in terms of encounters with people and the environment. Instead, there is a *de facto* agreement and emphasis upon the need for aloneness, tranquility, introspection, but particularly aloneness. An exception is found in the work of Schachtel, [60] who roots creativity in people's need to relate to the world around them. He writes: "The quality of the encounter that leads to creative experience consists primarily in the openness during the encounter and in the repeated and varied approaches to the object, in the free and open play of attention, thought, feeling, perception." It is clearly the case that no encounter with CAD can be characterized in Schachtel's terms, and it would be supercilious to nag about this inadequacy. Even as an orthodox believer in artificial intelligence and researcher in this very field, I am willing to wait. In the meantime, are there models for the machine as a creativogenic tolerance?

The most encouraging techniques are coming from computer-aided instruction, in particular, from those researchers who are bent upon amplifying learning through playing. Initiated by Papert, [47] a student of Piaget, this attitude toward what you might call creative learning is receiving overdue and popular acceptance. The notion can be abbreviated in the cliche that the best way to learn something is to teach it. The machine is consequently an intellectual playground in which the child debugs his own models in the light of differences between anticipated and exhibited behavior of the machine.

In design, such play may be the key to the inspirational facets of CAD. Berlyne [5] goes as far as to state that play "includes everything that is classified as recreation, entertainment, or "idle curiosity," as well as art, philosophy, and pure (as distinguished from applied) science." In design schools we are struck by the amount of dog-work that accompanies the process of creation. A variety of wisecreacks exist about the disproportionate amount of perspiration required for small quantities of inspiration. The very basis of CAD is to remove this drudgery, to change the balance, and to afford the opportunity for greater inspiration. It is here that we must be very cautious.

I consider architects as very tactile people. Removing all the toil is not necessarily a good thing. In fact, we may want to consider putting some of the handicraft back into design, still in concert with a





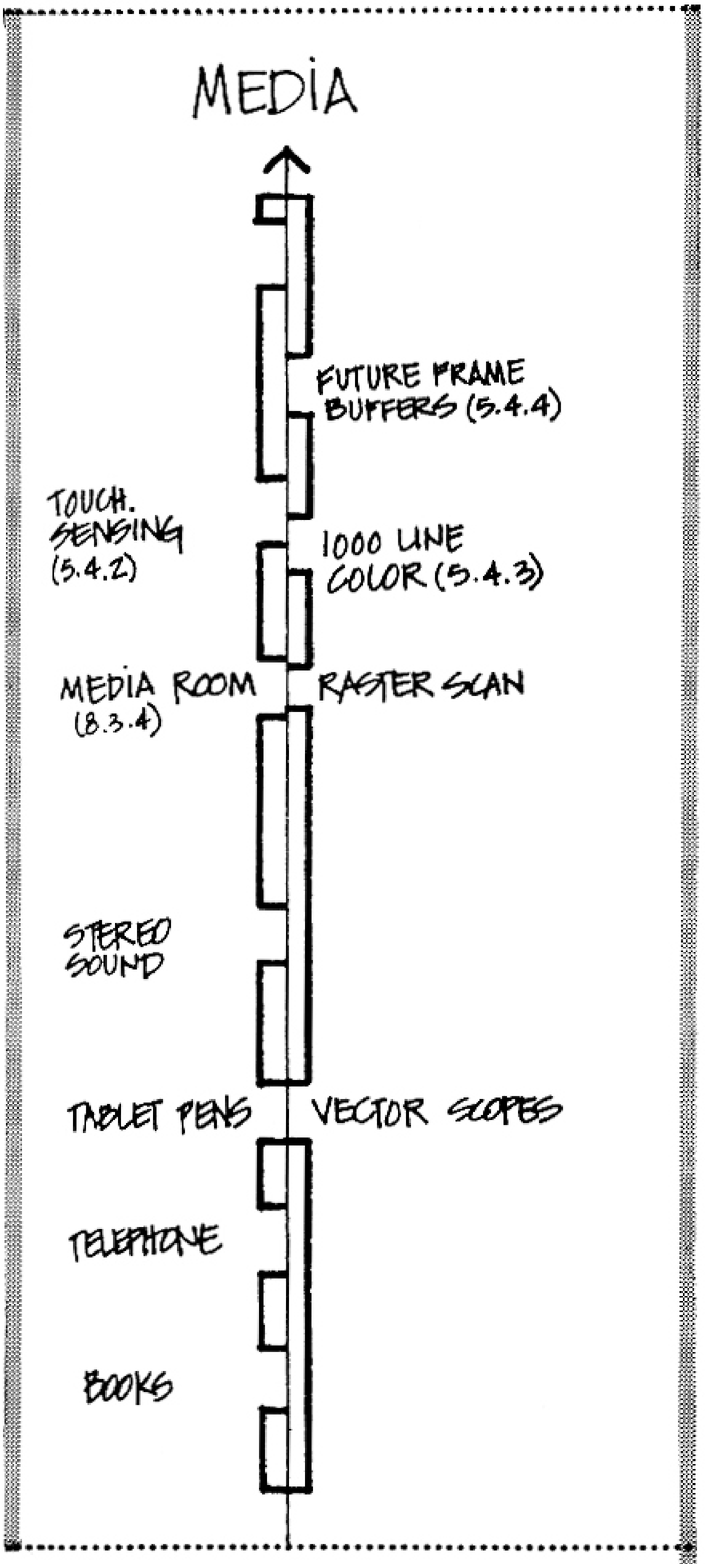
computer, not just removed in the name of efficiency. In a very therapeutic sense, I propose that there must be a tolerance for manual and graphical (in the case of architecture) sport and fascination, as things unto themselves. This is similar to a respect for daydreaming.

Osborn [46] calls daydreaming "the most common use of noncreative imagination." Here I must disagree and side with Singer [62] and Arieti [1] who share the position that "persons engaged in daydreaming would be characterized by a considerable exploratory tendency." In fact, we find some evidence that daydreaming leads to the unilaterally accepted creative-promoting condition of so-called free thinking. But don't be caught daydreaming in front of your terminal!

7. THE MACHINE AS A PLACE

This last section must be read in two ways: literally thinking of machines as places we inhabit [42], and considering an intellectual milieu of ambient information. [7] Both depart dramatically from current systems, all of which are highly directed and directional, in both their mechanics and their conception.

However, before postulating such a place, consider some accounts of creative environments, though admittedly passive (sometimes peculiar). For example, we are told that the poet Schiller liked to have rotten apples, concealed beneath the lid of his desk, under his nose when composing poetry. [63] A more common environment seems to be the bed, where Einstein, Descartes, Cannon, Poincaré and Brindley claim to have had their most profound ideas. [6] Helmoltz claimed that his inspirations came "never at the writing desk." [74] "In order to be creative Thoreau built his heritage, Proust worked in a cork-lined room, Carlyle in a noise-proof chamber, and Balzac wore a monkish garb; Gretry and Schiller immersed their feet in ice-cold water; Guido Reni could paint, and de Musset could write poetry, only when dressed in magnificent style; Mozart, following exercise; Lammenais, in a room of shadowy darkness, and D'Annunzio, Farnol and Frost only at night. The aesthetician Baumgarten advised poets seeking inspiration to ride horseback, to drink wine in moderation and, provided they were chaste, to look at beautiful women." [30] Several authors have had recourse to bathtubs. The ludicrous extrapolation is that of a waterproof, odoriferous, equestrian, noiseless computer.



With the exception of the last qualification, noiseless, these settings are more eccentric than practicable, eclipsing the primary purpose of featuring aspects of the environment, seemingly unrelated to computers. But, are they really so unrelated? Is there a germ of truth in the consideration of work places rather than work stations?

In relation to my introductory remarks about computer graphics, I will contend that the first kernel of truth comes from a multiplicity of media and extensive motor involvement with them. I am told of the admiral who delighted in reconfiguring formations of press-pin ship figures on a large bulletin board map. When presented with a formidable, tactical (definitely not tactile) computer system, he refused to use it, forfeiting information management for the bodily involvement with his vessels. This was not for sportsmanly reasons, but because he remembered his actions as body movements, not as coordinates. I believe that this example has relation to computer-aided design.

It is not infrequent to conduct design reviews by posting a set of large drawings around a room and to wander from section to plan to perspective back to plan, and so on. This is a very literal example of "surround," emulatable by computer, at some expense. The multiple drawings are in some sense less important than the feature of wandering and the notion of large. My eye becomes the window.

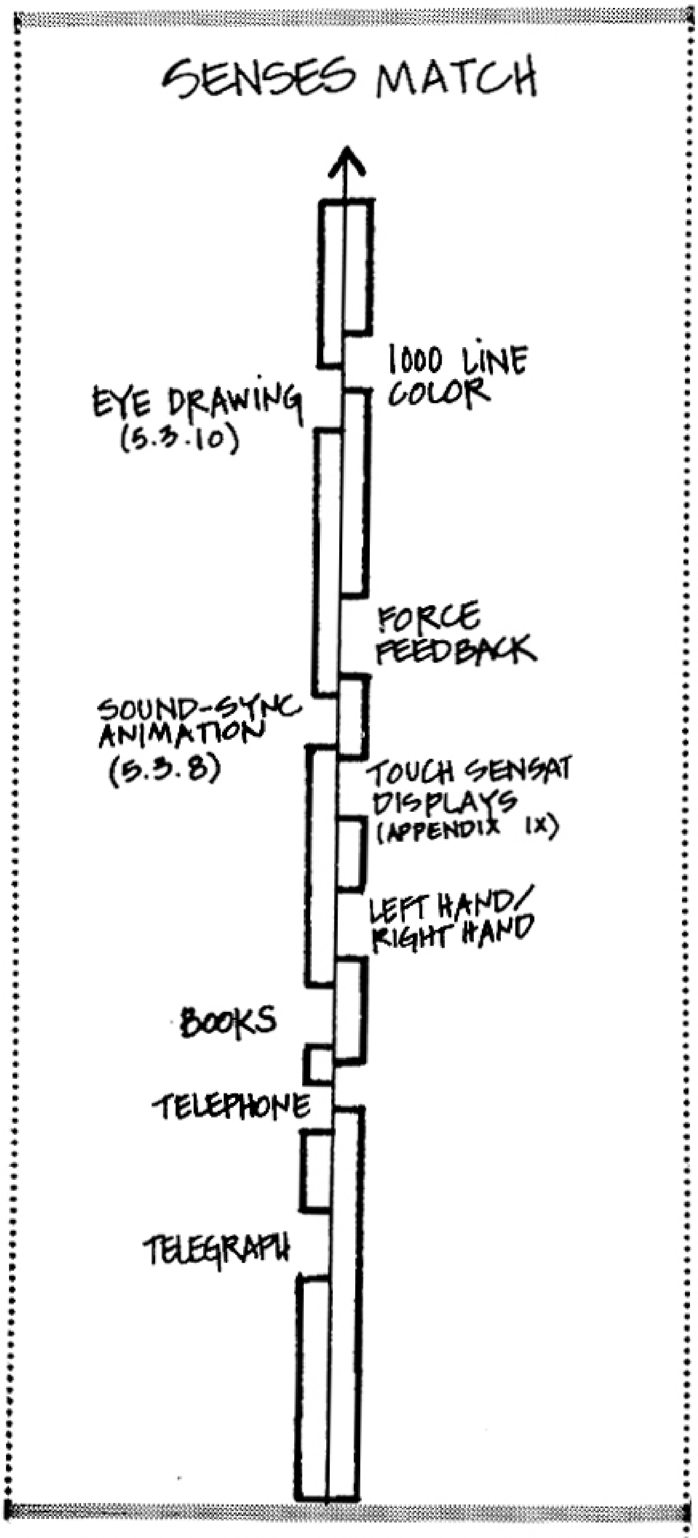
Immediately one worries about an information overload, a plethora of details, and a potential for overstimulation (which the psychoanalytic literature on creativity strongly warns us against). Consequently I offer the notion of sensory pruning, versus spatial limitation. The latter is characterized by current "window graphics" with the proverbial powers of zooms and spatial translation. The former has no precedent yet. In fact, it can be said to be the subject of my current research, starting at this writing (to be presented orally at IFIP Congress 77).

The reader will remember two earlier examples briefly mentioned: seeing a city at night or a ski resort in the summer. These illustrate sensory pruning and "un-pruning" in a very direct way. In the case of a city, cluttered with detail, color and frequently unsettling features like dirt, smog and ugly buildings, it can become very beautiful at night, predominantly black and white in the background, with most elements of form reduced to the hidden scaffolding for a sculpture of light. In reverse, we can imagine the winter-palace nature of a ski resort giving way to bucolic clutter.

A fuller analogy in spatial references is perhaps the fog to which we can all relate on land, at sea, or on Baker Street. A dense fog not only decreases our depth of field, but increases our sense of hearing. If we consider our data (as well as our computer) as a place, and if we know we are looking for a "file" with particular sound characteristics, it is quite logical to induce fog to find it, much like a blindfolded kidnappee attempting to retrace an abduction. I will call this *sensory pruning* in contrast to the notion of a window, *sensory framing*.

Is this a helmet, a room, or a football field of apparatuses? Regardless, what is critical is the notion of free body movement, not the solemnity of being posed in front of a keyboard. Additionally, I am presuming a variety of force feedback systems to insure complete tactile interaction, as well as light/sight and sound/hearing. Here are two examples, both taken from experiments underway which use a large digitizer/plotter (Computervision's) retrofitted to have the relation of the transducer to the servos under program control. In one case, planning a path on a topographical map (in color, etc.), the high-frequency response of the handheld puck allows the user to feel the terrain as reported by data on rockiness, marshiness, and the like. Or, less tactually iconic, consider the assignment of an arbitrary dimension to the force required to digitize. In this example, we can imagine planning a highway where the drawing of proposed routes in increasingly more difficult as a function of the number of families being displaced.

As a final point in regard to the computer as a place, a design place, it is important to expand sensory augmentation and sensory pruning to include the general notion of filters. Our perceptual



system itself is a filter and reductive. Given a universe of potentially numberless stimuli, one is constantly filtering information in both primary and secondary ways, in the Freudian sense. With directed attention we manage to locate a screwdriver on rocky ground or discriminate an old English sheepdog lying on a Flokati. More relevant, perhaps, with primary processes we find the ability to latch onto unexpected cues, like overhearing one's name at a cocktail party, when it was in fact mentioned in a low voice, in the distance, well below local and ambient sound levels. Or, as a final example of primary filtering, I offer a personal experience that many readers may have shared in one fashion or another. It has to do with cars. I recently purchased a Jeep. Since that time I have been amazed by the incredible increase of the population of Jeeps in the United States, seemingly several orders of magnitudes. I contend that, while 1976 sales may have been up, the increase is a perceptual registration of a personal entailment. That is: I tend to notice them, which is our introduction to personalized systems.

8. PERSONALIZED DESIGN SYSTEMS

In his chapter, "Factors That Tend to Create Creativity," Osborn [46] devotes a subsection to the idea: "Intimates can encourage best." Lasswell [29] refers to a "warmly indulgent relation between innovator and recognizer." This "climate of indulgence" is confirmed by Dentler and Mackler [12] who conducted tests for originality in undergraduates. In short, the object is *not* to need to eliminate what is likely to be unaccepted by the environment - *not to be on guard*.

This section is not about the love of a mother for her child, a love which unfolds praise and encouragement, a love which sees beauty in the collages and papier-maché brought back from first grade arts and crafts. Instead, I am interested here in notions of acquaintanceship, interpersonal hypotheses, and inferencing making, and how they augment a creative environment and drive a creative person. Is a personalized design system, i.e., an idiosyncratic system, the key to the creative use of CAD? I believe so.

Consider a human-to-human encounter with somebody you do not know, maybe from a different culture. The conversation is marked by explicitness, void of both metaphor and short-hand references to shared experiences. The result is a stilted interaction, more bent on the verification of understanding than on the incubation and illumination of ideas. In the extreme, I once likened computer-aided design to discussing Cézanne with a Martian by telegram. My mistake was in subsequently concentrating on the telegram (and its limited bandwidth) rather than on the Martian (and his/her/its lack of shared experiences).

Work styles are very personal. They seem to get more idiosyncratic the more creative the endeavor (as we have seen with Schiller's rotten apples). While it is hard to think of varying styles of touch-typing, it is easy to imagine innumerable methods of painting or writing poetry and music. For example, we know that Mozart thought out symphonies, quartets and scenes for operas entirely in his head and then transcribed them onto paper in their completeness. In contrast, Beethoven wrote fragments in notebooks and developed them over years, frequently from clumsy beginnings into miraculous results. Pask and Scott [50] would call Mozart a wholist and Beethoven and serialist. As they (Pask and Scott) have proved with learning strategies, I think we can prove that Mozart and Beethoven would need dramatically different computer-aided scoring systems.

The pitfall is trying to find dichotomies or to search for well-formed taxonomies of style, a pitfall of much of the work in human factors. Yes, people are right-handed or left-handed (or both), and the system should take this dichotomy into account (which it almost always does not). However, such simple polarities are representative of thought processes which are developed in great measure out of an entire lifetime of varied, personal and not-easily-sharable experiences. How to reflect these differences in a CAD system and to embody them in specific software and what I have called existential hardware is outside the scope of this paper and is dealt with elsewhere. [40]

Here, let me provide a few examples that range from the superficial to the profound application of personalized techniques, ranging from the difficult to the almost-impossible. Consider first handwriting. Some graphologists, for example Singer, [61] will go so far as to claim that a full range of cues about personality lie in our mannerisms of dotting *i*'s, crossing *t*'s, slanting *m*'s, etc. While I will not go that far, I will postulate that our handwritings (for those who still do that) do have unique signatures and that such signatures are useable for recognizing and discriminating in many inference-making functions. For example, in sketch recognition, with a mechanical design problem, we want to separate out projective geometry from annotations, doodles, shopping lists, or whatever. Without elaboration, the reader can appreciate that this is immeasurably easier with the added information of who did the writing; easier yet if we can observe the writing on-line (speeds, accelerations, and even pressure); but nevertheless difficult.

Other examples of personalized design strategies include various ways of moving from diagrams to projective geometry, of dealing with classes of problems, or of using preconceptions. They are all personal and progressively more difficult to incorporate into a computer aid. Additionally, they grow and change in conjunction with particular exchanges, where, for example, two people develop very personal languages of words, gestures, and expressions, frequently specific to a task. I am reminded of a story I cannot document. A painter of some renown was undergoing therapy, frequently doing drawings and making pictograms in the process. His analyst would interpret these, but to no avail therapeutically; the patient progressively got worse, moving ultimately into complete madness. During this time the drawings degenerated slowly, into unrecognizable and deviant shapes which only the analyst could decode!

9. THE RETURN OF THE SUNDAY PAINTER

The title of this last section is copied directly from the title of a chapter on "The Future of Computers in the Visual Arts." [39] I am reusing it to convey an aspect of CAD as a creative tool, to which I can only call attention, but at this time cannot justify, primarily for cultural reasons. Namely, I am interested in the creativity in Everyman, its amplification by a future of home computers, and its celebration by an important sense of fulfillment. Matussek [34] speaks of this as driven not by the environment or inherited talent, but by the function of the ego of every human being. Arieti, [1] however, cautions: "Too many of them (people) are so busy protecting themselves from insecurities of neurotic and social origin that they have no energy left for self-expression and growth, especially in the field of innovation."

At this point I must address the creative product, a topic I have cautiously avoided until now. In my examples I have loosely moved among the arts and sciences, from poetry to chemistry, from painting to physics. They all entail creative processes in the sense of going beyond that which already exists, but the products are quite different and their bonds with human existence are dissimilar. The product may be an innovation in understanding, a new dimension of utility, a feeling of transcendence, an aesthetic pleasure, or a good laugh. While one is no less important than the other, it is surely in the new dimensions of utility that we see the roots of CAD in engineering. In architectural applications we begin to find islands of subjectivity that form overall archipelagos of individuation. Finally, in the fine arts we are left only with metaphors, to which each person ascribes different meaning.

While it is noticeably unrelated to the innovations of circuit, cam, or even building, I will end with the latter because it affords the opportunity for instrospection and individuality, not just as wishful thinking for the future, but as an extreme, almost outrageous, demand on the man-machine system. Also, computer graphics as we know it and extrapolate it into raster scan technologies [37] is already moving into the home. Walker [68] reports on television-based consumer products: "In the drawing setup, it is possible to program a 'palette' of colors for composing the picture. And this system (Admiral's Videospond) can even perform elementary animation accompanied by audio commentary." For the first years, these devices will be graphical toys of some delight, but of little intellectual challenge or assistance, not unlike computer graphics in its early years in CAD. Then they will emerge as idiosyncratic systems of the most ubiquitous sort, potentially the most widespread amplification of creativity seen by mankind.

Such romantic visions are important fuel for the day daydreams of computer scientists and designers working on CAD. All too often we dwell upon making mechanisms for productivity which, like birth control, are most practicable for our neighbors, not for ourselves. We think of CAD in terms of rooms with raised floors from which one graduates while climbing the managerial ladder of success. Instead, I offer the extreme of the Sunday painter and point at the creative individual. I hope the reader will not look simply at the tip of my finger.

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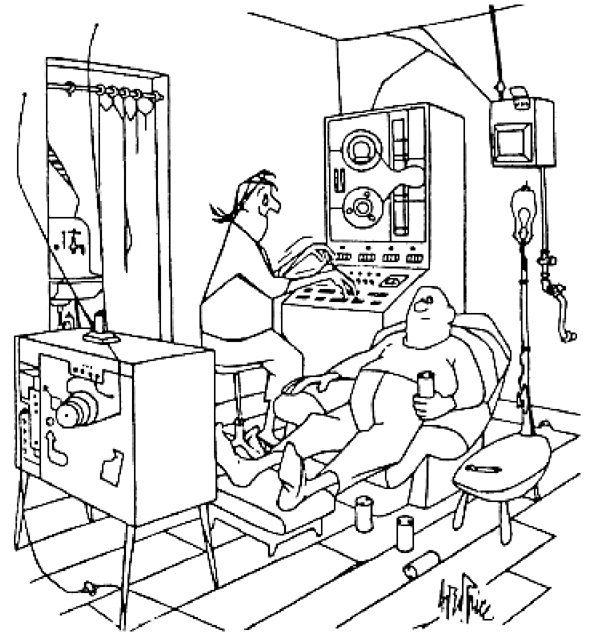
NOTE: Illustrations in this article are all from the definitive proposal, "Graphical Conversation Theory - Computer Mediated Inter- and Intra-Personal Communication" by Nicholas Negroponte and others from the Department of Architecture, MIT, 1977.



(Cartoon from January 13, 1968, issue of Business Week. Courtesy of George Price)

REVIEW: IFIP CONGRESS SERIES — VOLUME 7

Proceedings IFIP Congress 77 - Toronto, August 8-12, 1977

by Grace C. Hertlein, Editor, CG&A

THE CONFERENCE VS. THE PROCEEDINGS

As each year passes, I find conference proceedings perhaps more valuable than attending the actual conference event. When the hectic pace of conference travel is over, and reactions to varied presentations (and one's own work) are recent remembrances, there is a tendency for the thorough professional to sit down and leisurely study conference proceedings. What appears to be invaluable (exceeding by far the conference experiences, no matter how pleasurable), are the insights and knowledge gained by solid, undisturbed reading. In the calm of one's own environment, a deliberate scrutiny of meaningful papers can be an illuminating (and even, intellectually passionate) experience. In a good paper, absorption of the material is necessary, requiring at least a second reading.

Too often conferences resemble computer carnivals. Too often, a solid thinker is a dull speaker. The studied, deliberate reading of a paper is a better companion by far.

I believe, however, that because of inadequate reading skills, even thorough professionals do not read enough, and miss the joy of having the pleasure of a visiting colleague in one's own environment -- via the ease of conference proceedings.

IFIP CONGRESS 77 PROCEEDINGS

Because of space, I will not list the 67 sections in the IFIP Congress 77 Proceedings, but will focus primarily upon selections of interest to graphics people. At first I sampled the titles, and skimmed subjectively, the most intriguing titles, scanning swiftly for fascinating content. I was delighted to find that many of the papers which appeared to me to be most interesting, were invited works. Meaning, however, is in the eye of the beholder.

In reviewing the 1000 pages of this proceedings, it is impressive. There is a great range of subject matter. The international focus is always more exciting than regional or national conference material. This is a solid, thorough volume, that I would recommend highly to a computer science professional.

Here are a portion of the papers relating to graphics that I found fascinating:

SOFTWARE STUDIES - I
- On Generation of Test Data and Minimal Cover of Directed Graphs by Rajat K. Deb

PATTERN RECOGNITION AND ARTIFICIAL INTELLIGENCE
- A Feature Concentration Method for Character Recognition by Kazuaki Komori, Takahiko Kawatani, Kenichiro Ishii and Yukiyasu Iida
- Recognition System, Handwritten Characters by Kiyoshi Iwata, Masumi Yoshida, Eiichiro Yamamoto, Takeshi Masui, Yukikazu Kabuyama and Shini-ichi Shimizu

FINITE ELEMENTS METHODS
- On a Graphical Package for Nonlinear Partial Differential Equation Problems by Owe Axelsson and Uno Nävert

GRAPHICS
- An Interactive Geometrical Design System with Handwriting Input by Mamoru Hosaka and Fumihiko Kimura
- The Intermediate Language for Pictures by Teus Hagen, Paul J. W. ten Hagen, Paul Klint and Han Noot
- Multiple Colors and Image Mixing in Graphics Terminals by E. Carlson, G. Giddings, and Robin Williams

COMPUTER-AIDED INSTRUCTION
- Introduction of Computer Aided Design in an Educational System by Philippe Masse and Jean-Claude Sabonnadiere

PATTERN RECOGNITION AND PROCESS CONTROL
- The Discriminant Function Approach to Classification of Incomplete Pattern Vectors by Josef Kittler
- Validation Problems in Pattern Recognition Study of a Particular Case by M. Borillo, L. Fariñas Del Cerro and J. Virbel

TRENDS AND DEVELOPMENTS IN CAD
- Trends and Developments in Computer-Aided Design by J. Hatvany
- Focusing on the Internal Model in CAD and CAM Systems by Frank M. Lillehagen, Jórn Øian and Jan F. Mack

TECHNIQUES IN CAD - I
- The Analysis of CAMS by Computer Aided Algebraic and Symbol Manipulation by James N. Hanson
- A Computer System for the Synthesis of Reinforced Concrete Frames by Alina Golka
- Using a Conversational Translator Writing System for Generating Computer Aided Design Systems in Architecture by Gerard Courtieux and Daniel Guibert

GRAPHICS IN SOFTWARE ENGINEERING
- The Computer "Scientist" as Toolsmith -- Studies in Interactive Computer Graphics by Frederick P. Brooks, Jr.
- FORAL LP -- Making Pointed Queries with a Light Pen by Michael E. Senko

CAD -- PERSPECTIVES AND PROSPECTS
- Means and Levels of Knowledge Representation in the CAD System Germinal by Jack Foisseau, René Jacquart and Francois-Régis Valette
- On Being Creative with Computer-Aided Design by Nicholas Negroponte

AUTOMATED DESIGN IN ELECTRONICS
- Automation of Electronic and Microelectronic Design by M. A. Gavrilov
- NOPAL -- Automated Design and Programming of Testing by Noah S. Prywes, Yung Chang and Cihan Tinaztepe

TECHNIQUES IN CAD - II
- How to Design Variants of Flats Using Programming Language PROLOG Based on Mathematical Logic by Zsuzsanna Markusz
- Algorithmic Macro Design System for Shift Registers by Henri G. Marchand
- LSI by CAD Out of Daisy by D. B. Jarvis

INTERESTING PAPERS NOT RELATED TO GRAPHICS

A broad proceedings (and this is certainly one) has the benefit of allowing a specialist to read beyond the confines of his or her area of expertise, affording enjoyment and growth. Thus the innumerable topics not mentioned in this brief review may be of greater benefit for readers than immediately related topics.

Here is my subjective listing of other topics:

- Introducing Computer Science -- An Alternative by Ira Pohl and Alan Shaw - pp. 53-56.
- Some Approaches to the Management of Change by by Mayford L. Roark - pp. 109-112.
- Beyond Today's Computers by M. V. Wilkes - pp. 1-5.
- Computer System Integrity Safeguards by Normal R. Nielsen and Brian Ruder - pp. 337-342.
- New Trends and Related Problems in Computer-Based Education by J. Hebenstreit - pp. 201-208.
- The Impact of Information Systems on Organizational Thinking by Robert I. Tricker -- pp. 213-221.
- Software for Speech Output by Ian H. Witten - pp. 297-301.
- The Impact of Education in Computing on Science by Bernard C. Levrat - pp. 597-600.
- Another Face of Computing - Service to the Blind by Paul A. Fortier and Donald Keeping - pp. 677-682.

SAMPLE ABSTRACTS FROM IFIP CONGRESS 77.

THE INTERMEDIATE LANGUAGE FOR PICTURES by Teus Hagen, Paul J. W. Ten Hagen, Paul Klint and Han Noot, NETHERLANDS - pp. 173-178.

"The Intermediate Language for Pictures (ILP) determines the structure of a graphics system in which pictures are represented as ILP programs. ILP defines extensions to general purpose programming languages. Input and output is defined as generating and interpreting ILP programs. ILP ensures that a uniform concept is used during design. System modules can be applied to symbolic ILP programs for testing. Applications can be defined in terms of extensions to the, indeed easily extendible, ILP. New language constructs present in ILP are emphasized.

HOW TO DESIGN VARIANTS OF FLATS USING PROGRAMMING LANGUAGE PROLOG BASED ON MATHEMATICAL LOGIC by Zsuzsanna Markusz, HUNGARY - pp. 885-889.

"This paper describes an approach to the solution of an architectural problem: the planning by computer of the floor plans for flats built by the system of big panels. The program designs all the possible variants of the floor plans of a flat with given data within the framework of the big panel system. The paper also shows how well the modern problem-solving techniques developed in the course of research in artificial intelligence can be used to solve technical problems by computer."

AUTOMATION OF ELECTRONIC AND MICROELECTRONIC DESIGN by M. A. Gavrilov, RUSSIA - pp. 757-775.

"The paper is concerned with automation of electronic and microelectronic design with the structure of a computer-aided design system as an illustration. The basic design stages are described. Problems of designing the so-called "integrated" control systems are formulated. The properties of models of electronic devices are described, in particular, a finite automaton, a model used in design of discrete devices and algorithmical structures, and a model used in design of analog device. The basic properties of a hierarchy of design languages and the state-of-art in structure optimization methods for electronic units are described."

FOCUSING ON THE INTERNAL MODEL IN CAD AND CAM SYSTEMS by Frank M. Lillehagen, Jørn Øian, and Jan F. Mack, NORWAY - pp. 273-278.

"AUTOKON is an established CAD/CAM system for the design and production of ships and offshore structures. The system, in its numerous versions, is being used in some sixty yards worldwide. The Aker Group, the largest Norwegian ship and offshore contractors and joint developers of the system, has used the system as an information integrator for several projects covering most of the activities from early project to production. The last versions of the system, AUTOKON 76 (all batch) and AUTOKON-MCG (minicomputer graphics), are presented and the development of an entirely new system, INTERACTIVE AUTOKON, is explained. In so doing, emphasis is given to user experiences with the integrated use of the system and how these experiences form the foundation for the ongoing development. Specifications, design and implementation of databases and database-methodology are important aspects of this development."

TRENDS AND DEVELOPMENTS IN COMPUTER-AIDED DESIGN by J. Hatvany, BUDAPEST - pp. 267-271.

"Computer-Aided Design has become an integral part of the industrial scene. The emergence of low-cost programmable calculators, economically viable time-sharing and bureau services offering CAD programs of turnkey, problem-oriented systems, and of fully integrated large-scale CAD facilities has led to rapid proliferation. CAD is now recognized as a discipline that has acquired and developed its own tools based on skills in mathematics, computer graphics, database handling, simulation, optimization, artificial intelligence and other subjects. The areas where most progress is envisaged are the interactions of designer and computer, of the design process and manufacture, of design goals and the market, and of the product and technology with the social and natural environment."

RECOGNITION SYSTEM FOR HANDPRINTED CHARACTERS by Kiyoshi Iwata, Masumi Yoshida, Eiichiro Yamamoto, Takeshi Masui, Yukikazu Kabuyama and Shin-Ichi Shimizu, JAPAN - pp. 35-39.

"A recognition system for handprinted characters is developed by using a new recognition algorithm named 'Reflection Method.' In this method, we make the features of character in the shape of two segments, that is, reflection and particular segments, by only one-dimensional scanning. By means of these two kinds of segments, we can get both global and local features which normalize deformations of handprinting by use of a parameter. Applying this method, we have just realized a high speed OCR. A recognition rate of 99.6% is obtained in the developed hardware for FORTRAN set."