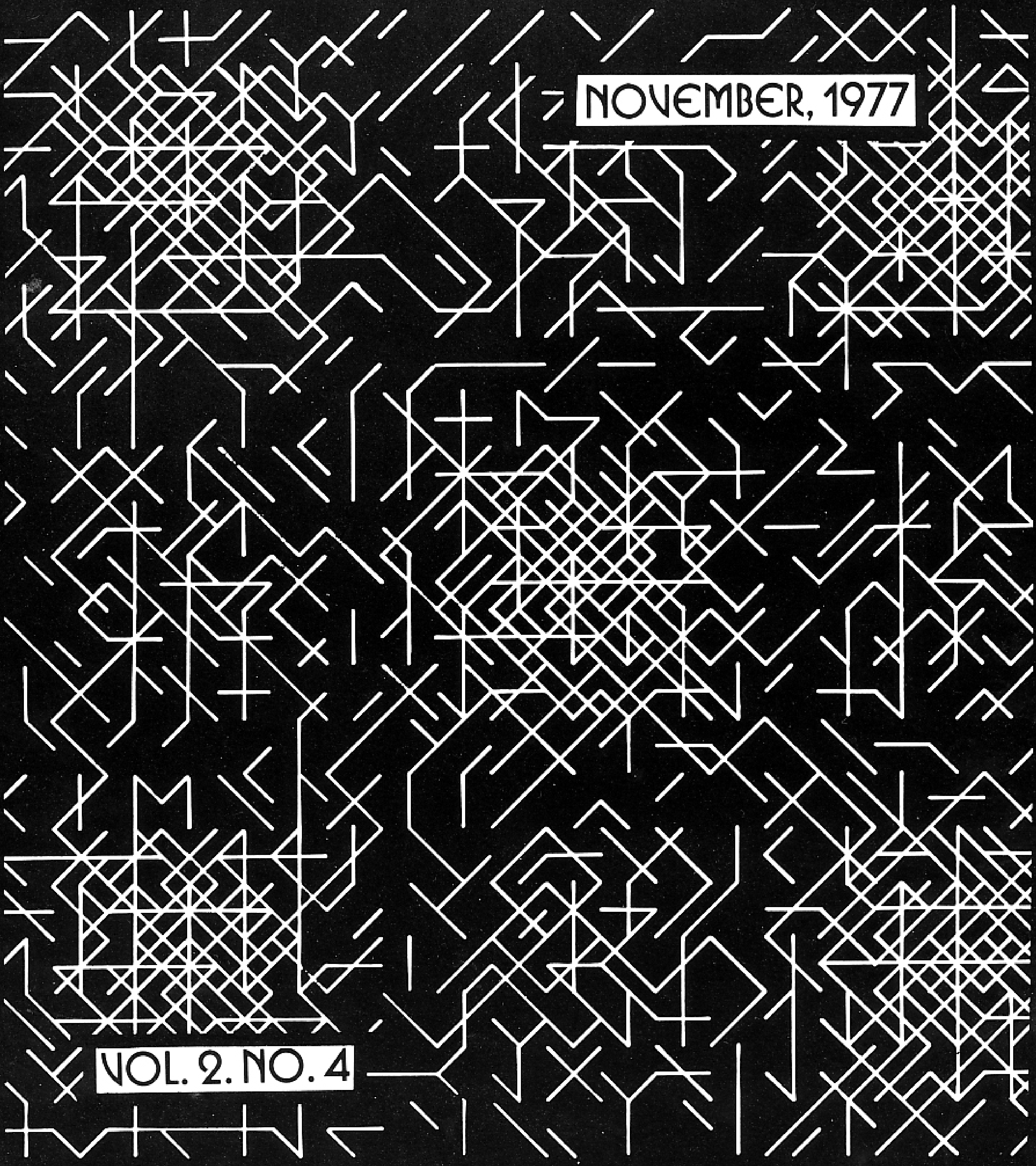
COMPUTER GRAPHICS AND ART



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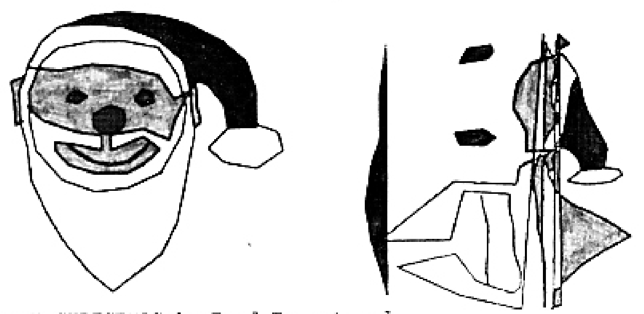

MERRY CHRISTMAS by Tord Tengstrand

EDITORIAL

IN DEFENSE, IN PRAISE OF COMPUTER ART AND GRAPHICS...

This editorial is essentially a reply and a rebuttal to three recent articles:

1. The August, 1977 editorial by Edmund C. Berkeley in the August Art Issue of Computers and People.

2. The September 12, 1977 article by Nancy French, titled "Is This Art?" (Miss French omitted the author's innumerable positive comments about computer art, focusing on less positive statements, which were part of an invitational manuscript.)

3. The August, 1977 article by Edmund C. Berkeley in Computer Graphics and Art.

PURPOSE

This editorial is a respectful disagreement between the writer and the material, the opinions in the above articles. Computer art is in need of defense and praise.

GENERAL REACTIONS

Controversial opinions are invaluable, because they evoke thought within the reader and the participants. They force us to think about what we are doing, and we need to think critically about computer art and graphics.

Can we compare a new art form that is 15 years old with the art of man that is 15,000 years old? Can we compare the work of perhaps 100 serious artists with the wealth of experience of 100,000 artists within the last 15,000 years? Can we compare computer art with the art form of photography that is almost a hundred years old, with at least 25,000 practitioners? The answers are obvious: this is not a fair, humane comparison.

However, the principles of great art, the principles of great photography -- these can and should be found in today's computer art.

Any art form, any discipline, can become myopic, can become infatuated with its own reflected image, like Narcissus. Our critics force us to examine our efforts, our products, and to think anew about our art.

IN DEFENSE OF COMPUTER ART

Here are some brief comments regarding the state of computer art.

1. LIMITATIONS OF SYSTEMS. Few campuses and installations have generous graphics systems. Programming languages for computer art are not highly developed. (Although there are innumerable systems, we need a high-level, transportable, special graphics language.) However, artists are transcending the limits of their narrow systems. They are using curve-fit routines, digitizers, etc. to depart from totally angular forms, from mathematical forms. They are assimilating the mystique of the computer, going beyond the limitations of available hardware and software. In doing so, artists are discovering new techniques, and are producing new art forms.

2. THE ORIGINAL VS. THE ILLUSTRATION. In studying and appreciating great art, we must go to the original works of art, not reproductions. Illustrations in color, in black and white, do not do justice to the original. Further, 95% of the illustrations of computer art are in small black and white form. We need to see art in the "flesh" to fully appreciate its beauty and its meaning.

3. PREJUDICES AGAINST COMPUTER ART. Computer people are naturally more fond of computer art than non-computer people. However, the prejudices against computer art would be alleviated greatly if more computer art exhibitions were available for more people. Perhaps computer art is handicapped with the label "computer". Computer art is art, made by people, with the help of computers. The tool that is used by the artist does not take away from the product. The brush is a tool. Electricity is a tool. The important thing in art is the idea of man, and its expression.

4. COMPUTER ARTISTS AND COMPUTER ART. We have a new group of artists in this field, added to the excellent core group of people who have remained in computer art. Their backgrounds are rich in varied disciplines. Their work reflects this diversity, of art united with science.

IN PRAISE OF COMPUTER ART

1. QUALITY. Many works of computer art are as or more interesting than their counterparts in manual art. Computer art has given contemporary art new insights, new patterns, a new modus operandi. Computer art and art are symbiotic.

2. PRACTITIONERS. All kinds of people are learning to make computer art. This includes the handicapped person, and people who have been afraid to create "art" in the past. Computer art has made art possible for more people.

3. THE STATE OF THE ART. Computer art has come full circle, back to art. Since 1975 it has focused on computer-aided design within diverse art media. Computer art has clearly transcended its early, and at times, limited expressions.

4. THE POTENTIAL OF COMPUTER ART. Computer art is an art form. It is neither superior nor inferior to traditional/contemporary manual art. When regular people can look freely at computer art, without labels, just as art, and make their own "evaluation" of this new art form, we will find that the man on the street will like computer art as much (or more) than many forms of contemporary forms of art. Let's take computer art beyond the conference exhibitions, to the innumerable small museums in this (and other countries), to the college and university campus galleries.

Editor, CG&A

VISUAL FUZZINESS

by Alex Makarovitsch
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75007 Paris, FRANCE

The purpose of this paper is to discuss several aspects of visual fuzziness and its relationship to computer graphics.

For more detailed information the author can make available other papers, written matter and graphic works.

Definitions and general discussion

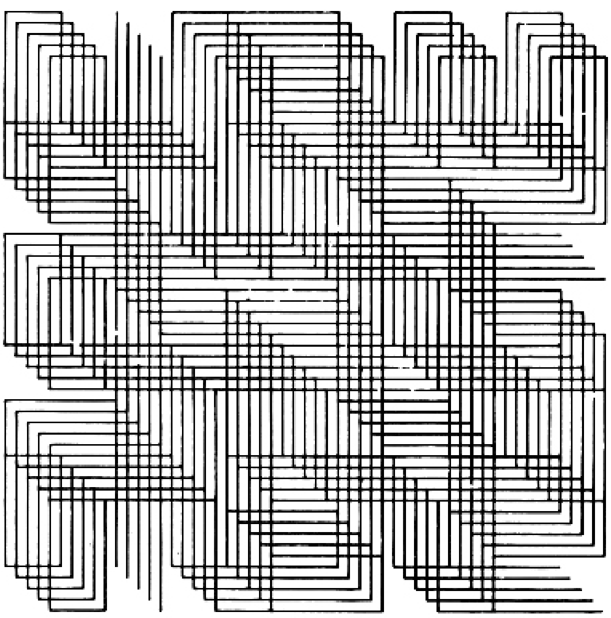
Visual fuzziness is always associated with a concrete or virtual "graphic being". The virtual graphic being can be expressed as a set with a finite number of elements each of them having a precise position. The concrete graphic being is the final result of a series of operations performed (using a support and appropriate tools) on the virtual graphic being ; in short it is the drawing or the piece of art.

Visual fuzziness exists through a fuzzy graphic being. The fuzzy graphic being (FGB) always has associated with it a reference graphic being (RGB), which is not fuzzy and on which operations such as :

keeping elements invisible
or
displacing elements
or
a combination of both

can be done to transform it.*
The results of these transformations are always fuzzy graphic beings.

BELOW: Untitled graphic by the author, A. Makarovitsch



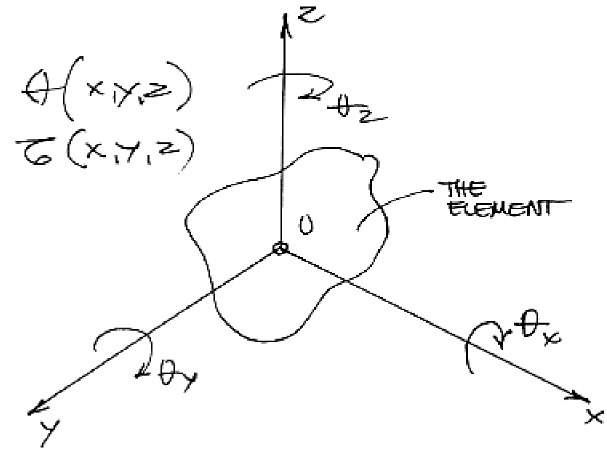
If we associate to the RGB set a function "ϑ" called "visibility function" and this function takes values in the $[0, 1]$ interval, this association will generate FGB's - one for each value of the visibility function.

In these new generated sets we have also to know which elements are visible and which are invisible, in short to know the distribution of visible and invisible elements. This distribution could be obtained by using : a law defined by the artist ; a random ; a complete predefinition.

To know if and how many elements are displaced in a FGB (compared with the RGB) a displacement function "δ" is defined. It also takes its values in the $[0, 1]$ interval. As far as the distribution is concerned the three solutions discussed before are possible as well in this case.

Another series of questions arises when discussing the displacement. Three types of displacements have to be considered : rotation, translation and a combination of both.

Rotation has to be done around the center of gravity of the element (origin of the coordinate system) ; translation will also be considered based on the same reference system.



$\vartheta = 0$ no rotation of the element
$\tau = 0$ no translation of the element
$\vartheta \neq 0 ; \tau \neq 0$ roto-translation of the element

Both ϑ and τ are important parameters of the FGB and give to it an important part of its personality.

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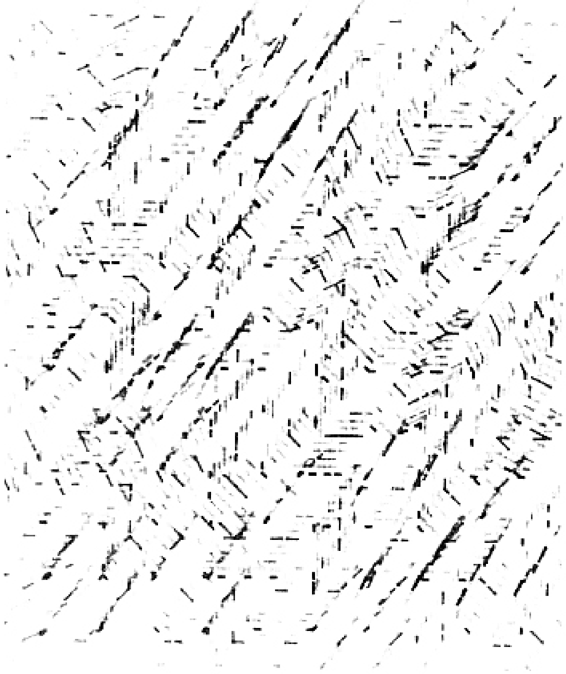
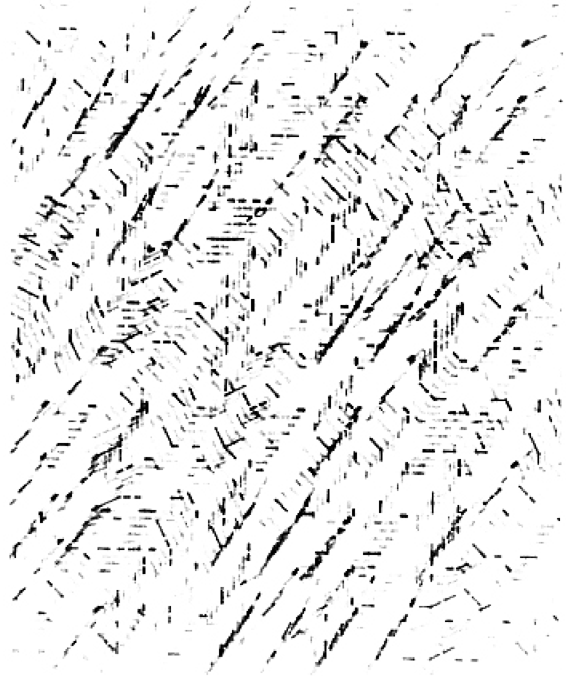
* One of the operators was discussed in detail in the Feb. 76 issue of CG & A - Vol. 1 N° 1





ABOVE: Black and white photograph of a colored panel by A. Makarovitsch. Output from the fuzzy graphic system described in this article bears a marked resemblance to contemporary manual fine art. As such it is particularly suited to large canvases and for textile applications.

To summarize, the following table indicates the different types of FGB's obtained by combining the discussed functions and parameters.

$\nabla = 0$	A	A	A	A	A	A	A
$0 < \nabla < 1$	B	D_1	E_1	F_1	D_3	E_3	F_3
$\nabla = 1$	C	D_1	E_2	F_2	D_4	E_4	F_4
	$\tau=0$ $\theta=0$	$\tau\neq0$ $\theta=0$	$\tau=0$ $\theta\neq0$	$\tau\neq0$ $\theta\neq0$	$\tau\neq0$ $\theta=0$	$\tau=0$ $\theta\neq0$	$\tau\neq0$ $\theta\neq0$
	$\delta=0$	$0<\delta<1$			$\delta=1$		

A The FGB is totally invisible

B The FGB is partially invisible and the elements are displaced

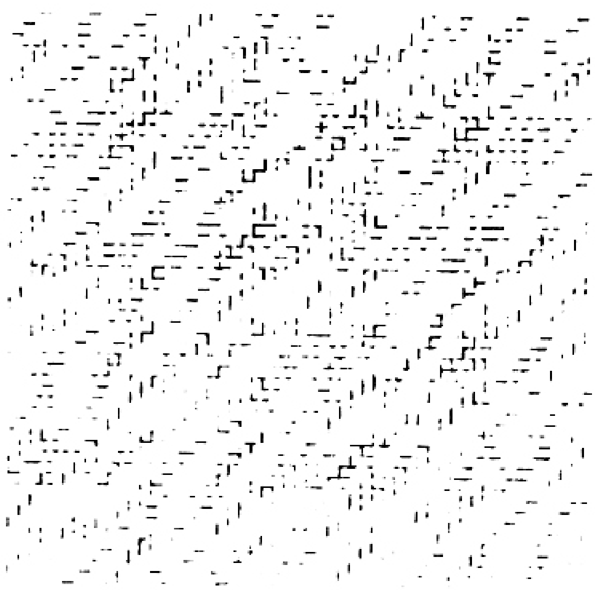
C The RGB (all visible, no displacement)

D FGB's partially or totally visible with part or all elements displaced by translation only

E FGB's partially or totally visible with part or all elements displaced by rotation only

F FGB's partially or totally visible with part or all elements displaced by rotation and translation.

It must be noticed that the functions ∇ and δ are associated with the set, θ and τ being associated with the elements of the set (in the above table it was assumed that $\theta = 0$ and $\tau \neq 0$ or $\theta \neq 0$ and $\tau = 0$ or $\theta \neq 0$ and $\tau \neq 0$ for all elements of the set. This is a particular case ; in the general case θ and τ are independent from element to element).



An example

If the RGB is chosen then a FGB could be determined knowing ∇, δ, θ and τ as well as the distribution.

Let us assume that the RGB is a straight line AB made out of 10 elements. (Fig. 2)

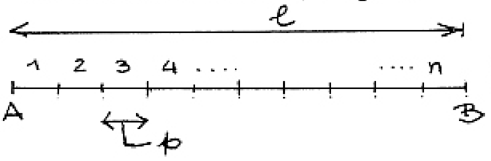


Fig. 2

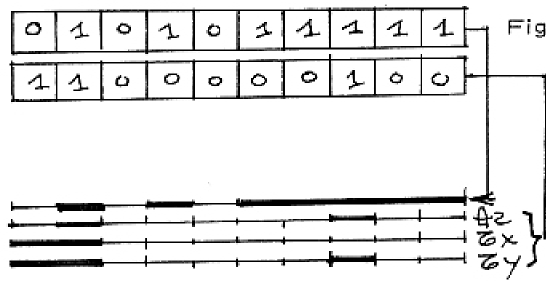


Fig 2a

Fig 2b

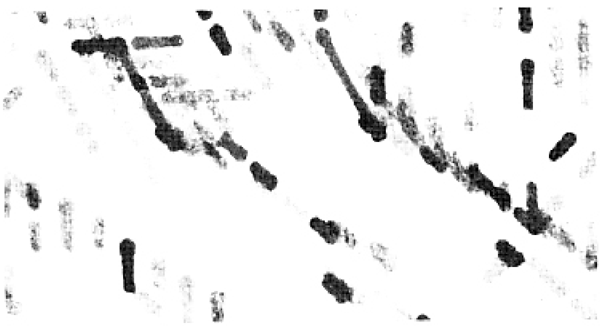
Fig 2c

For $\nabla = 0.7$ with the distribution Fig 2a

For $\delta = 0.3$ with the distribution Fig 2b

For θ_z =	0	$\pi/4$	$\pi/6$
For τ_x =	1	1	0
τ_y =	+2	-2	+1

Values for each element (out of the 10) which show displacement **



ABOVE: Detail of graphic below, magnified.

For $\tau_z = 0$, $\theta_x = 0$ $\theta_y = 0$

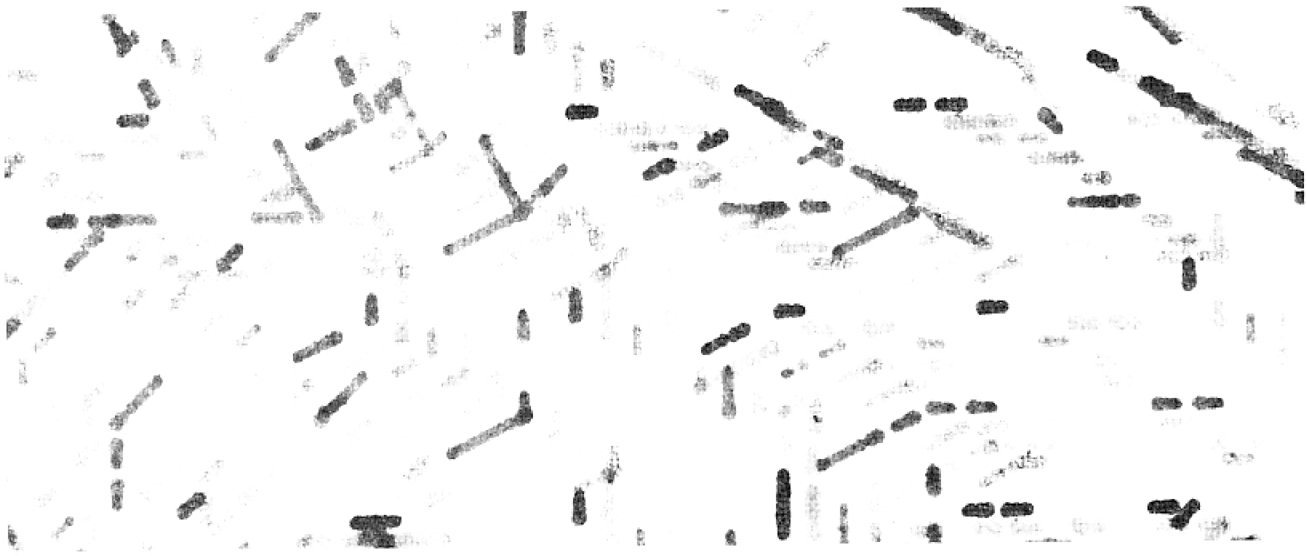
the result is a 2D FGB (Fig 2c)

If one more element is $\neq$ 0 the FGB becomes 3D.

For each 3D FGB there is an associated family of 2D FGB's which are the 3 projections on the reference xy , yz and xz plans. (see Fig 2d, 2c, 2f).

** When translations occur there is an important link between the unit of translation and the element dimension which leads to the definition of fuzziness "band" and "levels", these are treated in a other paper.

BELOW: Enlargement of graphic on page 5.



The position of the artist

The example was taken for the simplicity of the explanation but for any other bi-dimensional or tri-dimensional RGB the same approach remains valid.

This general approach brings to the artist the possibility to manipulate very heavy graphic matter through a limited number of parameters. These parameters have direct physical significance to the artist and therefore isolate him from concern with, and avoid the bias due to, the technical aspects of the tools used (too much concern with technicality has negative influence on the result and produce distorsion).

To produce first the RGB and then FGB's from the RGB, to be able to predict the result, a computer is needed (although the approach was not invented to fill up a computer memory or processor).

The artist has to think as far as the support and the instruments he has at his disposal can embrace his thinking (to paraphrase Michel Angelo). But neither the support nor the instrument will change the subtle essence of art. This means that if the computer is a great tool, it is no more than a great tool and it should be considered and used only as a tool.

BELOW: A "fuzzy" graphic by Alex Makarovitsch. "Fuzziness is achieved by lack of elements." Here the spatial relationship of the patterns becomes significant. Patterns achieved by fuzziness are more subtle than typical early works in computer art, related to contemporary fine art expressions.

A PRAGMATIC APPROACH TO THE COMPUTER ANIMATION PROCESS

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ABSTRACT

Computer animation has evolved from the mathematical simulation of simple physical phenomena, to full color, real-time, emulation of reality. During the technological quantum jumps of recent years, several procedural aspects of conventional animation have been skirted in lieu of expedient computer techniques.

These conventional animation procedures are resurrected in a pragmatic analysis of the computer animation process. A careful decision analysis relating production motive, conceptual content, projected audience, film budget, and animation staff, is encouraged before any computer-based production is undertaken. Graphics techniques are categorized as a malleable factor in the global animation process.

KEY WORDS: Computer animation, Microfilm Recorder

INTRODUCTION

The advent of microfilm graphics in the early sixties gave birth to a new medium of visualization and wonder --the computer animated film. The earliest computer filmmaking depicted scientific phenomena that would have been economically infeasible using conventional animation procedures. Any imagery that could be simulated with mathematical techniques could be put in motion by computer modeling.

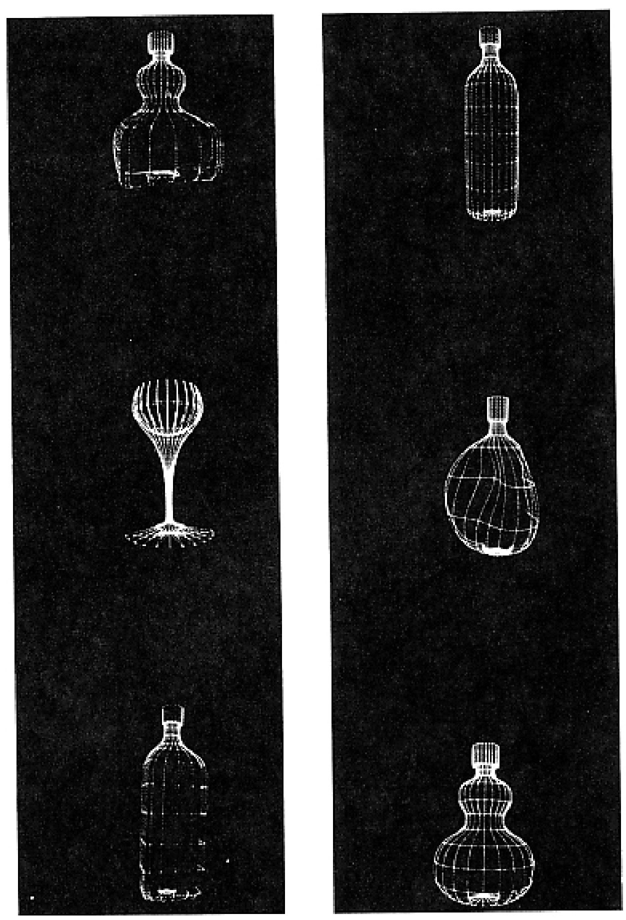
As computer graphics has evolved over the last 15 years, so have digital computer animation techniques become more sophisticated. Real-time graphic capabilities have expanded from simple, rotating wire-frame models to complex, 3-dimensional color half-tones. Hidden-line, surface patch, smoothing, and texture algorithms, coupled with state of the art raster technologies are leading to the total emulation of conventional animation artwork and movement by computer.

As computer graphics technologies have become more powerful and complex, the computer animation process has been dominated by these technologies. Conventional animation, bound by the labors of mechanically generating 24 frames per second, often relies upon an ingenious script, simple repetitive imagery, and exaggerated movements to tell a story. Careful planning goes into each phase of the animation effort to optimize the yield from a minimum of image movements.

Since computer generated motion is so easy to generate, the tendency is to mathematically duplicate a physical motion and apply that exact motion to an image. The result is often mechanical motion with little "life". Exact replication of some phenomena is, indeed, desirable in simulation or educational films, but iterative or random movements of mathematical imagery leaves most computer art films devoid of content and overflowing with effect.

The body of this paper departs from the realm of state of the art emulation techniques in presenting a systematic approach to the computer animation process. Computer graphic wizardry is downplayed in favor of a modular committee approach to the animation process. The computer analyst is discussed as a vital asset to the animation project, yet only as a technician.

BELOW: Wire Cage Bottle Design (FREEform Design Oriented Manufacturing System). Photo courtesy of Japan Society for Promotion of Machine Industry.



METHOD OF PRESENTATION

The animation process is discussed in three sections.

The first section describes an overview analysis of the animation project, establishing project viability as a function of the storyboard concept, projected market, production staff, and budget.

The second section reviews mandatory and desirable computing facilities. The thesis is that meaningful computer generated imagery can be produced with a minimum of computing support.

The final section systematically reviews the interrelated phases of a computer animated film with graphic output to a microfilm recorder.

Each section is discussed relative to a selected set of evaluation criteria. The analysis of the procedural components is general, allowing for a wide range of computing and production capabilities. However, these criteria may be refined to generate a methodology for computer animation, given a specific set of production specifications.

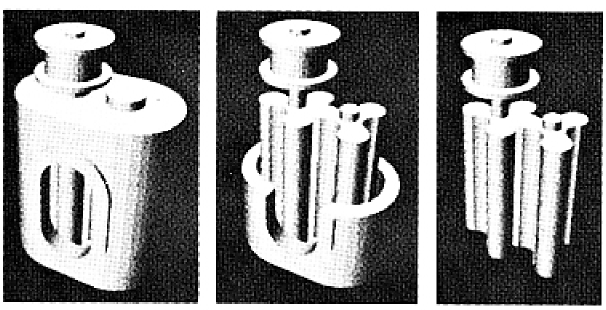
BACKGROUND

The background for much of the ensuing discussion has been derived from the evaluation of computer animation techniques at the Colorado University Computing Center, coupled with a thorough literature review. CUCC has a low resolution microfilm recorder and several storage tube terminals interfaced to a CDC 6400. A library of FORTRAN-callable animation software has been building since 1973.

Three years of painstaking trial and error development have emphasized the need for an overview analysis of a proposed animation project before commencing any production or programming efforts. Murphy's law has, indeed, held true: if anything could go wrong, it has.

OVERVIEW ANALYSIS OF A PROPOSED ANIMATION PROJECT

Before any production effort can commence, several general characteristics of computer animation should be understood. The areas of conceptual motive, projected audience, budget, and production staff should be pragmatically analyzed to confirm or deny the viability of the film before any "blood is spilled", and the project begun.



ABOVE: Solid-appearing animated graphics depart from the earlier wire cage forms. From Syntha-Vision, a look inside machinery to see how it works – without taking the machine out of production or dismantling it.

MOTIVE

The most important overall step in producing an animated film is to clearly define the reason the film is being made. Several potential motives are:

1. Profit – To make money from the production and/or distribution of the film, regardless of the topic;
2. Simulation – To model an abstract or physical phenomenon;
3. Education – To teach a concept, possibly coupled with simulation;
4. Advertising – To market a particular product/service/concept;
5. Entertainment – To evoke some form of emotion;
6. Experiment – To research and expand the capabilities of the medium without any other explicit motive.

Motive is interrelated with Concept, Audience, and Costs (discussed below) in the development of a cost/benefit analysis for the proposed animation. In a professional animation environment, this analysis may be strictly quantitative with balance sheet arithmetic governing most production decisions. Non-professional (or more precisely, non-profit) animators, who are their own clients, must qualitatively rationalize their film-making motives. The remaining areas of evaluation are structured primarily toward this class of animators.

CONCEPT

The above motives are applied to a specific topic discussed or caricatured in the actual animation. The concept is the essential message to be borne out in the film, such as:

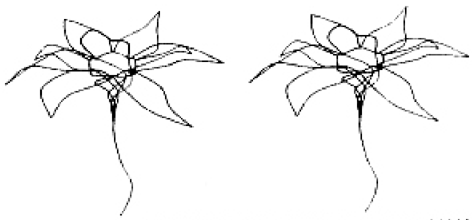
- How something works;
- Why you should buy a product;
- Analysis of an issue (air pollution, population explosion, etc.).

The conceptualizer ("idea person") will have fundamental definitions for the film's structure, flow, and mood. Will it be precise and structured or extemporaneous and funky? With some general framework in mind, the classes of animation imagery may be developed and sketched.

It is at this conceptual stage that decisions on the use of computer techniques must be made. Is the subject matter amenable to the available graphics techniques? In general, why are computer graphics techniques desirable for making the film?

With simulation and education, the computational and iterative capabilities of computing machines make them the only practical tools for animating mathematically-defined topics, even with relatively simple computing facilities. Advanced graphics hardware (frame buffer technology) and software techniques (special animation systems) have opened up an incredible potential for computer generated imagery. Virtually all forms of imagery can be created and, in some sense, brought to life.

BELOW: A real-time 3-D data generation technique, by Charles Csuri. As the user selects basic points for a flower with a 3-D sonic pen, the computer displays stereo pairs. An "off-line" program generates a type of cubic spline through these points to complete the flower.



The question posed here and developed in the following sections is how much stylization can the topic take and still retain its message.

AUDIENCE

At the conceptual stages of an animated film, the initiator(s) must determine the film's potential audience. For involved simulations, the audience may be only a handful of specialized scientists or theoreticians. Research or demonstration films are often more concerned with the technique, and hence, the potential of the medium will appeal to a wider audience (usually fellow researchers or animators).

In the latter, it is not the size of the audience, but the impact upon them that governs the worth of the film. This impact is more difficult to measure in computer entertainment films based upon iterative and/or random patterns of mathematical imagery. Rather than evoking tears, laughter, anger, or thought, a common response is "That's really neat! I wonder how they did that?" There is often more interest in the film mechanics than any intended message.

The film-maker(s) needs to meld motive and concept, to determine an interested audience. This audience may be theoreticians, computer people, colleagues, select clients, adults, children, "the masses", or just a few friends. The point here is to define a market for the film before production rather than after.

COSTS AND BUDGET

Funding an animation effort is a stark reality that can rarely be overlooked. In certain financially endowed environments (primarily research), purse strings may be rather loose, and budgetary concerns are either never a factor, or they are resolved, *ad hoc*, during production. In most settings, however, some budgetary scope is defined prior to production and adhered to during production. This scope may range from thousands of dollars down to dollars (the latter is especially true if mortgage payments are waived in lieu of production costs).

Costs may be categorized into several interrelated areas and stages of the production effort:

1. Salaries - This area is most critical when the actual production is the source of one's livelihood. Often, film-makers will settle for satisfaction, prestige, or royalties, instead of bread on the table.

2. Computing - This is a critical factor for film-makers who "buy time" on commercial hardware. Computing costs are less critical on wholly-owned stand-alone systems, or where the computing usage is via "soft-money".

3. Computer Graphics - Costs must be recognized for both test images and production microfilm shooting. Costs are normally broken down to a per-frame figure that is a function of microfilm recorder access (e.g., 1) recorder on site; film cost reflected in computer costs--both covered by soft money; and (2) tape processed on a commercial film recorder; hard-money cost reflected in image complexity and number of frames).

4. Laboratory - This includes optical printing, color separation, sound dubbing, etc. Computer research environments often have their own printing facilities under computer control. Commercial printing can involve significant expenses, particularly with multiple color separations and elaborate timing sheets. Sound costs must also be defined (musicians, studio, dubbing, copyright fees).

5. Marketing - This is primarily a function of the audience and the topic. Marketing is not a factor for specialized topics or in-house films. Distribution rights may be sold to agencies.

PERSONNEL

Several interrelated, yet technically diverse functions contribute to the production of an animated film. A broad categorization of the staff needed for an animated production is:

1. Conceptualizer - The "idea man" who conceives and outlines the film topic and develops the basic storyboard.

2. Creative Director - The individual(s) who "breathe" life into the storyboard and oversee all phases of production.

3. Computer Simulator - The person who translates the storboard panels into a modular mathematical model that may be processed using computer techniques.

4. Computer Programmer(s) - The programmers work from the simulation flow chart, utilizing computer techniques (usually programming) to define and animate the imagery.

5. Film Producer(s) - The producer is in charge of laboratory activities, including timing sheets, optical printing, color and sound.

6. Business - The business manager monitors all costs relative to the film budget and handles film distribution.

In most animation efforts, a single person will have multiple responsibilities. It is a rare individual who can perform all these roles and come up with a worthy animation.

The creative director probably has the most responsibility for the film's worth. Unfortunately, this role is often underplayed in computer films. In providing continuity and vibrancy to the film, it is best if this individual is not immersed in the technical matters of computing and film production. Though not involved with technical details, the creative director should be knowledgeable in the potential and shortcomings of computer graphics and in optical techniques.

An ideal staff consists of the creative director, computer person, laboratory person (producer), and an accountant, creating an integrated system of checks and balances during production.

INTERIM ANALYSIS

Five areas interrelate critical, non-technical factors that should be acknowledged and resolved before actual production begins. These five areas are: Motive, Concept, Audience, Costs, and Personnel. While the criteria composing these areas is essentially non-technical, each area assumes a requisite set of overlapping computing capabilities, discussed in the following sections as Hardware, Computer Graphics, and Software.

II. COMPUTING CAPABILITIES

HARDWARE

Several computer configurations are viable for generating computer animation. It is impractical to define a general animation system configuration because of the variance in imagery associated with the different computer animation techniques.

Perhaps the most critical component of the hardware configuration is a magnetic tape drive. The code to drive the microfilm recorder is writen to a tape. The microfilm recorder has its own processor and tape drive for generating the film off-line from the central computing configuration. The point here is that the computing installation where the animation code is generated need have no graphics hardware. The microfilm code can be generated at a central site, with the actual film generated at another computing installation.

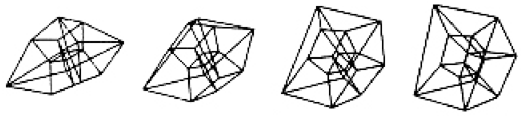
COMPUTER GRAPHICS DEVICES

The only mandatory graphics display is the final graphic output device. Animation has been produced from every form of graphic output device including storage tube terminals, refreshed displays, and raster displays. Even printer/plotter output may be registered and shot using conventional animation techniques.

This discussion deals with the microfilm recorder as the final output medium. Several recorder and camera characteristics should be detailed.

The recorder, itself, consists of a high resolution cathode ray tube approximately three inches in diameter. Actual resolution among different recorders varies from 1024 raster units in both X and Y to 16,384 units in each dimension. The finest recorders allow up to 64 line intensities and line widths.

BELOW: Illustrations by A. Michael Noll - The four-dimensional analogue of the cube is called a four-dimensional hypercube. A computer-generated movie of a rotating hypercube was made.



Cameras - A number of cameras may be interfaced to the recorder. For animation it is imperative that a pin register camera (either 35mm or 16mm) be used to insure exact image registration on each frame. The image may be obtained as a positive (black lines on a clear background) or a reversal (clear lines on black). The film emulsion governs the image resolution and density of the film. Extensive discussion of recorder and camera characteristics is given in Reference /1/.

While the microfilm recorder is the only mandatory graphics device, it is desirable to have some means of previewing imagery. Although interactive display devices provide maximum viewing flexibility, any type of vector plotting device is desirable. Even the line printer can provide crude approximations when no other devices are available.

SOFTWARE

The minimum set of software for computer animation to microfilm recorders is a set of FORTRAN-callable subroutines for generating code to drive the recorder. Most microfilm recorder vendors provide emulator packages that allow the code for their competitor's equipment to be processed on their device. Hence a single driver package will normally generate imagery on any microfilm recorder.

For vector imagery, it is desirable to have a higher level package of routines that simplify the definition and manipulation of imagery. Such a package should provide some degree of graphics device independence, so that the same routines can interface to both the microfilm recorder and preview device drivers.

Several characteristics of such a higher-level package are given below:

1. A data structure facility for maintaining and updating the imagery;
2. Linear transformations (panning, rotating, zooming);
3. Compound transformations;
4. Simple definition and manipulation of a focal point and virtual camera position;
5. Motion of composition components along a non-linear path;
6. Non-linear camera motion;
7. Automatic clipping and windowing in 2- and 3-dimensions.

By no means do these capabilities define a general animation software system. However, these facilities provide an expandable base for a wide range of simulations involving vector imagery.

Several specific animation software systems have been designed with final output to a microfilm recorder. Such systems /2,3,4/ are highly integrated and relieve the animator/user from the messy job of writing animation programs in a higher level language. The "ANTICS" system, developed and implemented by Alan Kitching at the Atlas Computer Labs in Great Britain /8,9/ has a wealth of animation capabilities with relatively simplistic image definiton and manipulation directives. Further, the system is written in FORTRAN, giving it a fighting chance of portability among computing installations.

Several other animation systems have proven very effective for certain classes of imagery on stand-alone computing systems/6,12/. As with ANTICS, they require no animation programming and are practical for use by artists and conventional animators. Unfortunately, general portability of such systems is sadly lacking, because of their dependence on special function graphics hardware and assembly language code.

Because of the diversity of both computer animation approaches and graphics hardware, it seems unlikely that an animation standard can or ever will be adopted.

INTERIM ANALYSIS

The foregoing criteria provide a skeletal outline of the necessary hardware, graphics, and software for generating animation imagery to a mifrofilm recorder. Each computing configuration will have a range of image generation capabilities delimited by these criteria.

It is the responsibility of the animation staff to define the true cost of producing the full range of computer effects on the available facilities. It is most critical to establish a point of diminishing returns within this range. Beyond this point, the imagery may be feasible to generate, but the cost of generation prohibits economic microfilm production. Examples are the computer cost of hidden surface removal and halftone shading.

Since the computing facilities can be well-defined, they are used as input to all the evaluation stages of a computer animated film. The previous discussion on the overall feasibility of the film relies heavily upon the available computing power.

In the next section computer graphics capabilities will be shown to implicitly govern the early stages of the actual film production.

III. PRODUCTION

With a viable concept, sufficient staff and budget, and an accessible computing system, the actual animation production can begin. As with the overview analysis and the assessment of available computing facilities, the production phase of a computer animated film can be categorized into several interrelated stages.

The following sections analyze each stage of production, reviewing the critical components of each, and identifying potential problem areas.

DELINEATION OF THE CONCEPT

After global confirmation of motive, audience, and topic, the specific theme of the film needs to be carefully clarified. The types of imagery (e.g., mathematical, stylized characters, sampled data, free-hand drawings, 3-dimensional) along with types of motion (e.g., linear, compound, faired, key-frame) should be identified. Also, any required or desirable image enhancement or special animation techniques (e.g., polygonal shading, multiple color/intensities, fades, dissolves, etc.) should be noted.

At this stage, the creative director and the computer analyst must identify any imagery, motion, or effects that are impossible, or more importantly, impractical with the available computing facilities. Unfortunately, computer analysts are prone to overstatement when describing the capabilities of their particular computing system. While, indeed, certain effects <u>can</u> be achieved, the time and/or computing expense is absurdly disproportinate to the gain from the effect. More often than not, the "special effect" is over-stylized and lacks the required impact.

A compromise attitude by both designer and programmer will often yield substitute imagery or effects that are far easier to program and oftentimes, are more appealing. Always be wary of the programmer who reviews a detailed script, then looks you squarely in the eye and says, "No problem."

THE STORYBOARD

An animation storyboard is analgous to the script of a play. The storyboard modularizes the concept into several interrelated scenes. Each scene describes a unit of time or action in the film.

The storyboard may be developed in stages -- the first pass describing only global motions and timing with each successive iteration adding more detail and refinement.

Typically, the final storyboard should have precise timings, details on both the type of motion and any special effects, and a description of the linkage between successive scenes. Multiple colors, hold frames, and cycles of motion must also be carefully defined.

Developing the final storyboard is truly a committee effort, requiring the inputs of the creative director, programmer, and producer. The storyboard is further complicated when live footage or conventional animation is to be merged with the computer animation. If the sound track is to be synchronized with the action, the track is normally produced first and explicit timings for the animation are derived from the sound.

While the final storyboard is detailed, it is not inflexible. Unanticipated problems in programming may necessitate major revisions in a motion sequence or the transition between scenes. However, it should again be stressed that the definition of all imagery and effects should be established as viable before any computer simulation is begun.

COMPUTER SIMULATION

The storyboard is normally defined as a sequence of sketches defined by terse prose under each modular scene. The prose gives a succinct, English description of both the action within the scene and the transition between scenes. Typical commentary might be:

- segment wipes on from top;
- dots move to center;
- side vibrates like taut string;
- base jumps gently then slowly settles.

The computer simulation phase of production translates the action verbs into definitive, mathematical motions that may be programmed.

Before dealing with the motion sequences, an explicitly dimensioned environment(s) is defined. All imagery to appear throughout the film is then defined or simulated in the units of this 2- or 3-dimensional mathematical setting. Ideally, a catalog of component images is developed along with the transformational and motion requirements of each image.

Each panel of the storyboard may be processed as a short modular segment. Common action sequences, occurring in two or more storyboard panels, should be identified. Any effect or motion that will be applied to different images should be noted.

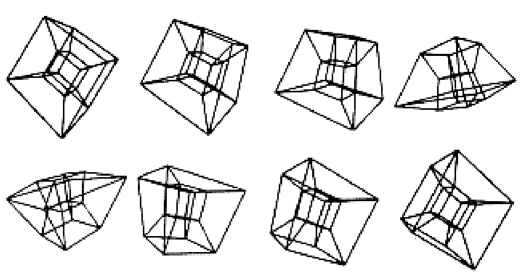
Establishing modularity among the storyboard scenes is vital to minimizing the computer programming, especially when the programmer must work directly with lower level graphics software systems.

A staged computer simulation should yield a simple, almost mechanical, program design that will maximize the iterative capabilities of the computer, while economically optimizing the trade-off of computer time versus human time.

PROGRAMMING

As stated above, with a modular storyboard, mathematical environment, and staged programming design, the actual programming of the images and effects should be straightforward. This is not to say that the programming is trivial.

Depending upon the sophistication of the graphics software package(s) and the facilities of the host computer configuration, the programmer may still have to rely on clever coding to obtain desired effects. The point is that a careful, modular design will minimize programming hassles.



ABOVE: Rotating hypercube by A. Michael Noll.

The available software packages will dictate the best approach to programming. The following suggestions assume the worst case -- that is, the animation must be simulated in a higher level computer language (FORTRAN), relying on only a basic set of graphics routines.

PROGRAMMING SUGGESTIONS

1. Develop, verify, and store a "data base" of the imagery (maintained on disk, or at worst, cards).

2. Define and program a set of utility routines for image manipulation, transformational mapping, viewing the mathematical environment; special effects, etc. Many of these types of routines are contained in higher-level graphics software systems.

3. Modularize the simulation design as much as possible. Many short, simple routines are better than a few large, complex programs, especially during debugging.

4. Build visual debugging hooks into the code. This is vital for previewing imagery when it is desirable to review, say, every 24th frame. This also implies approximation techniques for defining complex images (a variable number of segments in a circle or variable spacing between shading lines). Color separations will probably be coded separately. Some facility should be planned for previewing multiple color separations on the same frame.

PREVIEWING TECHNIQUES

Here again, the programmer/simulator must interface with the creative director and producer in verifying image definition, motion specification, and alignment of the image on the frame.

Each image component must be analyzed for precision, realism, and/or "effect". Initial imagery requirements (shading densities) may be relaxed or tightened as a function of previewing. Entire scenes should be assembled from their modular components and/or color separations and previewed.

Software sophistication, available graphics hardware and film budget will govern the extent of practical previewing capabilities. Ideally, an abbreviated preview film or "pencil test" is generated to review effects and analyze timings. This test may be a stylized version of the final film with:

1. Some fraction of the final number of frames (e.g., $\frac{1}{4}$);

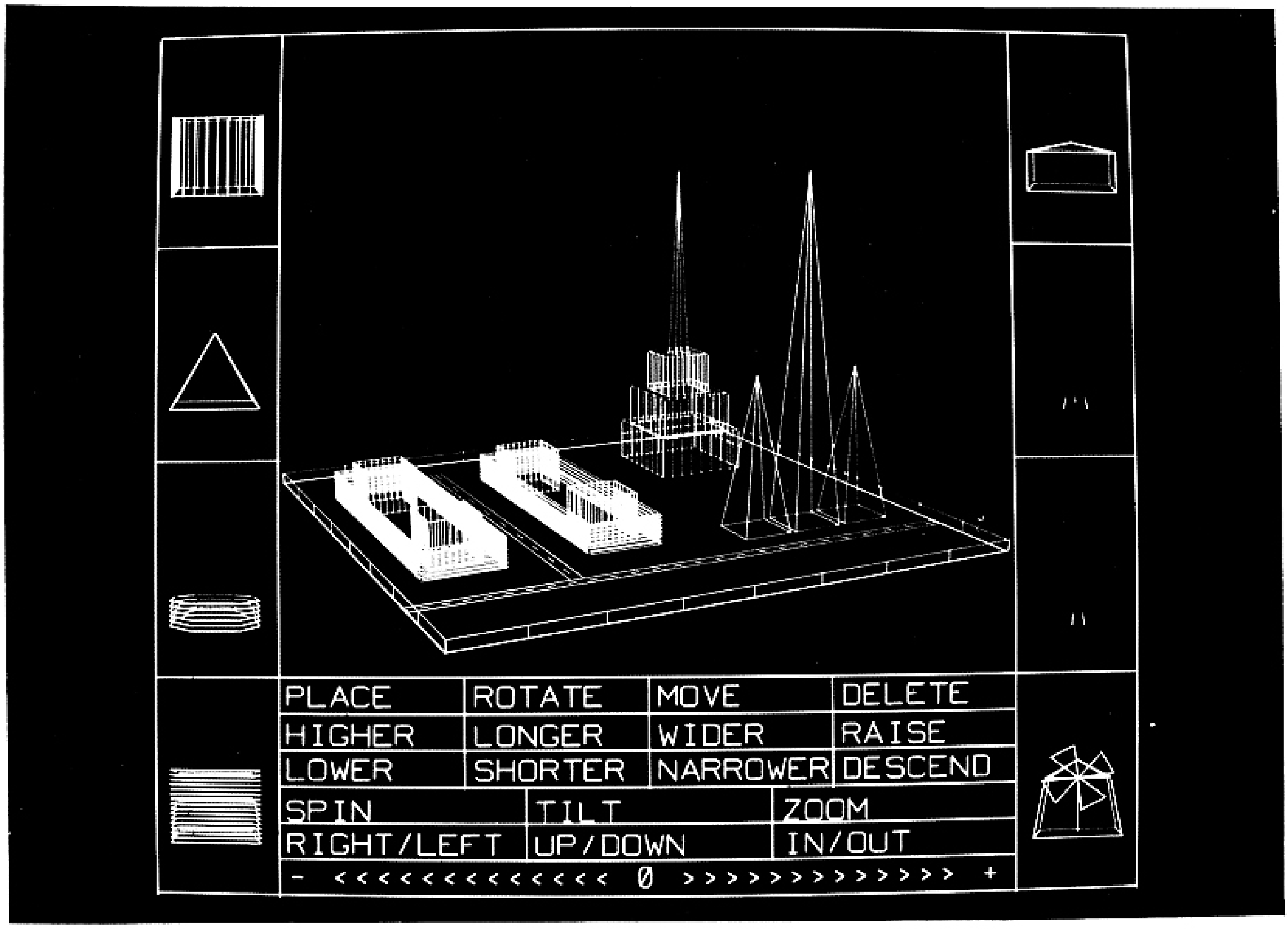
2. All colors are superimposed;

3. No hold frames;

4. No shading;

5. No hidden-line processing.

BELOW: Illustration by Evans and Sutherland, Architectural Design - THE PICTURE SYSTEM. Demonstration of the versatility of THE PICTURE SYSTEM for applications in architecture, city planning and urban design. The system allows complete flexibility for object selection, modification and motion.



Often, a pencil test is worth generating if the production staff has access to variable speed 35mm projection equipment. Moviola Corporation makes 35mm table model editors, with variable speed, forward-reverse drives for under $2000, that are ideal for this type of previewing. Hand-cranked viewers are much less expensive, but are difficult to obtain.

If the budget vetoes any test footage, several iterations of analysis, revision and re-programming may be required before proceeding with the actual film generation.

PREPARATION AND GENERATION OF THE MICROFILM

When all aspects of the computer model have been verified, the complete 35mm microfilm version can be generated. Before running the program(s) to generate the film, the programmer should again meet with the creative director and producer to confirm a set of procedures related to the eventual conversion of the 35mm to 16mm motion picture film.

The first criterion to be established is the size and alignment of the color separations on the 35mm frame. The programmer must define a mapping from the units of the dimensional environment (inches, meters, et al) to the raster dimensions of the film recorder CRT. Conventionally, the aspect ratio of cinematic footage is 4:3 (width:height).

Figure 1 shows a field guide. The field guide is a series of concentric rectangles used by animators to define the dimensions of an image as it will appear when projected. The outermost rectangle corresponds to the maximum dimension. In optical printing, the 16mm camera is aligned to this outermost rectangle, called the 12-field. The successively smaller concentric rectangles represent the maximum viewable area after successive image transfers along visual media. Each image transfer to a different medium will further shrink the viewable area. (See page 15.)

For example, conversion from 35mm to 16mm followed by conversion from 16mm to video tape will successively crop the animated imagery, so that only part of the image within the 9-field will be visible on a TV monitor. The programmer should, therefore, clip imagery at the 12-field, remembering that only portion of the picture within the 9-field will eventually be visible.

Two alternatives are available for generating color separations onto the recorder. On low resolution CRT's each separation must be generated on a separate frame. As a result, for a three color film (three different colors in motion in one time) three microfilm frames may be necessary for each final frame of 16mm. On high resolution film recorders (e.g., the FR80), up to four separations may be included on the same frame of 35mm film. Each separation is generated in a quadrant of the frame and is, therefore, one-fourth the size of the normal 35mm frame. Besides the need for a high resolution CRT, this approach demands micrometer control in the optical printer to make sure each separation is exactly registered.

When only a single image is to be generated on a frame, the encompassing field guide should be exactly centered, both vertically and horizontally, between the perforations on the film. Care must be taken so that the 12-field does not extend completely to the perforations, thereby allowing light from the perforations to bleed through during the printing process and taint the 16mm image.

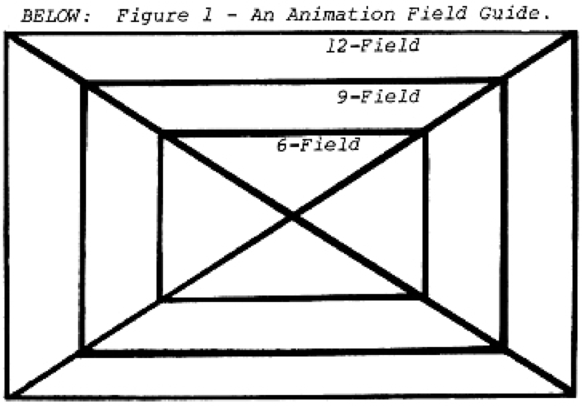
It is the joint responsibility of the programmer and producer to correlate the raster dimensions of the recorder CRT with the actual photographed image on the 35mm film. If the film recorder is in-house, this may be accomplished by a series of field guide alignment tests followed by mechanical adjustment of the microfilm camera. When sending film to an off-site film recorder, it may be possible to demand camera adjustment for a single animation run. Animators must rely on the recorder/camera mapping specifications listed by the microfilm recorder vendor, and the maintenance policies at the recorder site.

As partially mechanical devices, film recorder systems are prone to Murphy's Law. The most error-prone hardware is the 35mm camera. Besides the frame centering problem mentioned above, two other potential problems are worthy of note.

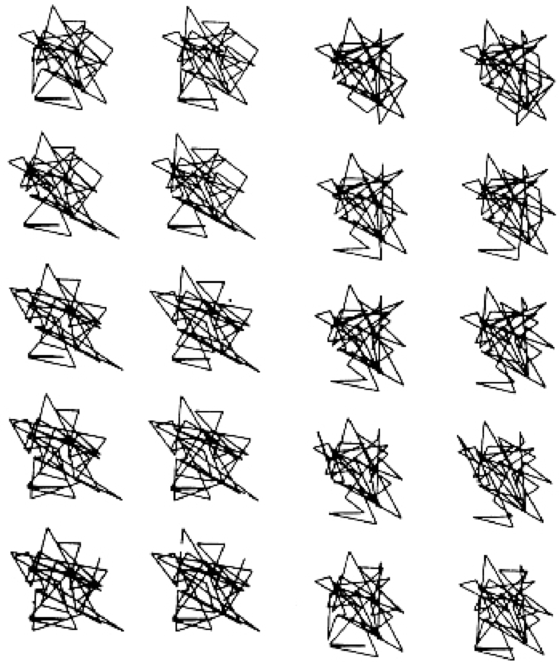
It is possible for the camera to become misaligned so that the field guide is tilted on the 35mm frame. A fraction of a degree tilt will be noticeable when projected on a large screen.

Perhaps the most aggravating problem is image alignment between successive 35mm frames. The animator assumes that all images on all frames are exactly registered with respect to the perforations. With high quality pin register cameras this should, indeed, be the case. However, since absolute alignment is normally crucial only for animation, this aspect of camera adjustment may be overlooked during routine recorder maintenance for long periods of camera use.

BELOW: Figure 1 - An Animation Field Guide.



BELOW: Illustrations by A. Michael Noll - The computer was programmed to produce a series of 3-D pictures -- a computer-generated 3-D movie. The procedure is to specify mathematically the 3-D coordinates of the points in a line representation of the desired object. The resultant procedure is somewhat similar to the conventional animation process.

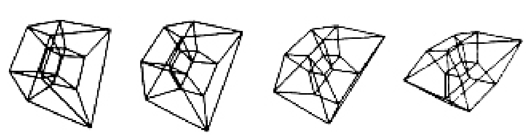


The result is that camera parts will wear, introducing slop into the film feed mechanicms. This slop, which may be only 4 or 5 vertical raster positions on the actual 35mm image, will cause the image to noticeably vibrate up and down when projected on a large screen. The tendency may be to attribute this vibration to the register mechanism of the 16mm projector. However, the microfilm camera is confirmed as the problem when held back ground imagery remains steady as the moving foreground randomly oscillates.

If the animator must rely on the facilities of a computing installation, he should establish a good rapport with the recorder maintenance personnel and always shoot and review test footage before generating a lengthy movie.

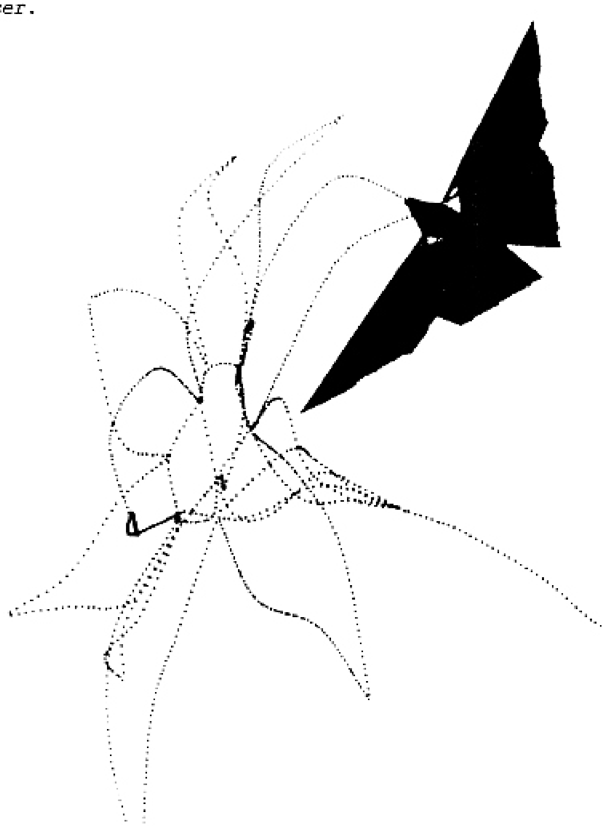
Because of these camera problems, it is best to shoot all microfilm in a single run. This minimizes the chance of human error or equipment misalignment when loading and unloading the camera between successive animation runs.

This does not imply that the microfilm recorder code must be generated in a single job step. The programmer is still encouraged to output the final imagery in a modular fashion, appending each completed scene/color to a composite animation tape.



ABOVE: Rotating hypercubes by A. Michael Noll.

BELOW: Illustrations of animation by Charles Csuri. Here the butterfly moves in real-time tangentially along any 3-D path (in this case, a 3-D flower) with z-axis motion simulated by proportional reduction in size of the butterfly as it moves "away" from the user.



Scene Identification

Depending on the availability and operation of the optical printing facilities, some form of scene identification may be desirable on the microfilm before each scene. A recommended approach is to generate a few blank frames, a terse message with a production number, scene number, and color, followed by a full field guide superimposed with the first or last frame of the scene. The field guide provides a means of registration if the film is ever torn or spliced. The message provides unambiguous scene identification.

Subsequent frames, making up the scene, may be sequentially numbered outside the 12-field. This frame number then will be outside the region transferred to 16mm film, but will simplify reference to a single frame within a scene.

Often in commercial labs, the optical printing process is completely numeric. The 16mm printer camera is registered on a single field guide, and the film imagery is never again checked. For peace of mind, if nothing else, the addition of field guides, scene descriptions, and frame numbers is worthwhile.

FINAL PRODUCTION CONSIDERATIONS

If proper care is taken in the programming and generation of the 35mm microfilm, the printing process should be relatively mechanical. Indeed, some optical printers are entirely controlled by microprocessors.

The critical phase prior to the actual printing is to define the mapping from the 35mm microfilm image to 16mm motion picture film. This involves the preparation of an exposure sheet which identifies, normally by frame number, the one-to-one or one-to-many mapping of 35mm microfilm frames to 16mm motion picture frames.

At this stage of the production few decisions need be made on the exposure sheet. All mapping ratios and timing decisions should be made during the computer simulation stage. Several factors are:

1. The Mapping Ratio: 35mm to 16mm

   In most conventional animation settings, 2 or 3 frames of 16mm film are shot of each artwork frame. Work with 35mm Computer Output Microfilm (COM) is analgous. If the motion is slow, up to 4 frames of 16mm film for each microfilm frame (e.g., only 6 microfilm frames/second) will adequately simulate motion to a human viewer. Faster motion will appear jerky unless this ratio drops. Very fast motion may necessitate a ratio less than one (i.e., superimposing more than one microfilm frame on a single frame of 16mm) to simulate blurred motion. Very fast motion is difficult to animate using either conventional or computer techniques. A strobing effect occurs when the animation camera instantaneously freezes the motion on a single frame, providing no continuity between successive frames.

   To emulate the human eye, the camera should show 1/24 second of motion on each frame. Fast moving objects (e.g., a race car) will move a finite distance even in such a short time, creating a blurred image. At 24 frames a second the human eye melds these blurred images into acceptable motion sequences.

2. Backgrounds and Hold Frames

   If an image is to remain stationary for a series of frames (a background graph or a title), only a single microfilm frame need be generated.

3. Cycles

   A single action sequence may be duplicated in different scenes (e.g., a moving background or a rotation). Such a scene need only be recorded once on 35mm film.

4. Reversals and Other Effects

   A single piece of 35mm film can be used for a variety of effects. Motion can be reversed by shotting the scene backwards. motion is slowed by multiple-framing from 35mm to 16mm and speeded up by shooting every other frame ("skip-framing") of the 35mm. Sever superimposition techniques are possible by overlaying a series of 35mm frames.

Economic tradeoffs dictate the complexity of the exposure sheet and printing process. If computer time and microfilm are cheap, it may be preferable to generate every single frame of the final film onto microfilm. The exposure sheet and optical printing become trivial with a direct one-to-one mapping from 35mm to 16mm.

The other extreme is free use of an optical printer while paying commercially for computer time and microfilm. In this case it may be desirable to minimize both processing time and microfilm frames, relying on the printer for timings and special effects.

Most often a cost will be associated with both computer usage and lab work. An economic balance between computer processing costs and optical printing time can normally be achieved. Typically, a multiple-framing ratio between 35mm and 16mm, along with single 35mm hold frames, will lower the number of generated microfilm frames.

Regeneration of simple, repetitive sequences on the microfilm will significantly ease the printing process with only a small additional cost for generating the extra microfilm. Ideally, neither the 35mm microfilm nor the 16mm motion picture film should be backspaced during printing. If the printing process requires human control, all practical steps should be taken to minimize errors.

Several additional laboratory steps are relevant to computer animation procesures. They include:

1. Color filter techniques;
2. Special printer effects (e.g., dissolve);
3. Merging computer imagery with live footage or conventional animation;
4. Dubbing the sound track;
5. Multiple prints.

However, since they involve detailed laboratory techniques, a full description is omitted from this discussion.

CONCLUSION

The interrelated procedures involved in the proproduction of a computer-animated film have been discussed in three phases:

1. A decision analysis on the overall feasibility of the film;
2. An evaluation of the available computing facilities;
3. The actual film production.

Each of these phases is further detailed with respect to a battery of overlapping functions and/or aspects.

Computer Graphics techniques open several new vistas for simulation and image synthesis. Yet computer animation is shown to closely parallel conventional animation techniques, with iterative capabilities of computing machines drastically reducing the human mechanics of the animation art.

While this incredible image potential and time savings potentially expand the art of animation, computers and computer graphics techniques are still only tools and procedures in an expansive portfolio of techniques for bringing images to life.

The critical element of any animation remains the creative talents of the conceptual animator, telling a story with pictures that move.

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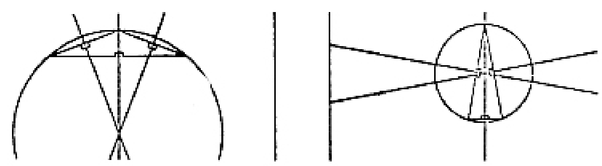
Ken Knowlton, Plainfield, New Jersey



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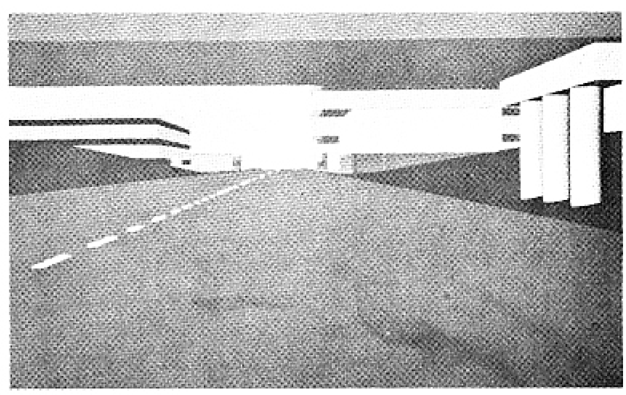

ABOVE: Illustrations from SynthaVision...The city planner is able to plan renewal projects or build a whole new city -- then move through the projected streets before blueprints are made--test vehicles, "drive" a new highway -- via animation.

4. ____________________, "Towards a Computer Animating Production Tool," European Computer Conference, Brunel University, United Kingdom, May 1974, pp. 172-185.

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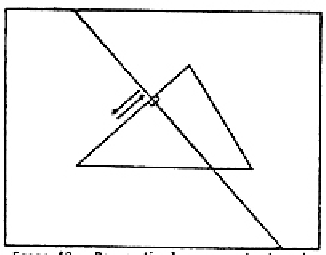
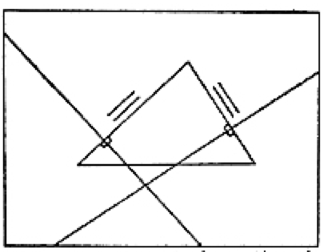
13. ________, "SYNTHEVISION: How a Computer Makes Films that Really Move," Audio-Visual Communications, May, 1975.

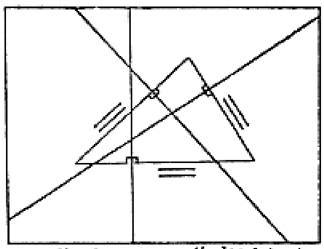
EXCERPTS FROM A RECENT FILM ON "TRIANGLE CENTERS" by James Warner. Here are brief excerpts from the storyboard from a computer-animated film. (Readers may write the author for full details/ sketches from the storyboard.)



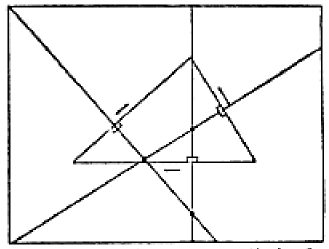
Scene 49: Perpendicular moves back and forth along the side almost to the ends for three sweeps (8 3/4 sec.).



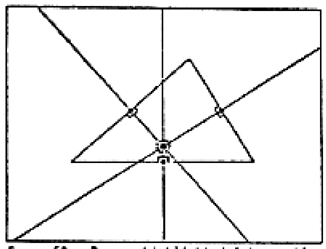
Scene 50: Left perpendicular continues to sweep back and forth. Right perpendicular fades in, doing the same sweeping motion (10 sec.).



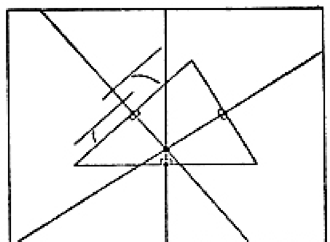
Scene 51: Bottom perpendicular fades in, sweeping along base of triangle (10 sec.).



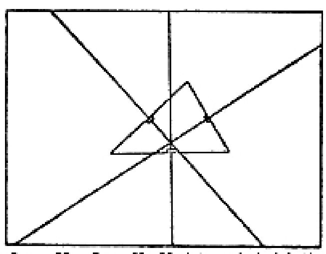
Scene 52: "Ping-ponging perpendiculars" slow as they simultaneously approach the center intersection.(2½ sec)



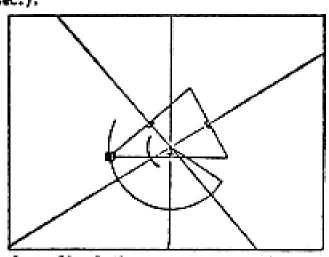
Scene 53: Pop on highlighted intersection point. Also pop on intersection points where a perpendicular crosses a side (6 sec.).



Scene 54: Repeat scenes 17-20 showing that the perpendiculars split each side into equal halves (24 sec). Hold (4 sec.).



Scene 55: Pop off all dots and shrink the triangle, right angles, and perpendiculars (2 sec.).



Scene 56: Radius pops on and begins tracing a circle. As circle touches each vertex, highlight the vertex point (6 sec.).

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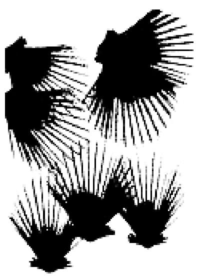

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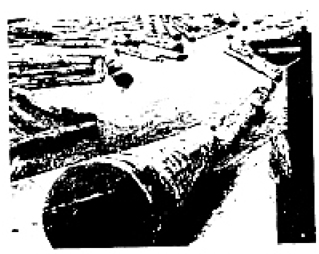

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SCHERZO FOR MATRIX AND FIGURES

by Edvard Zajec and
Dr. Matjaz Hmeljak
Via Degli Alpini 101
Opicina, Trieste
ITALY

"The resulting constructs will not be autonomous compositions but simply different versions of one and the same composition. What really counts then, in developing a pictorial idea with the use of a computer is a well articulated process, or a set of constructive procedures, which should be structured enough to be significant and open enough to allow a wide margin of unpredictability...And here we have experiments, or work in progress."

INTRODUCTION

If one of the aims in using a computer is to develop a series of images rather than a single final picture, then this aim can hardly be considered complete, when the compositions formed by a program are so similar to one another that they cannot be distinguished unless seen side by side. This situation is not very far from the traditional "one final result" and is well illustrated by the well-known phrase, "If you have seen one, you have seen them all".

The reason for so little differentiation usually does not reside in the formal idea itself, but rather in the poor articulation of the compositional process. When the latter is merely a set of "assembly instructions", it will not suffice to sprinkle a few random choices here and there to reach a good level of diversification. The resulting constructs will not be autonomous compositions, but simply different versions of one and the same composition. What really counts then, in developing a pictorial idea with the use of a computer is a well articulated process, /1/ or a set of constructive procedures which should be structured enough to be significant and open enough to allow a wide margin of unpredictability.

It is according to the above subjective view that the program which we are going to describe has been developed.

To use a paradox, what we were after in developing the program "Scherzo for Matrix and Figures" was a scheme which would not be schematic. Comprised in this search there was also the question of how to arrive at compositions of figures on the plane by avoiding on the one side, the constraining regularity of a grid structure, and the mindless aglomeration of random scattering on the other.

SETTING UP AN ENVIRONMENT

The formal vocabulary of the system has been limited to the composition of three basic shapes:

- the triangle,
- the rectangle, and
- the circle.

Stylistically this choice fits well into the 20th Century Non-Objective art tradition (abstract, concrete...) and is not an innovation in itself. This choice simply reflects the decision to remain, at least formally, on familiar grounds, and on a level of relative simplicity, in order to concentrate on the development of the process.

The task at this point was to find a set of constructive procedures which would combine the three basic shapes into compositions according to an order which would be meaningful but not obvious. We had already decided not to use grids or random scatterings as compositional devices in arranging figures on the plane; however, we could always try and see how these features functioned if transposed to an operative, procedural level.

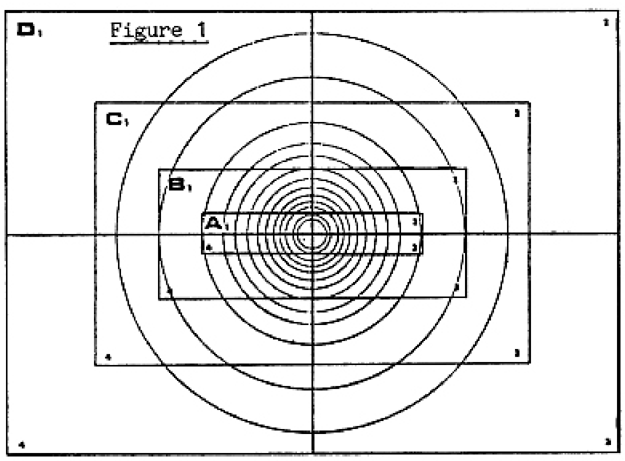
In this way we came to the idea of using a sixty-four cell square matrix as a container, or as an environment in which a series of events would directly influence the final configuration of a composition. The random distribution of elements comes into account in the first part of the process, which is concerned in setting up this environment.

This setting simulates a situation where we have a container divided into sixty-four partitions, each of which is in turn filled with a given number of elements.

As a first operation, each partition is progressively numbered from one to sixty-four. Program-wise, this operation sets the value for the first element in each partition. Secondly, each partition is assigned another number, but this time at whim (randomly), as if we were picking one number at a time out of a box containing sixty-four numbers, and we were casually putting it into one of the partitions until all the partitions were filled.

This procedure continues until all the elements have been placed in the sixty-four partitions. There are four other elements which each partition contains. These relate to the size, shape and positioning of the figures in a composition.

Each partition contains two radius sizes chosen from a range of sixteen radii(see Figure 1) - a shape indicator chosen from one of the three possible shapes, and a position indicator chosen from one of the sixteen possible subdivisions of the composition area. (See Figure 1 below.)



NCELL,RADK,RADN
POSIT,SHAPE,NEXT

FIGURE 2

1	1 7 11	2 14 8	3 3 12	4 11 15	5 16 9	6 7 11	7 14 3	8 15 12
	5 2 21	7 2 9	5 3 64	15 2 7	2 1 54	16 2 5	2 1 42	7 3 35
9	9 12 5	10 5 10	11 9 2	12 11 5	13 5 3	14 16 11	15 8 14	16 2 16
	1 1 47	12 2 38	2 3 34	5 3 56	12 2 37	10 2 6	4 3 27	6 1 51
17	17 7 13	18 14 13	19 10 7	20 2 6	21 8 16	22 11 14	23 15 4	24 9 10
	11 2 44	12 1 11	6 3 52	11 2 50	7 3 57	14 2 20	11 3 24	4 3 43
25	25 8 5	26 12 16	27 1 8	28 12 4	29 13 3	30 9 5	31 14 1	32 10 12
	3 1 23	9 2 8	14 1 59	13 1 17	7 3 48	6 1 25	4 2 1	16 2 18
33	33 7 1	34 6 11	35 4 8	36 5 12	37 14 1	38 13 8	39 6 14	40 15 2
	14 3 45	5 1 61	3 2 58	8 2 36	15 1 3	13 3 28	16 2 19	12 2 62
41	41 9 9	42 10 9	43 15 3	44 11 6	45 4 6	46 6 13	47 5 9	48 16 4
	9 3 30	4 3 49	15 3 12	1 1 55	13 1 26	3 2 13	1 1 10	14 1 29
49	49 6 10	50 16 4	51 8 1	52 1 14	53 2 15	54 3 13	55 1 4	56 4 4
	1 2 63	13 1 16	6 3 2	8 3 53	8 1 15	10 1 32	6 3 46	11 2 31
57	57 13 2	58 3 16	59 1 15	60 2 15	61 6 7	62 12 7	63 3 10	64 13 7
	16 3 22	16 3 40	3 2 4	2 1 60	16 1 39	9 3 41	18 1 14	7 1 33

```
48 29 10 13  2  1  3  2 14  1     -0-0-0-0 0 0 0-077-0
29 48  3  6  1 .3  3  2  9  2     -0-0-0-0 0 0 0-077-0
48 29 10 13  2  1  3  2 14  3     -0-0-0-0 0 0 0-077-0
29 48  3  6  1 .3  3  2  9  4     -0-0-0-0 0 0 0-077-0
48 29 10 13  2  1  3  2 14  5     -0-0-0-0 0 0 0-077-0
29 48  3  6  1  3  3  2  9  6     -0-0-0-0 0 0 0-077-0
```

ABOVE: A sixteen-cell square matrix with equiprobably distributed elements. The coded information in CELL NR. 1 reads as: 1-NCELL (cell number); 7, 11-RADK,RÅDN (radius sizes); 5-POSIT (field position); 2-SHAPE (rectangular); 21-NEXT (pointer to next cell).

Our environment is completed when all these elements have been distributed over the sixty-four cell matrix (see Figure 2).

The subroutine SETRAND displayed in Figure 3 shows how this procedure was actually implemented in FORTRAN. In the value assignment process, subroutine SETRAND is called separately once for each element. (See page 22.)

TAKING A STROLL WHILE OBSERVING

So far we have concerned ourselves with establishing a preliminary groundwork, a platform which is the result of our personal choices and decisions. The vocabulary of shapes, the range of formal attributes, and the programming language, are choices which reflect our previous experience.

These choices may be in the esthetic or technical fields, and they represent the outside limits, those fixed constituents which remain constant in the development of the program.

The random distribution of the elements in our environment is the result of a great number of single local choices which were left to the computer. Consequently, all the information that we have about our environment at this point is that it is a sixty-four cell matrix, and that each cell is a table containing six more or less randomly assigned elements.

This is the stage where most composition processes stop, letting the artist in turn select those compositions in output which he considers valid, or which better approximate his esthetic criteria.

The table illustrated in Figure 2 could be an example of such a composition, if the numbers were substituted with lines, colors, or any other figural element. But since our matrix is not a factual composition, but merely a symbolic framework, we could go back and check to see if further information could be gained about the state of its elements. /2/

BELOW: Varied experimental compositions, plotter output run with a CDC 6200 at the Computer Center of the University of Trieste.

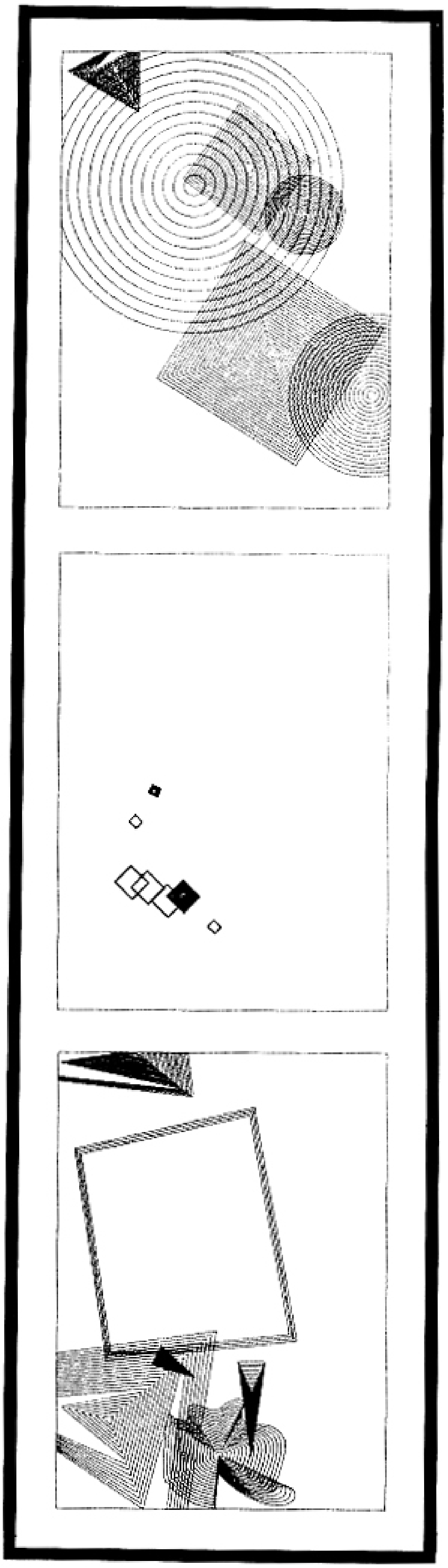
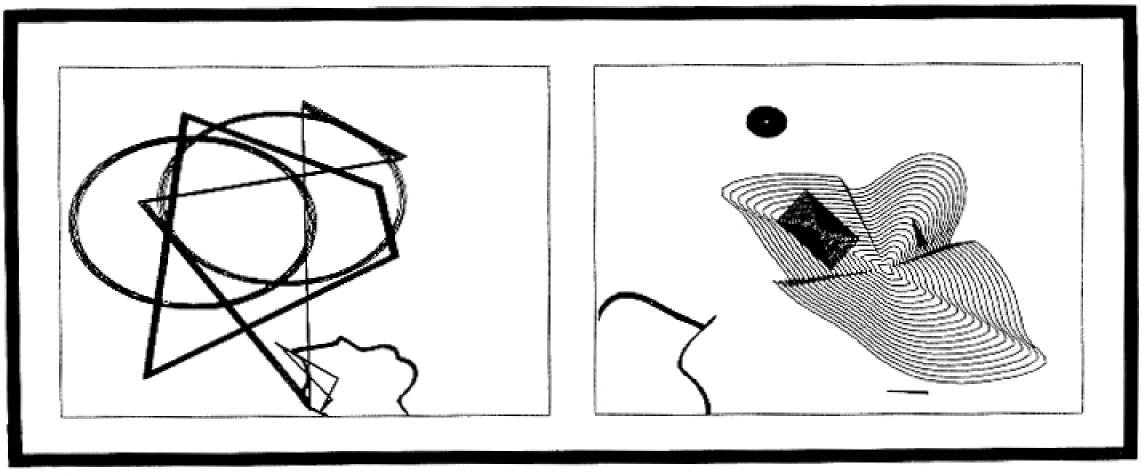


FIGURE 3

```
      SUBROUTINE SETRAND(VEC,NVEC,NELEM)
C
C     SUBROUTINE SETRAND   RANDOMLY ASSIGNS A SET OF NELEM VALUES
C     (1..NELEM)  TO THE ELEMENTS OF AN ARRAY VEC(1)..VEC(NVEC).
C     THE RESULT IS A QUASI-EQUIPROBABLE DISTRIBUTION OF NELEM VALUES
C     OVER  NVEC  ELEMENTS.
C     E.G. IF NVEC = 8,  NELEM = 3,  THEN A POSSIBLE OUTPUT IS
C     VEC(1)..VEC(8) = 1 3 1 2 3 2 2 1
C     ( VEC(1)..VEC(6) CONTAIN ELEMENTS 1,2,3  N TIMES EACH,
C     WHERE  N= NVEC/NELEM,  AND VEC(7),VEC(8) CONTAIN VALUES
C     RANDOMLY CHOSEN FROM 1,2 AND 3.
C
C     INPUT PARAMETERS = NVEC, NELEM
C     OUTPUT PARAMETERS =  VEC(1).. VEC(NVEC)
C
C     SUBROUTINES USED KRAND(K)
C        IS A RANDOM GENERATOR GIVING INTEGER VALUES IN THE RANGE 1..K.
C
      INTEGER VEC(NVEC)
C
      IF(NVEC*NELEM. EQ .0) GO TO 90
       DO 10 K=1,NVEC
   10 VEC(K)=0
      N=NVEC/NELEM
C     N IS THE N.R OF TIMES EACH ELEM WILL APPEAR IN VEC
      NVEC1=N*NELEM
C     NVEC1=N.R OF VEC ELEMENTS COVERED RANDOMLY WITH A UNIFORM DISTRIB.
      IF(N.EQ.0) GO TO 50
C
      DO 40 I=1,NELEM
C     NOW INSERT N TIMES THE CURRENT ELEMENT I INTO VEC(1)..VEC(NVEC1)
      DO 30 J=1,N
      KOUNT=0
C     RANDOM CHOICE
   20 K=KRAND(NVEC1)
      KOUNT=KOUNT+1
      IF(VEC(K).NE.0) GO TO 20
C     IF ALREADY SET TRY AGAIN,IF NOT,ASSIGN-
   30 VEC(K)=I
   40 CONTINUE
C
      IF(NVEC-NVEC1.EQ.0) RETURN
C     VEC IS NOT YET FULL,FILL TRAILER ELEMENTS
   50 NVEC1=NVEC1+1
       DO 60 K=NVEC1,NVEC
   60 VEC(K)=KRAND(NELEM)
      RETURN
      END
```

BELOW: Plotter sketches executed at the University of Trieste by E. Zajec and M. Hmeljak. The above subroutine allows the artist to produce a great variety of pleasing patterns.



This meant establishing a set of rules which would reveal, according to some qualitative criteria, what kind of order relationships, if any, existed between the elements in the environment. The results of this search would in turn yield that information which will be evident or found in the final compositon as a set of unique formal coincidences.

It is rather plain that some of the actions to be performed in the environment would be implied (to a degree) by our previous choices. The first two numbers for instance, contained in each cell, were placed there according to a previous intention to set up a "strolling-mechanism" with which to tour our matrix-environment, while searching for significant relationships. The actual functioning of this mechanism starts by casually choosing a cell and proceeding from there to the cell indicated by the second, randomly assigned number. This action is repeated until the desired number of moves is reached. Concommitant with this action there is an information gathering process by which the contents between the sending and the receiving cells are compared and catalogued.

DETAILS OF THE PROCESS

For a more detailed description of this process, we will start with the first move which sets the total number of figures for a composition simply by dividing the larger number in the starting cell by three. Each move determines the formal characteristics for one particular figure. It has been set that the shape and the field position indicated by the sending cell determines the actual shape and location of that figure in the overall composition.

Each cell also contains two radii for greater size variety, but only one is chosen to be compareu and then combined with the one chosen in the receiving cell. This comparison and combination not only determines each figure's size, but also its structure.

The argument of structure is the first in the series of those qualitative tests which are meant to evidence any contents of the matrix. In the six arrays named, the contents are:

- NCEL (cell number),
- RADK, RADN (radius 1, 2),
- POSIT (field position indicator),
- SHAPE, and
- NEXT (pointer to next cell).

Each figure is computed according to the data contained in: NCELL(ICELL1)...NEXT(ICELL1).

CONCLUSIONS

If to transmit information means to reduce uncertainty, this program does just that, by the quality of compositions which it produces, reducing the number of unarticulated (and therefore unacceptable) compositions in the overall output, to a very narrow margin. /3/ At the same time this information is not redundant, since it would be quite a task to be able to predict the exact path that is going to be taken, or the kind

BELOW: Figure 4 - A flow-chart illustrating the compositional process.

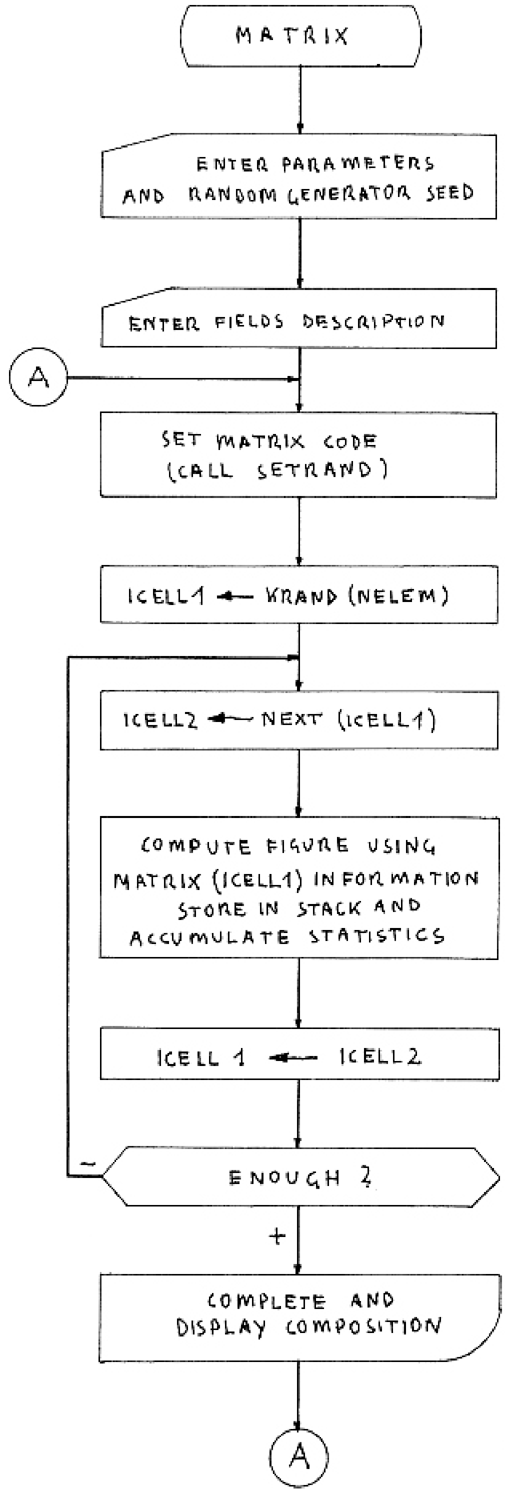


FIGURE 4

and amount of order relationships that will be encountered in a particular matrix. We have, for instance, compositions which are highly structured, and others which are quite freely articulated, as can be seen from the illustrations in Figures 5 and 6.

The printer output (not shown) is quite pertinent as an example in this respect, since it illustrates a situation which was not directly planned, but came as a side-effect. The particular configuration of this composition which, by the way, is the outcome of the matrix displayed in Figure 2, can be seen as a visual representation of a loop. By coincidence, the two numbers in the sending and receiving cell are the same, but in an inverted position, forming a closed circuit which reduces all the compositional information to the contents of just one pair of cells.

The main point, however, or the meaning behind our work is seen in the articulation of the process, which on the one hand, allows a wide margin of differentiation by setting and then touring a newly-set matrix for each composition -- and on the other, by adding significance to the final configuration through a careful testing for orderly relations in the initial randomly set matrix.

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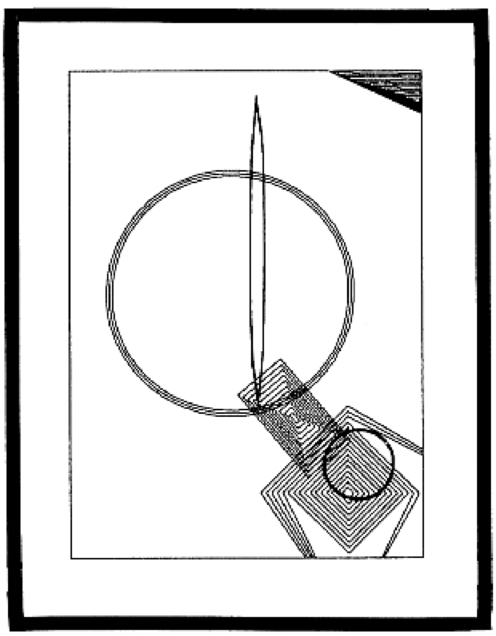
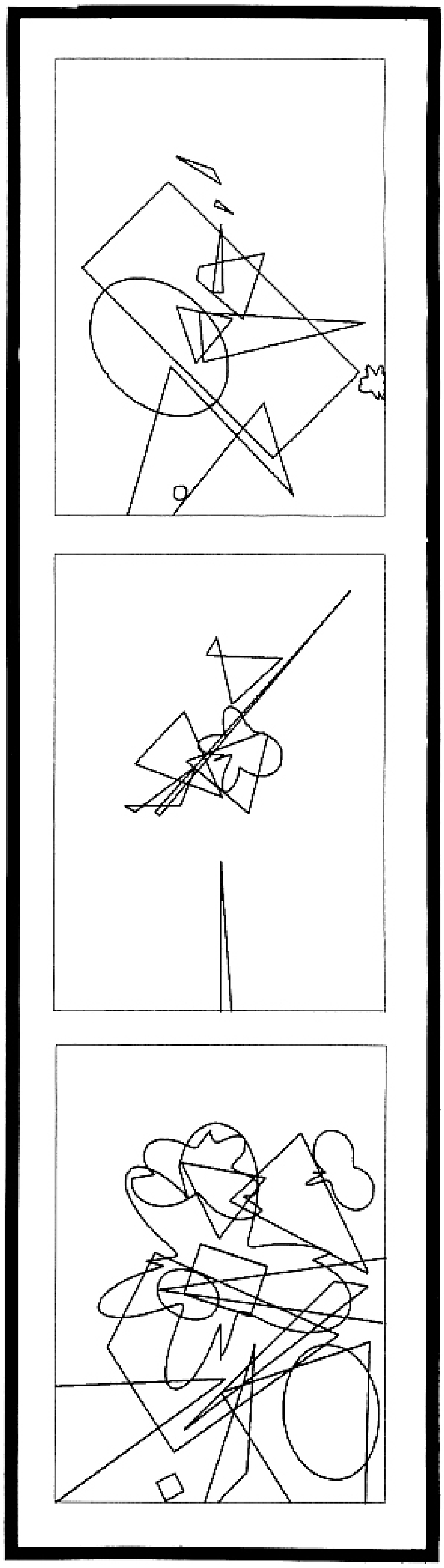
/2/ Singh, J., Great Ideas in Information Theory, Language and Cybernetics. New York City, N. Y.: Dover Publications, Inc., 1966, pp. 75-77.

/3/ Rapkine, L., "Notes for a Scientific Theory of Aesthetics, Leonardo 3, 1970, p. 351.

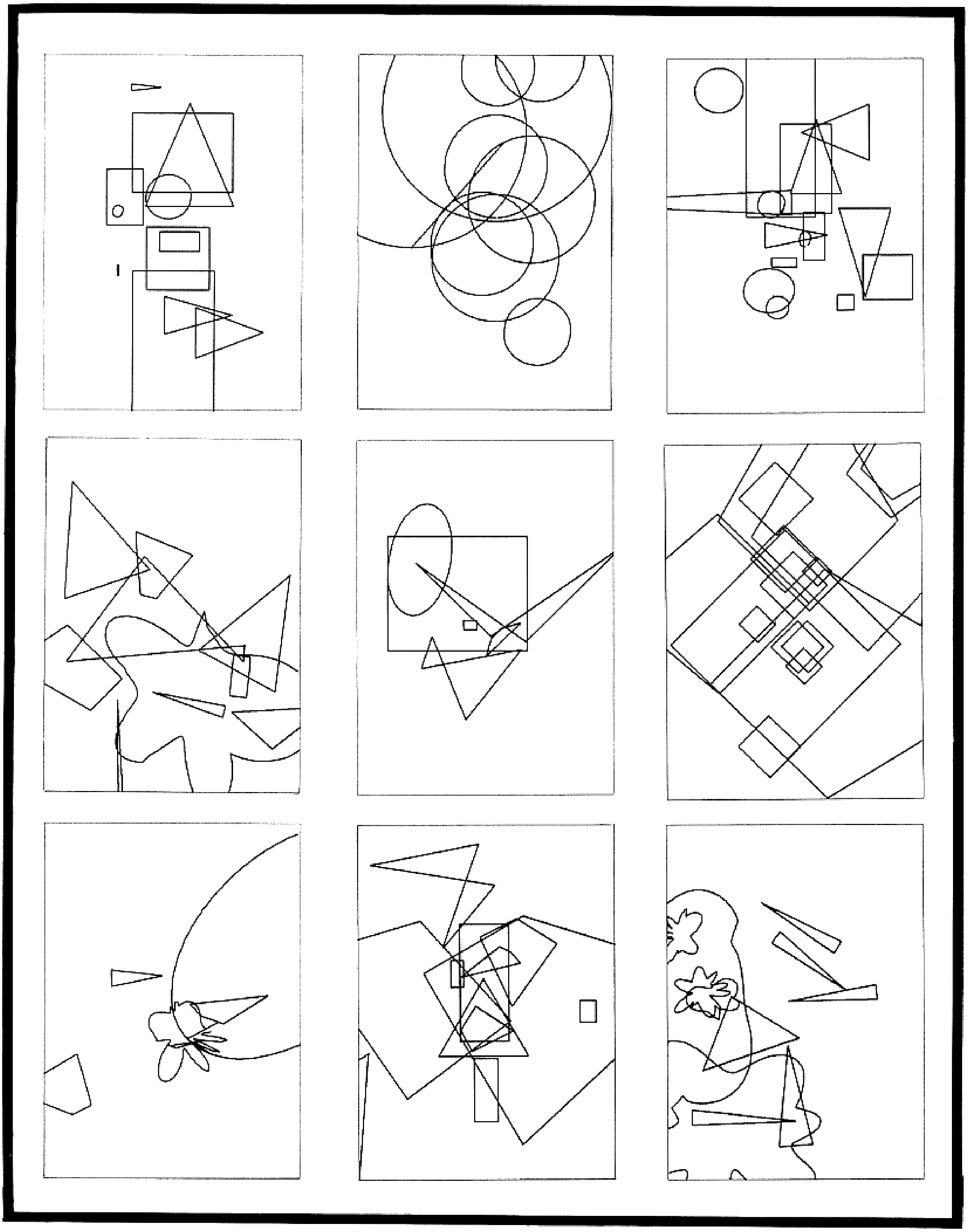
BELOW: Plotter sketch by E. Zajec and M. Hmeljak.



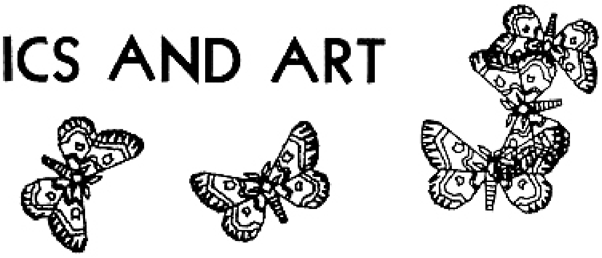
BELOW: Angular forms are combined with curved patterns, resulting from SUBROUTINE SETRAND, listed on page 22. FIGURE 5



BELOW: FIGURE 6-Other sketches by Edvard Zajec and Matjaz Hmeljak, from the Computer Center, University of Trieste, Italy. "These compositions are the result of the program and methods cited in this article. There is nothing final in these pictures, and we consider them as experiments, or work in progress. We believe that the plotter sketches would be most interesting to take back into painting or serigraphy."



COMPUTER GRAPHICS AND ART



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DESIGN TECHNIQUES AND ART MATERIALS IN COMPUTER ART – PART II

by Grace C. Hertlein, Associate Professor
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PART I

In Part I the need for an interdisciplinary approach in teaching computer art was emphasized. The new trend, of taking plotter and cathode ray tube output, back into art was reviewed, along with examples of this new art.

Particular emphasis was given to varied approaches of teaching computer art for different kinds of students.

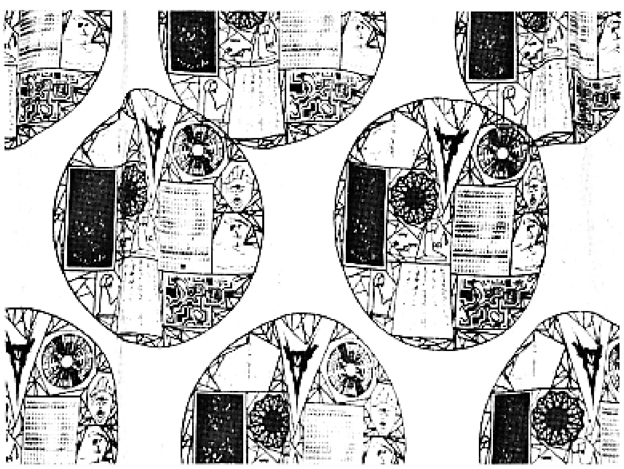
Class-tested techniques used by the author were reviewed in depth. Approaches to design were listed, along with methods of introducing these techniques.

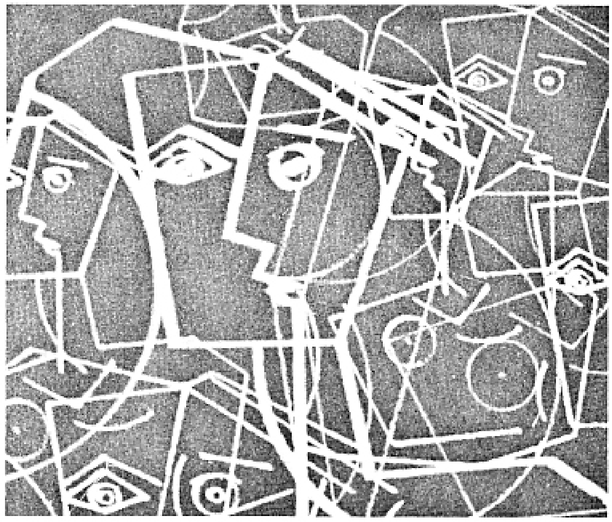
PART II

Special design derivation art exercises have been developed during the past seven years. These techniques have been effective for students without previous art training. However, they have been equally effective with experienced artists, enabling these students to explore a host of new techniques useful in their creative work.

Specific ideas relating to the use of art materials are discussed in depth, along with new techniques of photographic development. This includes manipulation of negatives made from computer art, use of transparent sheet film, the introduction of Diazo techniques, and finally, experiments in serigraphy (or silkscreening).

BELOW: Silkscreened textile by the author with designs from many sources: Egyptian hieroglyphics, African masks, snow crystals, and varied illustrations from the August art issues of Computers and People. The illustration is the cover of Computers and the Humanities.





ABOVE: Detail of a graphic by the author, 1973. The design is a derivation from Picasso.

Since new terms are introduced in this article, an alphabetical glossary of unique terms is given.

The purpose of this moderately long article is to offer class-tested ideas for computer artists and teachers of computer art. Since this material is not available in other literature, it is presented in depth, with the hope that it will be useful to others.

IV - DESIGN DERIVATION EXERCISES

The word "derive" means to depart from a given source. Derivation art exercises are a series of specific explorations, in which the artist uses several sources of input, then experiments to walk away from the original source, achieving many related but variant designs.

One may regard almost all ideas as input from some source. That source might be music, mood, nature, the environment, etc. The mind processes the input source material in devious ways. Within this frame of reference, whatever rests in the consciousness, is material from a source. It did not originate within the mind without input of some kind. However, the many ways in which the mind processes, synthesizes input sources varies greatly. And this processing of the mind, which is then output as a source can be very complex and subtle.

There are fashions in sources. There have been dogmas regarding the proper sources of design. These have ranged from animals in prehistoric days, the gods of the ancients, the gods of man throughout history, to the abstract, non-representational forms of this century, and to the present preoccupation of mathematical-scientific forms as sources for computer art.

In order to execute these art exercises, it is necessary to use a very thin tracing paper, such as Grumbacher Art Tracing Paper. The method is to draw or trace a source design, and then to trace spontaneously over the first input design and alter it deliberately, either by addition or subtraction methods. Use of a black felt pen, with a thin line gives a professional look to beginning work. Designs should not be too large (no more than 4" by 4", to facilitate execution of the innumerable variations required. Generally between 5-10 pages of derivation designs are made for each specific design. It is important to have students begin these exercises in class, so that they have a very clear idea of the assignment, and how to begin and progress. A great difference should exist between the pages of derivation art exercises.

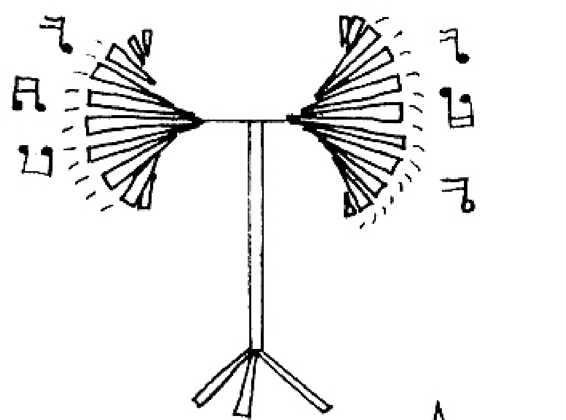
The illustrations shown are examples of changes made by a student, spontaneously, going from a source design, to find a great many variations. These designs are typical of beginning computer art students, and were executed by a mathematics major, minoring in computer science. His comments on the exercises were that it was a "fun assignment," that he listened to music while drawing, and that it took one evening of time. He commented that he felt creative when doing the exercises, and was surprised at what resulted from the assignment.

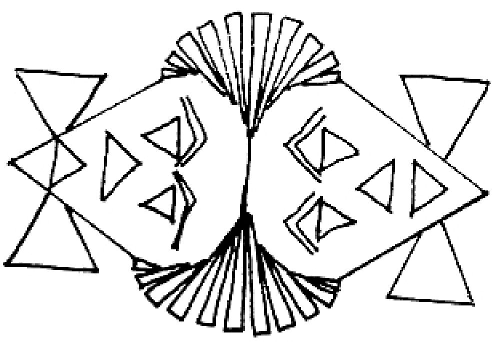
In executing the art exercises, the works most pleasing to the artist are noted, identified, and analyzed, using the checksheets as a guide. Execution of the exercises should be quick, spontaneous, and almost without thought. The goal is to develop facility in alternative planning, brainstorming, learning a technique for outputting alternatives naturally. Here are sample sources.

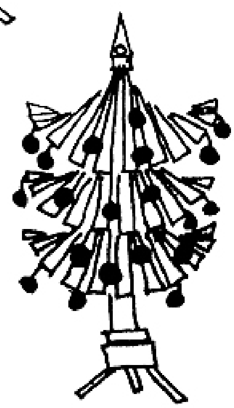
1. OBJECTS FROM NATURE - Objects are chosen and studied, according to the preferences of the artist. Examples are leaves, shells, pods, crystallography patterns, flowers, micro-photographs of snow crystals, scanning electron microscope patterns, aerial photographs, stress patterns, etc. It is important to have a range of subject matter within a group, to avoid a recipe-like product from the class.

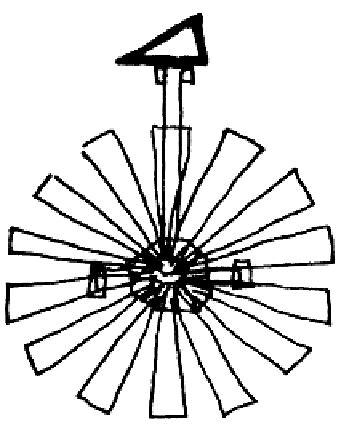
2. MANUAL ART ILLUSTRATIONS - A favorite artist or work is chosen. Examples are: cave art, paintings from Greek vases, Indian hunting designs, illuminated manuscripts, Pablo Picasso, Andy Worhol. The art sources should have a personal appeal for the student, in order to be effective in derivation exercises.

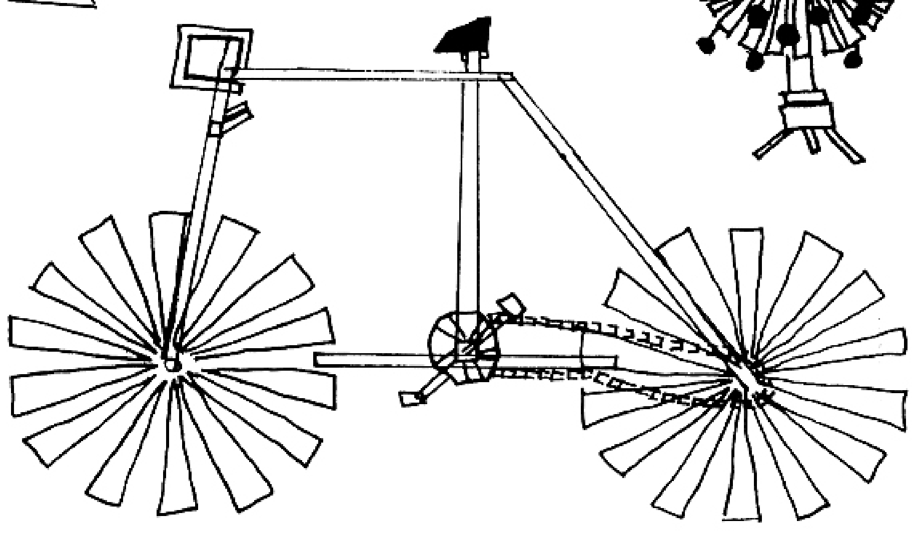
3. ENVIRONMENTAL SUBJECTS - Any pattern from the world of man (or other worlds, outer space, etc.) is included in this category. Sources may be city buildings, bridge patterns, bicycles, people, bodies of water, celestial sky patterns. Again, this and other sources should be chosen as examples of personal preferences -- not executed as mere assignments.









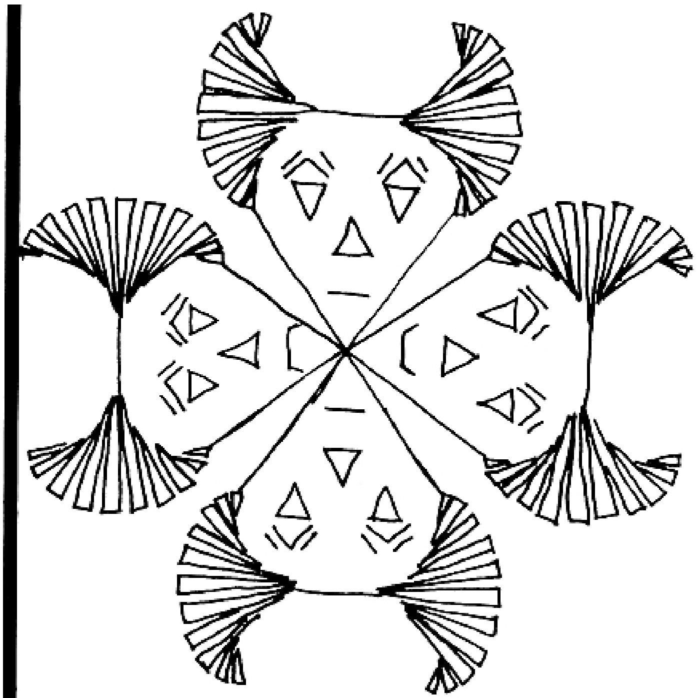


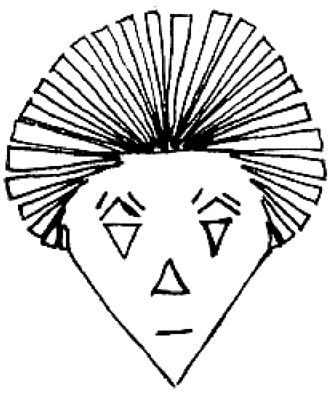
ON THIS PAGE: *Selected Manual Sketches for the Design Derivation Exercise Assignment (Week II of Class)* by Rick McKenzie, exploring variations of a source idea.

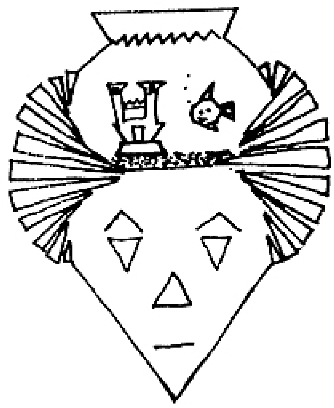
4. FROM THE MIND OF MAN - Clear cut ideas that do not fall into specific input patterns are included in this category. Yet they may, in reality, be processed, synthesized derivations from man's outer world. An example might be: (a) Sketch a vivid dream that can be readily recalled; (b) Imagine the most pleasurable moment in your life -- draw the main feelings; (c) You are floating over the world, and can choose any place in time, any place in the world, any living form. Make a choice, and sketch some of the ideas that come to mind.

5. THE AUGMENTED MODULE VS. THE SINGLE COMPONENT MODULE - A single design component is one element of design: a leaf, shell form, etc. The augmented module is the leaf or shell form mirrored on the X, the X/Y, and the Y. In lieu of the one leaf pattern, the module becomes the four leaves. This "added to" or augmented module becomes the component, which is manipulated via subroutines to become new sources of art. Artists may derive innumerable modules by exploring these variations. (See the examples by Rick McKenzie.) In this exercise, the portions of module are traced, to reveal new variations that are feasible to serve as an "augmented" or enhanced module. This particular technique results in very professional work.

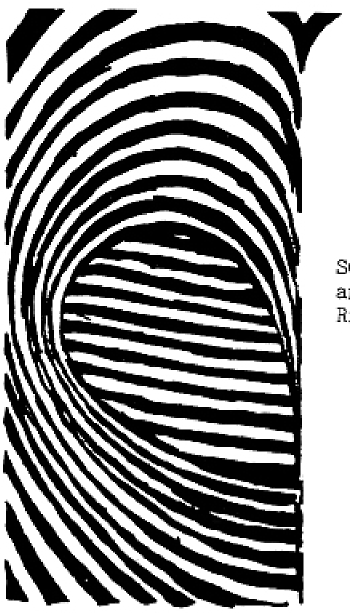
6. RELATED MODULES - Far more manipulative possibilities exist when a personal library of related modules serves as a source of design. Again, to use the leaf and shell examples, recall all the leaves in the world -- all the shell patterns -- all the known functions in mathematics. These are examples of related modules, that may be used together to form new graphics. Two or three related modules give a richer design effect than reliance upon one module. Illustrations of related modules are shown on page 35.

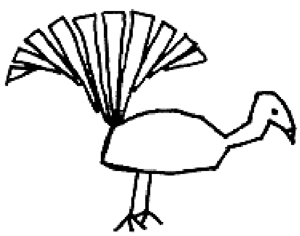




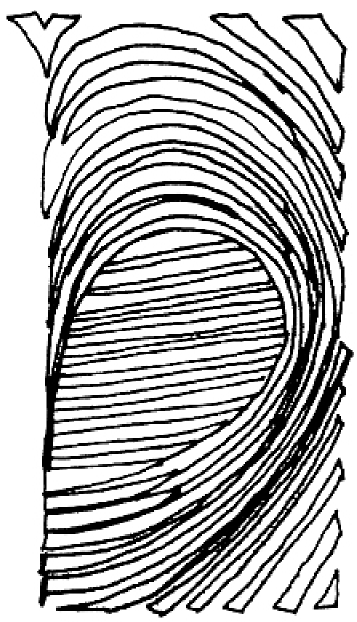


ILLUSTRATIONS ON THIS PAGE: *Selected Manual Sketches for the Design Derivation Exercise Assignment* by Rick McKenzie, one of the author's students, a Mathematics major, Computer Science minor.





SOURCE DESIGNS: Bottom and immediate left by Rick McKenzie.



V - MATERIAL EXPLORATIONS

It is well at this point to bear in mind that while artists are researching design derivations, they are learning more about programming methods, software development, and material explorations.

Individuals respond in very sensitive, almost idiosyncratic ways to art material development. What is one person's meat is another's literal poison. One artist may delight in DayGlow (blacklight) papers, which would be abhorrent to another.

Studying actual works of computer art is perhaps the most helpful way to discern a "material direction". Observing effects in laboratory class demonstrations is another method. Use of the art checksheets is immensely helpful in this area.

Readers interested in more definitive details of photographic material development may wish to study the latter portions of the paper, "The Microfilm Plotter and Computer Art" cited earlier. General comments, of a moderate nature, are given here.

1. BEGINNING EXPERIMENTS WITH MATERIALS - We make a deliberate plunge into art papers taped to a 30 inch drum plotter during weeks two and three. This is deliberately unannounced, to achieve spontaneous reactions from students. Art papers are brought to these laboratory sessions, and beginning students are aided in making the first plunge on art papers, with varying colors of felt pens. During this first session, which includes a brief introduction to the effects of complementary, analgous colors and underpainting and overpainting techniques, paper is free! This serves as great motivation for students to take the art material plunge.

Deliberately, varied types of papers are first shown: absorbent rice paper; traditional tan and white parchment papers; pastel papers in a range of colors; Dayglow in shocking colors.

Working on art papers is so much more effective than on industrial papers, that one wonders, why do artists use the antiseptic, unaesthetic industrial paper? The character of the paper body, its texture (or lack), its color, combined with varied colored pens is significant in altering the character and connotations of computer art. Artists are perhaps unaware, that a great many art papers can be taped around a drum, or taped on one end, allowed to hang on the other, and with this combination of art papers, varied widths of pens, varied types of inks may be used, to afford innumerable exquisite effects not obtainable with industrial papers. In addition, special inks may be used on acetates and mylars, to utilize the dimensional effect of overlays, which may be run on both sides of the paper.

In our classes, students are required to execute art work in two areas: (1) art papers and (2) photographic manipulations.

2. BEGINNING PHOTOGRAPHIC MANIPULATIONS - One month into the semester, students are taken to darkrooms, and reversals of beginning exercises are made. Solar prints are introduced at this time. Black and white 35 mm negatives are made by the instructor for students, from their industrial paper works. Students mass produce positives of these negatives in this first photo esssion, and they are taught to manipulate them in the manner of the Microfilm Plotter paper reference, given earlier. By the end of week four, students have completed satisfactory works on art paper, with varied colored pens -- and finished photographic works.

3. NEED FOR COLOR STUDY - For non-art majors, a quick session on color, values, and connotations ensues. Students mark off a sheet of paper into equal portions, and test out color combinations, to discern their individual preferences.

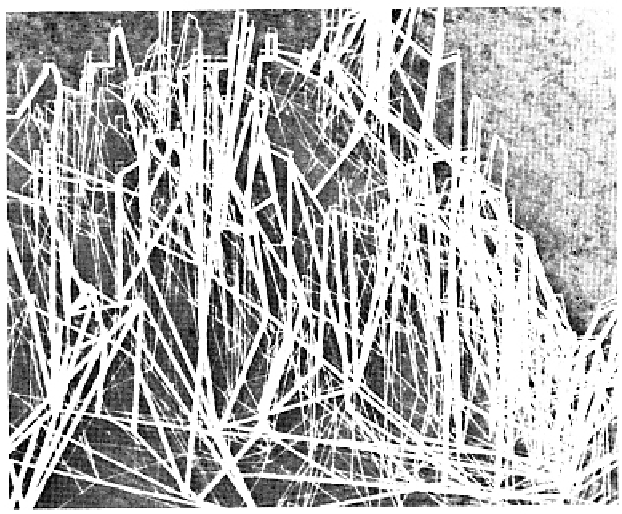
A trip to the Student Bookstore and a nearby art shop allows artists to respond to colors, textures, and limitations of papers. This paper study, coupled with their color preferences, saves time in running finished works of higher quality. The absorbency, lack of absorbency, the ability of a paper to take innumerable line ink applications -- all these are discussed, demonstrated, and tested.

4. PARTICIPATION RUNNING AND ART PAPERS - Combinations of related modules allow for explorations of a larger number of works than choosing from a limited menu of designs. (See illustration below.) Students are introduced to "production running methods", whereby the artists will run all the graphics on a magnetic tape once, running each record (or graphic) on a different piece of art paper, with varying colors (and thicknesses) of felt pens.

A second overprinted image of the same (or related modules) is placed in a related color over the first. (Overprinting or overpainting is printing over the first image, generally offset.) Requirements are to work from light to dark, to avoid dirty colors. Two, three, or four overprintings complete a given graphic. If the artist is in doubt as to whether the work is complete, it is put into the portfolio, to analyze later. The color tests made earlier help the artist to discern an individual color palette.

After this initial practice and analysis, most students are able to analyze themselves, why a graphic is complete or undeveloped, and what specific colors may be used from beginning to end, in a highly personal manner.

BELOW: *Mountain* by the author, executed in 1970, on parchment paper, with pens and brushes.



5. DIAZOS AND PHOTOGRAPHIC MANIPULATIONS - The word "diazo" derives from "Azo," in Greek, meaning without life. Diazonium compounds are organic compounds containing pairs of nitrogen atoms. These compounds are decomposed under irradiation by ultra-violet light into chemically inactive compounds that release free nitrogen in the process. /1/ After exposure to the light, the diazo is exposed to aqua-ammonia vapor to neutralize the acids, and the diazo dye is formed in the unexposed areas.

Diazos come in a marvelous range of colors. The most attractive are the acetates. However, even the common blueprint paper (which is a diazo) is artistically effective, and it is not a blue, but a blue-violet. Brownline (blueprint) paper is a rich sienna in color.

Generally, one uses an acetate with heavy ink applications in black for diazos -- or a transparent sheet film (negative and/or positive) to make the diazos. The diazo is placed under the transparent sheet film (positive or negative), put through the bottom of a blueprint machine, exposed to the light, then put through the top and exposed to the ammonia vapor. (Instant art!) Using positives and negatives, and a color range of diazos, graphics may be produced in minutes that are effective artistically. The most attractive aspect of using diazos is that they can be used in so many different ways:

- Diazos combined with vari-colored diazos;
- Diazos over art papers;
- Diazos over photography papers;
- Diazos over transparent sheet film.

6. TRANSPARENT SHEET FILM - A technique commonly used in the author's classes is to take a graphic run with black ink on white industrial paper, and to make a positive and negative transparent sheet film. (One trade name for this film is Kodalith.) The film is used to print (contact) onto photographic papers, and it may also be used to make direct photographic serigraphs. (Above mention was made of the use of transparent sheet film to make diazos.) The film material itself is very handsome and may be matted over foils. The size of the film used depends upon the artist's budget. Generally our students use 8 X 10 inches, which purchased wholesale, costs the student 28¢ per sheet. Some students prefer to work larger, 16 X 20 inches.

7. SERIGRAPHY - Serigraphy, or silk-screening is accomplished by using a Kodalith (transparent sheet film) to make a photo-sensitive emulsion (in this case, Ulano film) that is placed on a stretched screen of silk. The images are computer-designed. Artists often use multiple screens, and manipulate images in successive printings.

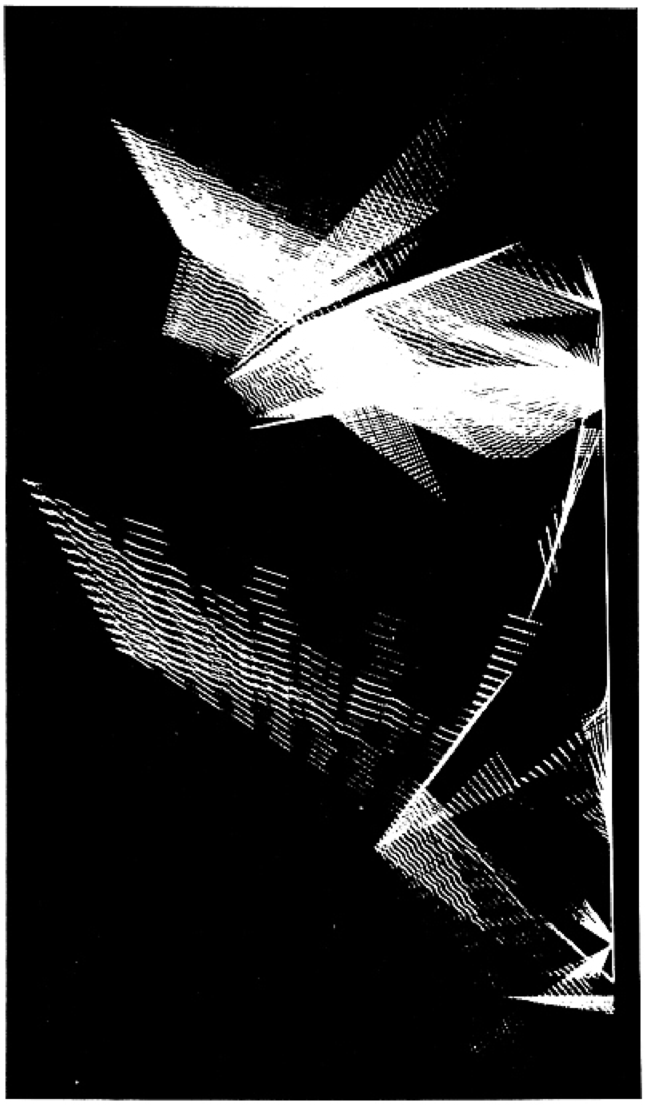
Silkscreening is demonstrated on papers, textiles, plexiglas, etching plates, etc., so students will have an exposure to some possibilities of media explorations. In many cases, special laboratory sessions are held to make screens, develop emulsion films, and printing is accomplished in group sessions, using facilities that will allow hanging of papers and textiles until they are dry. Student response to silkscreening is very enthusiastic. Applications are generally in editions of graphics, with limited textile works.

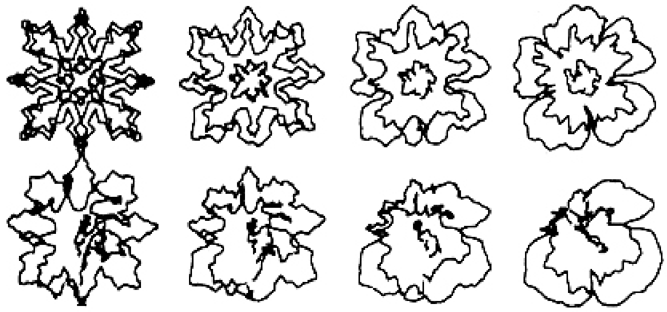
8. COMBINATIONS OF MEDIA - Every class is considered to be an "exposure" to varied media approaches and techniques to achieve computer art. Since our present courses focus upon primarily one-semester experiences in computer art, students observe and participate in demonstrations of media combinations, but are free to choose the final forms for their art. (Many students, however, continue their own art by finding out the schedule for photographic/silkscreening sessions, and participating with current classes to produce new works.)

All students are required to explore at some depth, personal use of art papers and colored pens (and in some cases, use of special pens and brushes in a flow-pen assembly). They are also required to explore some facets of photography and mixed media combinations. A growing minority of mass communications students are evidencing interest in the applied graphic arts fields.

By using a core of required experiences with each group, and exposing students to a larger range of potential artistic experiences, students achieve personal works by programming, by special participation running techniques, by photographic manipulations, and by graphic arts processes. In the immediate future, a brief exposure to 3-D computer art in holography is planned for 1977-78.

BELOW: Continuous Line Design by Joy Pearson, a nurse.





ABOVE: Detail or portion of "Seasons Greetings" by William Kolomyjec. This is a popular technique in computer art, transformation of the design as it proceeds through serial imagery.

SUMMARY

Computer art is a relatively young art. It has grown from an esoteric pastime of mathematicians, small in number, to embrace a growing following of people from many disciplines. This new field has transcended the parameters of its first phases. Computer art is becoming an art/science.

This new art form will soon find an accepted place in the art world. The technology of computer science has been absorbed into the world of art, revealing a newer art, interdisciplinary, hybrid, a "natural" result of art in a technological era.

If this new art form is to fulfill its obvious potential, artists will have to become more scientific, more rational, less egocentric. Scientists will have to become more artistic, more whole, more willing to define the measurable elements that are within art. And this new wholeness will give birth to ever-new discoveries in art/science. The world is in dire need of this larger vision.

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/24/ See Reference /2/.

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GLOSSARY OF UNIQUE TERMS

ADDITION - Adding to a module (design). Additional lines, interior or exterior patterns may be added to the basic form. In addition, a second (or third) module might be added to the first module, and varied combinations result in new variations. Example: Varied fish forms.

AUGMENTED MODULE - The module (design) is manipulated, and this altered, enhanced design then becomes the module, which is then manipulated again in diverse ways. (See page 29 for examples, where the augmented module is the rotated head form.)

DERIVATION DESIGN EXERCISES - Special exercises devised by the author, described in detail on page 28. A method to achieve varied sequential designs from a given source.

DIAZO - For background information and further details, see page 31. Special papers with a choice of a diazonium/coupler combination, which determines the color of dye. Generally developed in a blueprint machine or a special Diazo Film Developer. A source of this material is:

GAF Corporation
Repro Products
140 West 51 Street
New York, N. Y. 10020

Engineering/drafting supply houses carry these materials.

GENERATIVE - A series of generations of patterns attained from a source. Generations of designs may be developed in the design derivation exercises, and also by photographic manipulation. In the latter, the manipulated design is photographed, and by manipulation, this second pattern (generation) is altered, resulting in a third generation.

MATERIAL DEVELOPMENT - The art materials used in creating computer art include many variables: types of pens, pen points, colors of ink, types of ink, textures and colors of art papers, etc. Material development also includes photographic materials: diazos, transparent sheet film, serigraphy, etc. Material development is a very personal series of choices.

MINIMALIZATION - To subtract from a pattern until the design becomes a symbolic essence form. The life work of Piet Mondrian is an example of this technique. Example: How much can one subtract from a tree pattern and have the form remain a tree pattern?

MODULE - The original design that is programmed. The module is a block or portion that is intended to be varied and augmented via programming. It is not a finished graphic, rather a foundation pattern to be plugged into other routines.

PHOTOGRAPHIC MANIPULATIONS - There are many methods for changing and altering computer art via photography. This is partially discussed on page 31. Again the module is important. In lieu of manipulation via programming, the module is changed and enhanced via photography. See Reference /1/ for complete details.

RELATED MODULES - Modules of design that can be used together harmoniously to achieve new graphics. Ideally, a library or grouping of modules will afford innumerable graphics. See pages 27 and 33 for examples.

SUBTRACTION - Taking away portions of a module. Minimalization is the end product of subtraction.

SOURCE DESIGN - A design that one begins with -- but departs from to achieve new designs that are more personal. The source might be nature, a photograph, an illustration, a pattern from science, mathematics, etc. The source is not programmed, but is rather a seed to generate new ideas for the artist.

ART OF THE SPACE ERA EXHIBITION

"Art of the Space Era" is an invitational international exhibition of computer art to be held at the Von Braun Civic Center of the Huntsville Museum of Art, Huntsville, Alabama.

The exhibition is scheduled for January 14, 1978 through July 30. The exhibition will be shown for six consecutive months at the Von Braun Civic Center.

In addition to the computer art section of this special exhibition, the following international artists have committed works to the show: F. B. Baschet; Dan Flavin; Kieth Sonnier; Chryssa; Wen-Ying Tsai; Earl Reiback; Len Lye; James Seawright; Juan Downey; Chuck Prentiss; Otto Piene; Thomas Tadlock; Boyd Mefferd; and Stan Verderbeek.

Grace C. Hertlein, editor of CG&A, is coordinator of the computer art exhibition.

Invitations have been sent to fifty selected artists. Half of the invitations were sent to foreign artists, the other half to computer artists in the U.S. CG&A will print illustrations from the exhibition early in 1978.

APPENDIX

STYLISTIC ANALYSIS OF COMPUTER ART

I. ANALYSIS OF COMPONENT FORMS

A. Polygon Manipulations

- Evenly Decrementing Polygons
- Irregularly Decrementing Polygons
- Combinations of Related Polygon Forms
- Identical Polygon Forms with Asymmetric Sides
- Combinations of Non-identical Polygon Forms
- Overlapping Polygon Forms
- Experimental Polygon Forms
- Polygons within Varied Design State Forms

B. Continuous Line Designs

- Maze-Like Patterns
- Non-Maze Patterns or Abstract Forms
- Examples from Art History:
  - Primitive Cave and Wall Paintings, Pictographs, Petroglyphs
  - Archaic Pottery or Ceramic Derivations
  - Primitive Seals from India and Sumeria
  - Egyptian Hieroglyphics
  - Aztec, Babylonian Figure Forms
  - Persian Wall Reliefs, Sculpture
  - Archaic Texts, Illuminated Manuscripts, Tapestries
- Natural Derivations
- Combinations of Related Continuous Line Design Forms

C. Curvilinear Components

- Angular Components used with CUFIT to Achieve Curved Versions
- Irregular Components input via Rand Tablets and Digitizers
- Combinations of Angular and Curved Component Forms

D. Structural Components

- Repeated Groupings (Programmatically Looped) Horizontals, Verticals, or Diagonals
- Bauhaus Architectural Patterns
- Structures Constructed of Groupings of Polygon Forms (Buildings)
- Derivations from Any Specific Architect (Nervi, Corbusier, Mies, van der Rohe), Etc.
- Archaic Forms, Greek Columns, Aqueducts, Arch Forms
- Bridge Patterns
- Architectural Modules from Structural Architecture
- Combinations of Structural Forms

E. Contemporary Fine Art and Computer Art Derivations

- Josef Albers
- Piet Mondrian
- Pablo Picasso
- Maurice Escher
- Paul Klee
- Kenneth Knowlton
- Frank Stella
- Andy Warhol
- Derivations from Other Computer Artists (Define)
- Cybernetic Serendipity Derivations
- Other Artists (List)

F. Alpha-Numeric Forms

- Alpha-Numeric Design (Posters Anti Something)
- Alpha-Numeric Design (Posters Pro Something)
- Environmental Signs, or Combinations
- Advertising or Package Design
- Corporate Image Logos
- Combinations of Other Components <u>and</u> Alpha-Numerics
- Alpha-Numerics as Components

G. Natural Derivations

- Shell Forms
- Seed, Pod, Spore Forms
- Mushroom Forms
- Smaller Sea Forms (Non-Fish), including Microscopic Patterns
- Fish Forms and Larger Sea Forms
- Paleontology, Extinct, or Archaic Forms
- Beast Patterns (Mammals, Reptiles, Etc.)
- Butterflies, Moths, Insects
- Bird Forms
- Tree, Leaf Forms
- Flower and Grass Forms
- Dogs and Cats
- General Flora Forms
- Human Forms
- Other Natural Derivations (List)

H. Mathematical Forms or Derivations, Including Other Scientific Forms

- Flight Forms (Formulas for a Number of Points Emanating from a Given Point — See Illustrations)
- Mathematical Functions and/or Formulas
- Patterns from Fluid Dynamics
- Derivations from Molecular Model Building
- Shape Generation Forms Using Fourier Descriptors, Transformations
- Transformations from One Object into Another
- Crystallography
- Microscopic Patterns from Science
- Any Forms from Mathematics and/or Science (List)

II. ANALYSIS OF DESIGN STATE VARIATIONS

A. Increments and/or Decrements

- Even Decrements within the Form
- Irregular Decrements within the Form
- Even Decrements Departing from the Form
- Irregular Decrements Departing from the Form
- Decrements toward Specific Points or Areas of the Form (may vary within each ensuing form in a given work)

B. Offsets (With or Without Change of Scalar Value)

- Simple Offsets
- Complex Offsets
- Intermediate Offsets
- Asymmetric Offsets
- Symmetric Offsets
- Any of the Above with Changes of scalar Value

C. Rotations

- Regular, Evenly Repeated Rotations of the Form
- Irregular Rotations (May be Random within Each Sequential Form)
- Random Rotation of Angles Varying within Each Ensuing Form
- Complete Rotations (Full Circle)
- Incomplete Rotations (Partial Circle or Rotation)

D. Radiations

- Simple, Growing Scalar Values
- Complex, Growing Scalar Values
- Growing Scalar Value Forms, then Decreasing Values of Form
- Full Radiate Forms
- Incomplete or Partially Radiating Forms

E. Mirrors

- X Mirrors Only
- Y Mirrors Only
- X/Y Mirrors
- Combinations of Mirrors and Any of the Aforementioned Forms

F. Randomization

- One Form Only, Directional Components (One Way)
- Directional Forms Proceeding Several Ways (Up, Down, Right, Left)
- XSTART Use Only Randomized
- YSTART Use Only Randomized
- XSTART, YSTART, XFACTOR, YFACTOR Randomized
- Number of Times (ITIMES) (Lines, Rays, etc. in a Component) Randomized
- Angle Randomized
- Combinations of Above and Any of the Aforementioned

G. Three-Dimensional Views and Transformations

- Lorenz Transformations
- Fourier Transformations
- 3-D, Viewing the Component from Varied Angles
- General Transformations, One Object becomes Another
- Other Transformations (List)

H. Serial Imagery

- Block-Like Forms, Redundantly, without Negative Space
- Redundant Forms, with Use of Space as a Design Element
- Elongated X or Y Forms (Horizontal or Vertical Repetitions of Forms)
- Any Combinations of Serial Imagery with Varying Borders Around Forms
- Metamorphic (Changing) Serial Imagery
- Circular Imagery, Large to Small Forms
- Circular Serial Imagery, Small to Large Forms
- Block-Like Forms, Large to Small Forms
- Block-Like Forms, Small to Large Forms
- Combinations (List)

APPENDIX - Concluded

III. ANALYSIS OF FORM

A. Component or Module

- Highly Symmetrical
- Highly Asymmetrical
- Moderately Symmetrical
- Moderately Asymmetrical
- Complexity of Initial Pattern
- Simplicity of Initial Pattern
- Intermediate Pattern (Neither Complex nor Simple)
- Minimal or Essence Forms
- Highly Representational Patterns
- Semi-Abstract Modules
- Futuristic Patterns
- Organic Modules
- Non-Organic Modules
- Fine Art Derivations
- Contemporary Art Derivations
- Environmental Derivations
- Natural Derivations
- Microscopic Forms or Derivations
- Scientific Derivations (List)
- Other Derivative Sources (List)

B. Design State Variation Analysis

- Simplicity of Repetition of Form (Applications of Pattern)
- Complexity of Repetition of Form (Highly Complex)
- Intermediate Degrees of Repetition of Form
- Listing of Preferred Design State Variations
  - Analysis and Listing of Reasons for Such Design State Variation Use
  - Listing of Design States Used Thus Far
  - Listing of Design States Not Used (Reasons for Non-Use)

IV. ANALYSIS OF COLOR (PAPERS, INKS, PENS)

A. Papers and/or Pen Colors

- Hot Colors
- Cool Colors
- Transparent Inks
- Opaque Inks
- Colors within A Graphic
  - One Color
  - Two Colors
  - More Than Two Colors (List)
- Earth Colors
- Natural-Appearing
- Realistic Colors of Materials
- Contemporary Colors of Materials
- Unnatural Colors of Materials
- Analogous Colors
- Complementary Colors
- Other Colors (List)
- Non-Realistic Use of Materials
- Traditional Uses (List and Define)
- Psychedelic (DayGlo or Black-Light)
- Experimental Uses (Discuss)
- Futuristic (Foils)

B. Materials (Papers or Other Materials)

- Traditional Art Papers (List)
- Contemporary Papers from Art or Applied Art (List)
- Industrial Materials
- Multi-Media Materials (List)

V. ANALYSIS OF INPUT, PROGRAMMING, AND EXECUTION MODES OF WORKING

A. Programming, Running/Execution Methods

- Totally Preplanned (No Participation)
- Allowance for Participant Running/Execution
- Heuristic Programming and Running (No Intervention — Totally Computer Designed, Executed)

B. Input Methods

- Rand Tablet (or Digitized Methods)
- Cards and X/Y Identification of Coordinates
- Joystick
- Mouse or Cursor
- Lightpen
- Combinations (List)

C. Output Methods and Product

- Static Graphics on Art or Industrial Papers
- Films, Non-Static, Moving Graphics
- General Multi-Media (Define and List)

D. Programming and Design State Variation Methods

- Canned Routines (Cards)
- Canned Software (Library)
- Personal Writing of All Programs and Design State Variation Routines
- Programmer Makes Decisions
- Heuristic Systems Make Decisions
- Intermediate States
- Others (List and Define)

BELOW: Related designs in one composition, "Beasts in the Field" by the author.