

This paper presents a series of graphic design experiments using an experimental color graphic display system. Design principles and capabilities of the experimental color graphic display system are discussed from a graphic designer's point of view. The system allows a designer to choose freely among 128 different colors, various form modes, and collage capabilities, including image mixing. The designer need be neither a programmer nor one who understands the technical aspects of the system to use it creatively. Experimental results are shown visually here, some of which have been used as cover designs for IBM publications.

Experiments in computer-aided graphic expression

by J. F. Musgrave

Graphic design serves either a communications purpose or a decorative purpose. Such designs can be pictorial, typographic, or both, and can be created for use directly or for reproduction through conversion to another medium, such as by duplication, transmission, or projection.¹ Recent innovations in computing systems now offer artists and designers—without a knowledge of programming or electronics—an alternate to such standard tools as brush or drafting equipment. Computer systems can now respond to the hand of the designer, displaying a creative image on a color video monitor that can be photographed for numerous applications. This paper discusses and illustrates certain capabilities encountered in adapting interactive computer graphic techniques to creative design. Visual experiments performed are presented together with a brief synopsis of related current work of others in this field.²⁻¹⁰

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Design principles and concepts

Consider first certain design principles and concepts in historical perspective. The characteristic that distinguishes the graphic designer from the painter or sculptor is primarily one of pragmatics.¹¹ For the graphic designer, *design* must functionally solve specific problems and simultaneously be artistically pleasing. External requirements and limitations, such as subject, reproducibility, and cost in part determine the form of the solution. Like other specialized areas, such as architecture, graphic design is the "embodiment of form and function: the beautiful and the useful."¹² This principle is rooted in the evolution that occurred as technology and art changed in the late 1800s and early 1900s.

form and function

William Morris, who started the Arts and Crafts Movement in Europe in the late 1800s, stated that art should become involved in such practical design endeavors as that of furniture. In the early 1900s, two American architects, Louis Sullivan and Frank Lloyd Wright,¹³ asserted that *form* (appearance) should follow *function* (purpose), a principle that has developed as a way of reconciling art and utility. Wright also spoke of the machine as a positive force with which the artist must learn to work.¹⁴ In 1919, Walter Gropius opened Staatliches Bauhaus, a school that was designed to be a consulting art center for industry and the trades. The goal of the Bauhaus, as it has come to be known, was to teach the application of such aesthetic elements as the rules of rhythm, proportion, light values, and full or empty spaces to the practical arts in the world in which we live. For Gropius, the machine was the modern medium of design to which designers must come to terms.

Using the principles of *form* and *function*, the communications graphic designer approaches an assignment from several vantage points and with a variety of fundamental questions. For whom is the design being created? Further, how will the design be produced? Will it be duplicated, transmitted, or projected? Production considerations at this point are essential. For example, if the design is intended for publication or other print media, the designer must supply the proper mechanical artwork for the printing process. Other factors for consideration include cost/performance constraints.

The experimental graphics system discussed in this paper is shown to meet these many criteria (function), while at the same time allowing one to produce pleasing and novel designs (form). Just as Gropius, Morris, Sullivan, and Wright had previously done, today the designer can again choose to come to terms with technology, now in the form of the computer. The experiments in

graphics discussed in this paper show that the computer can be used as a design tool that responds to the creative decisions of the graphic designer.

Computer-aided graphic expression

Computer-aided graphic expression is a responsive new medium that employs a computer, video display equipment, and related control hardware and programming. Computer-aided graphic expression is still in the embryonic stages of exploration for graphic design applications. One version of this approach, an experimental color graphic display system at the IBM Research Laboratory in San Jose, California, has been programmed to provide a creatively flexible medium for a graphic designer.

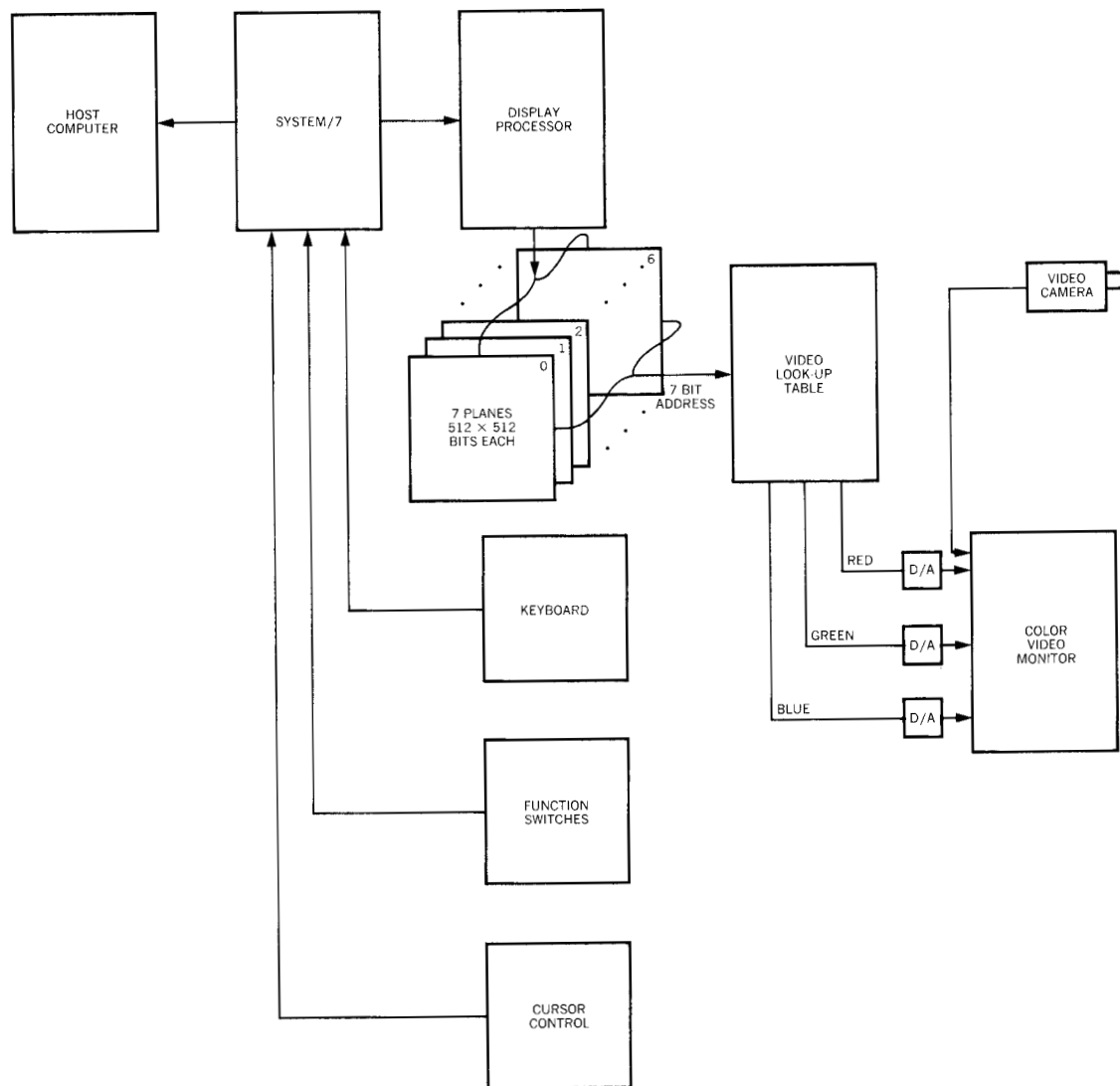
The system, shown schematically in Figure 1, consists of a digital display generator connected to a color video monitor. In the display generator, a vector generator (which determines the position and size of a displayed line or pattern) and a character generator (which produces the internal code for characters or non-alphanumeric picture elements within the line or pattern) are used to set bit patterns into the planes of a "refresh" storage. Timing generators read through this storage, add synchronization signals, and provide three video carrier signals (one for each visual primary color—red, blue, and green) to the monitor via digital-to-analog converters (D/A).

Each plane of the refresh storage is an array of 512 by 512 bits, which corresponds to the array of 512 by 512 picture elements, or "pels," that can be displayed on the monitor. There are seven planes of storage that together provide a seven-bit color number for each pel. The color number acts as a seven-bit address to a Video Lookup Table (VLT). Each of the 128 addressable locations in the VLT has a twelve-bit word that determines the red, green, and blue intensities (four bits each) that combine on the screen of the monitor to form a specific color. There are 16 possible intensity levels for each primary color, and hence 16^3 (or 4096) possible hue/intensity choices. Because of the limiting capacity of the VLT, however, only 128 distinct colors can appear in any one picture, and the user must choose the ones that are to be made available when the VLT is being loaded for use.

128 colors

The vector generator can start or end on any pel on the display. The vector generator sets color numbers into the refresh storage planes in a proper pattern to approximate a straight line in the chosen color. Thus the commands to the display generator to draw a colored line are as follows: Set Color 1; Start x, y; End x, y.

Figure 1 The experimental color graphic display system hardware



The display generator is interfaced to a minicomputer via 16 bi-directional data lines and associated control lines. Further, the system has a keyboard, joystick for cursor control to designate the correct working positions on the screen, and option-selection or function switches.

The minicomputer can also be programmed to communicate via a standard RS232C telecommunications interface with a host (System/360 or System/370) computer, from 110 to 9600 baud (bits/s). This configuration is termed a terminal or stand-alone mode¹⁵ of operation in which the minicomputer buffers and formats the data

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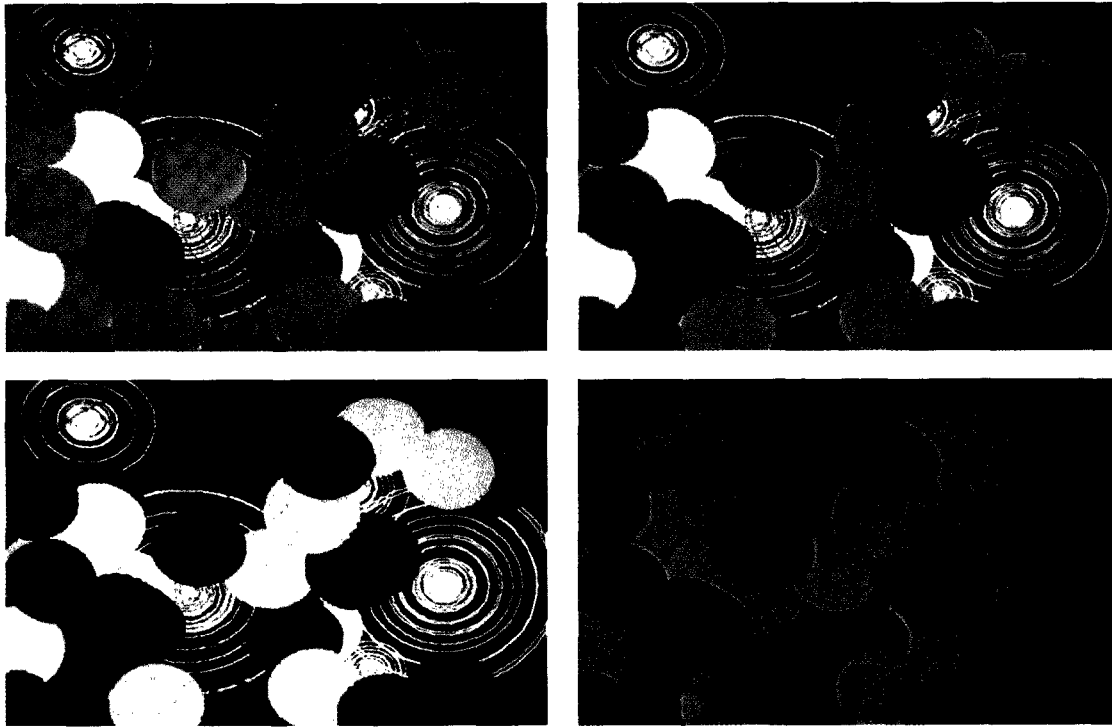
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Figure 3 Changes in psychic effect of three different designs (a, b, and c) as colors are altered





(C)

Color

A designer's attitude toward color is a determining factor for graphic style. The use of color can be divided into the following general approaches:

- *Light functions to reveal forms.* Here, color is used to define forms (or objects) and is subordinate to them. Leonardo da Vinci was a proponent of this approach, which is sometimes called "color as imitation."
- *Light functions to reveal color.* Here, the illusionistic representation of form is subordinate to color. This is the color attitude developed by the Impressionist painters.
- *Light, form, and color are one.* This idea underlies the development of much contemporary art since the era of the Impressionists. Laszlo Moholy-Nagy, Wassily Kandinsky, and Josef Albers, all teachers at the Bauhaus, subscribed to this view. Here, color is used more for the direct perceptual sensation it can evoke than for symbolism or imitation.

**visual
selection**

The experimental graphic display system offers the user a selection of 128 available colors at one time. The selection of color is made visually. This is an extremely important advantage to a graphic designer who gives equal importance to light, form, and color. All 128 colors are displayed at the bottom of the video monitor. By moving a joystick, the designer brings either a cross hair or other cursor symbols into the center of the chosen color, and is then able to bring that color onto the drawing area of the screen. As the designer creates, an immediate image is generated, and the designer can continue to make spontaneous color decisions visually. Figure 2 shows the development of a design as visual color decisions were made.

Immediate image

**light,
color,
form**

The immediate image for judgment is extremely important to a designer who has discarded the traditional classical approach. The classical approach may be seen by examining the technique that had been developed by Renaissance painters of color glazes over monochromatic underpaintings. Here, color functions as an embellishment rather than as the material from which the picture is constructed.¹⁷

In contrast, the graphic designs presented in this paper were mentally explored by the designer prior to their creation because of their specific function. The form of the designs was not drawn out in advance; rather, it was developed as the designer made visual aesthetic decisions based on the equal merits of light, color, and form while using the system. Because the experimental color graphic display system is programmed to respond to the hand of the designer with the immediate image available for judgment, this light-color-form process is possible.

**color
change**

A key advantage of this system has been found to be its capability of allowing complete and instant color changes without altering form (from the layout point of view). This enables the designer to explore extensively the relative nature of color. By altering colors in a design, the psychic effect of the design is altered. Figure 3 shows the changes that occur to a design when the color is altered.

**cost/
performance
considerations**

From a practical point of view, the color capability and the immediate image for judgment are advantageous to a graphic designer when cost/performance considerations are relevant. With 128 colors at hand, tremendous creative opportunity exists. Presently, a designer might choose colored papers or paint for a large color selection, thus requiring lengthy mechanical hand work as the de-

sign evolves. With the experimental color graphic display system, no mixing of paint or matching of colors is required. A given color can be selected instantly over and over again. Further, there is no layout work that involves the cutting of paper, gluing, or pasting. Each design described in this paper took an average time of one to two hours for creative evolution. One estimates that the time involved in the mechanics of painting or collage techniques for similar designs would be a minimum average time of six to eight hours each. If the designer were to alter the colors completely, the mechanics of the design would require complete redoing.

Also, with the experimental graphic display system, prior to incurring the sometimes sizeable expense of prints and dummy layouts, the designer is able to obtain audience reaction immediately, an important consideration when approval or deadline factors are present.

If we examine work being done by others today in graphics and image processing using computers, we find work representative of light functioning to reveal form and light functioning to reveal color, as summarized at the beginning of this section. Blinn and Newell² have extended an algorithm developed in 1974 by Catmull¹⁸ for rendering images of bivariate surface patches as areas of simulated texture and lighting. From the graphic design standpoint, their paper addresses the attitude that light functions to reveal forms, and color functions to define form. Blinn and Newell are able to create the appearance of shiny surfaces, visual effects seen as the results of a specific direction of light source, and the introduction of textured patterns (which function as local color) on the surface of an object. Their paper presents a method of generating images with a higher degree of naturalism than was previously possible with the aid of a computer.

naturalism

A form of graphics that follows the attitude that light functions to reveal color (the Impressionists' view presented earlier in this section) is the work of Manning. Manning has developed a form of graphics that he calls Blocpix.³ Manning uses computer-developed patterns in conjunction with an optical processor to obtain colorful abstractions. He also uses photographs of faces as input to his optical processor.⁴ In the Blocpix approach there is an illusionistic representation of form that is subordinate to Manning's square-pattern divisionistic approach to color.

impressionism

Similar in visual effect is some of the work of Lillian Schwartz presented in a film entitled *The Artist and the Computer*.¹⁹ With the use of a computer, Schwartz was able to divisionalize photographs and present them in a manner that recalls the work of Seurat.²⁰

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**mechanics
of form**

Today, if a designer feels uncomfortable with a particular tool, he may avoid certain design possibilities simply to avoid using that tool. Drafting equipment provides an excellent example. The mixing and thinning of paint to a consistency that flows from the ruling attachment on a compass without smearing the design can be tedious and time-consuming.

The form modes on the experimental graphic display system are used with such ease that the designer quickly loses all inhibitions or fear of using certain techniques for lack of skill. With the form modes, the designer has control of a medium that is fully capable of producing effects that resemble those produced by drafting equipment, pencils, chalk, paint and brush, paint and knife, and other traditional media—all without the need of practicing hand control of the diversity of tools.

**computer
art—art
computer**

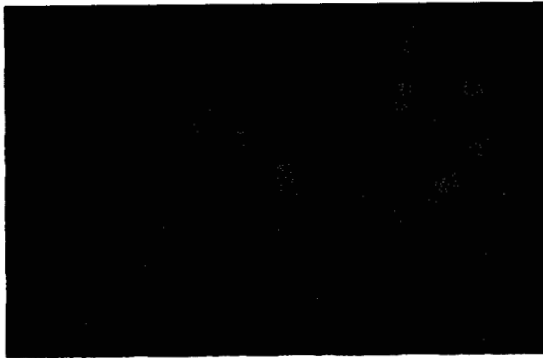
Computer-aided graphics has been criticized as giving an overly precise appearance to forms. For example, Tyler⁶ became interested in computer-aided graphics through experiments in visual perception because he was particularly interested in avoiding line-dominated forms that he saw as typifying computer graphic forms. In the works of Longson, Kolomyjec, Knowlton, and Mohr,⁷ line and grid patterns do indeed appear to predominate. Kawano²² offers a possible explanation. Kawano stated the need for a distinction between "computer art" and "art computer." *Computer art* might be characterized as a style or school of modern art that uses a computer as an additional tool for the artist. In contrast, *art computer* is characterized as a system that produces graphic images that correspond to the level of a program by a given programmer, and behaves by the control of that program. Creative freedom in an art computer system is therefore restricted to each program or variation of programs available.

The graphic images and methods with which I have experimented are computer art. It is perhaps the lack of distinctions between art computer images and computer art that has led to assumptions that computer-aided graphics is mechanical and line dominated.

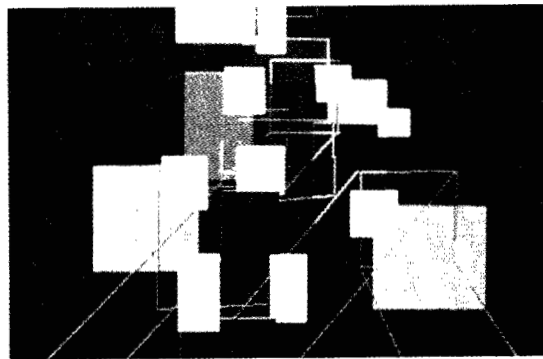
Because of this lack of clarity in terminology, I have not used the term computer art in this paper and have chosen instead to describe these experiments as "computer-aided graphic expression." Although the experimental graphic display system is capable of aiding the designer to produce mechanical forms, this is not its primary purpose. To the graphic designer, the importance of the computer-aided graphics system discussed in this paper is the freedom the system offers from the mechanics of form.

Figure 4 The form modes

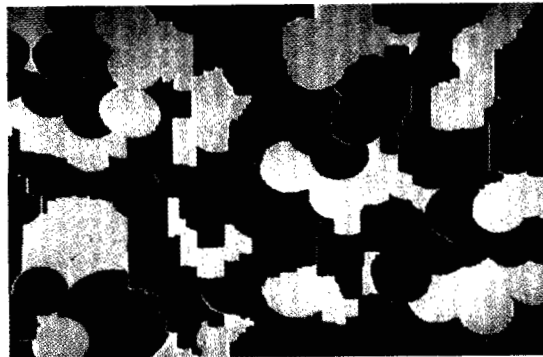
CONTINUOUS LINES



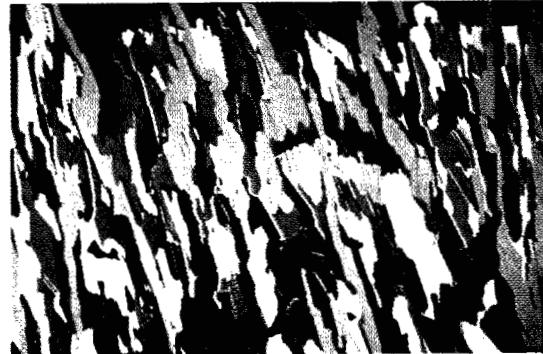
SOLID RECTANGLES AND LINES



SOLID RECTANGLES AND CIRCLES WITH ROTATION



COLORED AREAS WITH ROTATION



LINES WITH ROTATION



ROTATION OF LINES AND CIRCLES



CIRCLES



Collage

The use of textural variety to achieve a satisfying structural balance in forms two-dimensionally is known as "collage." The origin of the technique is uncertain, but it is generally associated with the Cubist painter, Georges Braque.²³ Braque used the collage technique to reveal the richness of colors and textures he believed had been ignored in such everyday materials as paper, fabric, and wood. Braque was seeking to deny the classical technique as a necessity to artistic validity. He used surface texture as an integral decorative factor, not merely as local color on form. (Because of the nature of the technique discussed here, it also has some of the characteristics of montage.) Today the collage technique is sometimes used by graphic designers to enhance imagery and intensify visualizations. Rand¹² speaks of collages as visual puzzles that the viewer may perceive and decipher for himself. The viewer may thus participate in the creative process.

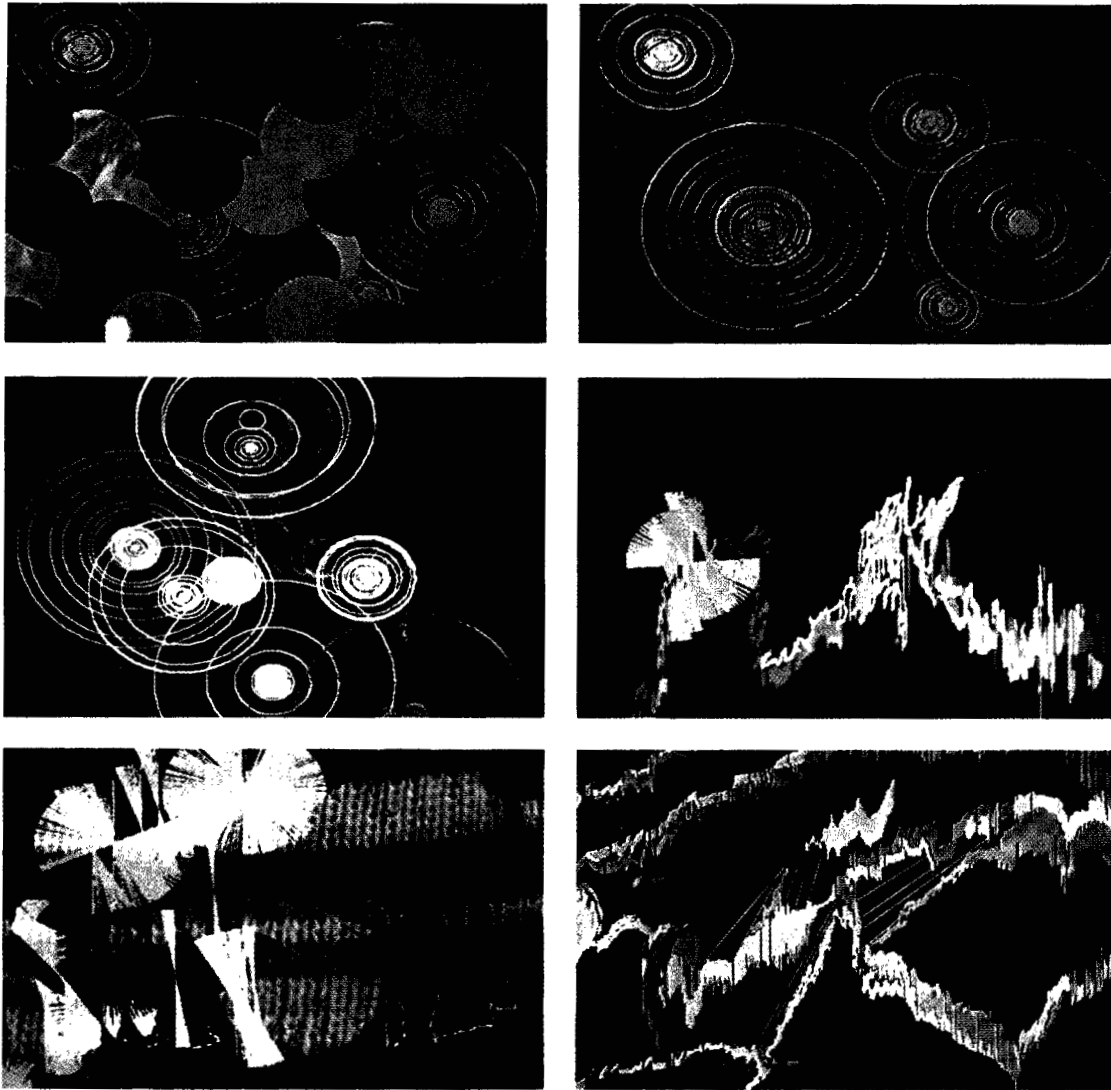
image mixing

The experimental graphic display system offers the designer the opportunity to explore collage technique through *image mixing*. With image mixing, a video camera brings an image onto the video display screen. The designer may then use the 128-color capability along with the form modes to create video collages by superimposing color and form upon the original image. Image mixing can also be used for annotating a drawing or the image of an object, thereby giving the illusion of three dimensions. Figure 5 shows designs that were created this way.

texture

With the image mixing capability, texture can be introduced as a design element in computer-assisted graphics. The designer can bring a textured image onto the display screen and then add color to the image. He can then work on top of the image with form modes to create collage-like graphic designs. Image mixing may also be used to create transparent color overlay effects, as shown in Figure 6. This is another way for the designer to integrate textural effects into a design. The graphic designer is also able to enhance the video-collage effect by modifying the final form of a design outside the computer graphics system. Consider the enhancement of video raster texture. When a photograph is taken of a design from the video display screen, the raster lines of the monitor appear in the photograph. These lines contribute a textural quality to the design that resembles that of grainy paper or fabric. This low-contrast textural effect can be intensified by inducing contrast. For example, a design can be silhouetted and then printed by the four-color process on a contrasting background that has been printed in a flat color. A collage effect is thus created by combining lithographic techniques with those of computer-assisted graphics.

Figure 5 Creating a collage by image mixing



Textural effects can also be produced by using the form modes. Figure 7 shows a design that resembles needlework. Embroidery, applique, and quilting have long been used photographically for their textures as design solutions.²⁴ Similar effects can be created with the experimental graphic display system. Collage-like effects that the designer may explore with the experimental graphic display system can thus be advantageous from a cost/performance point of view in the production of artwork for publication.

Because collage techniques enhance imagery, others are experimenting with computer graphic methods for producing collage-like imagery.

Figure 6 Using image mixing to create a transparent color overlay effect

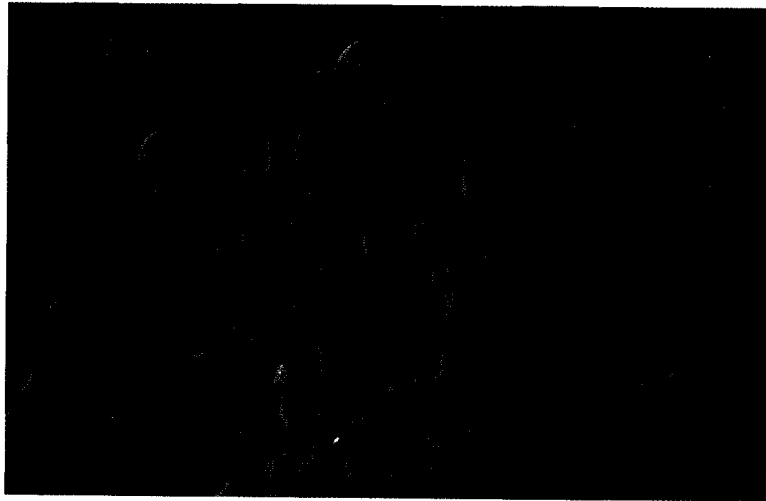
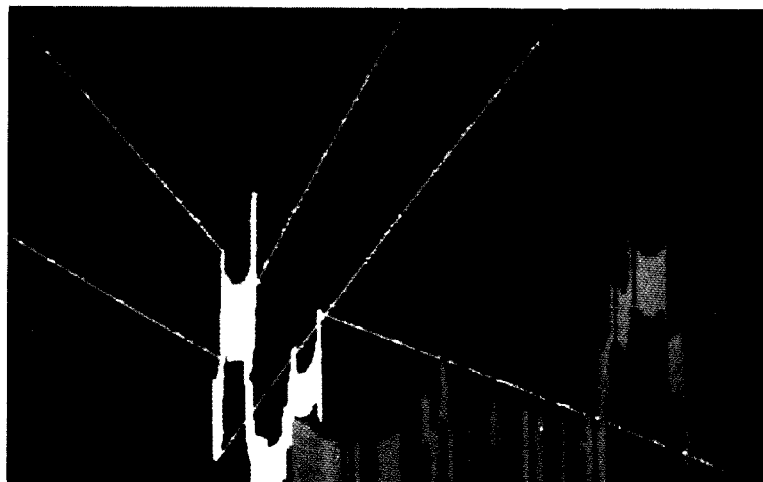
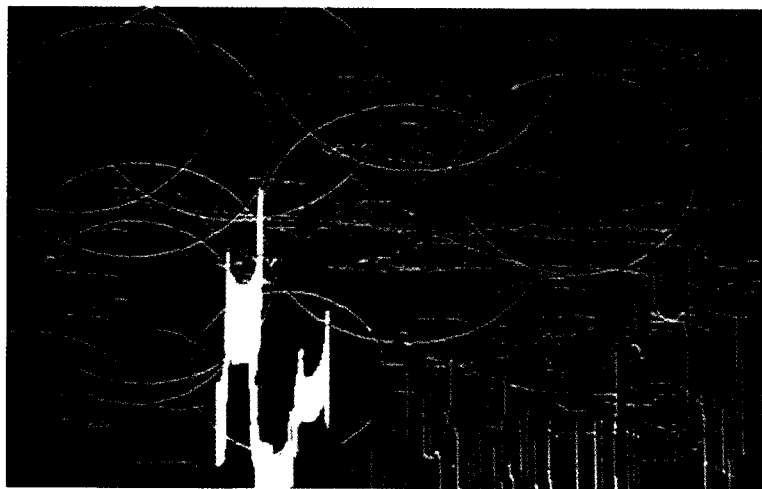


Figure 7 Using the form modes to create the appearance of needlework



Tyler⁶ has developed some interesting collage effects using a computer and a microfilm plotter. Mallery¹⁰ has developed textural effects using a two-color plotter, and Leavitt²⁵ has worked with a light pen attachment to create textural patterns based on line interaction. With the experimental graphic display system discussed in this paper, however, the graphic designer does not have to write (or have written) programs to create each collage, nor is he restricted to a specific form. The designer is free to explore a vast range of visual possibilities.

Portfolio

The graphic designer is able to store and retrieve designs with the experimental graphic display system. Thus, for example, the designer can create several designs and then display them sequentially for audience reaction and approval. Rapid approval could result in a considerable cost saving before there has been an investment in processing, printing, or if there are deadline considerations. Also, if the design is interrupted during the creative process, the design can be stored and then recalled when work can continue. This is advantageous for the occasional times that a designer creates a design, but is not totally satisfied with it. Finally, a stored record can be made of the designer's work over a long period of time, since most designers and artists keep a portfolio of their work.

Summary and concluding remarks

The graphic display system discussed in this paper responds flexibly to the creative imagination of the designer. The selection of 128 different colors, with the capability of completely changing the colors while retaining the form of a design, offers immediate images in a variety of color combinations and allows for various collage techniques.

With this system there is the added cost/performance advantage of reducing the investment in tools, and in the photographic processing not needed for collage techniques. Several designs made during one week of design activity using the system have subsequently been used for covers of IBM publications.¹⁶ With the use of computer storage, the designer may retain a portfolio, or develop several design alternatives before investing in dummy layouts or printing. Computers now offer designers the opportunity to develop creatively in ways that we are just beginning to explore. Technology makes it possible for the creative artist to step away from traditional tools and interact with the computer in exciting and innovative ways.

**cost/performance
advantage**

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I wish to thank the management of the IBM Research Laboratory at San Jose, California, for providing their facilities and for making possible the experiments in creative art discussed in this paper. I especially thank Robin Williams, creator of the experimental graphics program, and Gary M. Giddings for their technical discussions, and Phyllis Reisner for teaching me the basic function of the system. Also, thanks to Art Appel, IBM Thomas J. Watson Research Center, Yorktown Heights, New York, for his encouragement and interest in this project.

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