Interactive Color Graphic Composition at C-MU

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Abstract

While various systems have existed for several years allowing interactive on-screen composition of color graphic enteties, only recently have persons trained in the graphic arts turned their attention to the design and development of these systems with the goal that they be quick and easy to learn, visually appealing, powerful, and pleasant to use. This has prompted research and development efforts at C-MU on two systems with these goals-- *C-MU PAINT*[1], a drawing and painting system, and *FONDSY*, a *FONt Design SYstem*. These systems allow a person with little or no background in computing to compose color images with text, line art, and hand painted images with as little as twenty minutes of instruction. Interaction is through an electronic tablet, and control of the system is through an on-screen tree-structured menu system, so that no memorization of commands is necessary.

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Electronic Drawing Systems for Artists

Probably the first artist to make use of an electronic drawing system, was Mary Ellen Bute, who, in the early 1920's worked with with a primative *CRT*, with a joystick control, allowing her to draw directly on the screen. Computer control came nearly 40 years later, with Ivan Sutherland's *Sketchpad* [3]. Since that time, processors and memories have dropped drastically in price, and high resolution color computer graphics equipment is now within the price range of many. Color computer graphics composition systems now exist for a wide variety of applications. The *Genigraphics* system, produced by a General Electric division, is one well known expample, oriented toward production of business graphics. A recent survey by *Broadcast Management/Engineering* [1] lists some 20 paint systems for generation of artwork for broadcast TV applications. Few systems exist, however, oriented toward graphic arts production work. Such systems should at least allow a graphic artist to sit at a console and develop high resolution original artwork consisting of hand drawn linework, text, colored areas, textures, and photographic elements, allowing direct output of the composite images to a high quality, high resolution hard copy device. Further, to be of use, the system must be designed specifically for the convenience of the designer, rather than that of the computer, or the programmer of the system.

The Design Problem of Designing Systems for Designers

The most significant problems in the design of graphic systems for use by designers are design problems. To these problems, there exists no solution that may be arrived at through analytic means. There exists no formula, or set of rules that one may follow to achieve a good design solution, whether to an architectural, product, graphic, or other design problem. Rules can help a designer to avoid certain pitfalls, but they can never be the sole basis for a design. The composition of an interactive computer- graphic system is such a problem. Rules may remind a system designer not to require input of a user without prompting him, and may help him to avoid red text on a blue background, but they cannot guide him to a good design.

Screen layout of a system, for instance, is a very important aspect of the

system. The design should be well thought out, and present information in an orderly and pleasant manner. The combinations of colors used on the screen should be carefully planned and matched. Devices and manners for entering and communicating information must be devised that take a great step forward from the current typical system utilizing alphanumeric questions and answers as the only form of user interaction.

The design of all of these elements are similar to problems traditionally dealt with by designers. For instance, the invention of new tools to solve old problems is the forte of the industrial designer. The arranging of graphics and text to communicate information has been the traditional work of the graphic designer. Here, only the presentation medium has changed, not the nature of the problems to be addressed, hence the call must be made for designers to apply their talents to the design of design systems.

Human Factors

One of the weaknesses of most systems currently available is the lack of attention paid to human factors considerations. Regardless of the capabilities of a given system, it is of little value if it is difficult to learn the use of the system, and slow to use for the experienced user. To be of value, a system must be designed with the user in mind. This suggests that a system should perhaps be custom designed for each user. While this may not be possible as such, a number of features may be provided in a system to make it easy to learn, forgiving of mistakes, and easily customized to fit any particular user's needs.

By separating the functional parts of a system, the user interface portion may reside as a separate part, one that may be changed easily, and customized as needed, without affecting the functionality of the system. This allows the development of separate versions of a system, each having identical functionality, yet each having a different interface, oriented to a particular group of users. Thus, for instance, a set of basic graphic functions may be packaged into an *advertising design system*, a *packaging design system*, a *font design system*, or a general purpose *paint system*.

Of primary importance is the ability of a system to grow with its users. The system should be considerate of the beginning user, allowing easy learning

of the system, but yet not slow down the experienced user with extensive prompts, etc. Menuing systems with obvious command names, for instance, allow a beginning user easy access to the functions of a system, however allowing command strings to be entered that would duplicate the function options available through the menus allows an experienced user to concentrate his attention on the object he is designing, without having to look away, to pick a command from a menu.

The composition of a screen layout is an important design consideration. The selection of colors, and the organization of the screen must be carefully thought out, with the comfort of the frequent user being the ultimate criterion.

C-MU PAINT, a drawing and painting system

C-MU PAINT was developed to provide general drawing and painting capabilities to a wide range of users in various diciplines. The system assumes no prior computing experience, and is designed to be powerful, easy to learn, and easy to understand.

The system is additionally designed to be low-cost, and operable independent of external computing resources. The system uses an *AED-512* color graphic terminal, having a 512x512 frame buffer, with 8 bits of color information. Having a lookup table with 24 bits of information per color, this allows over 16 million color combinations, with 256 on the screen at any one time. Processing is performed on a *DEC LSI/11-03*, an inexpensive, general purpose mini-computer. All programming is done in *PASCAL*, to allow easy software transportability. Currently, all storage is on *RX02* floppy disks, chosen for their relatively low cost, and to allow a wide range of users to have direct control over their storage. The primary interaction devices are a digitizing tablet and pen, and the keyboard of the *AED*. The joystick provided with the *AED* is not used due to the difficulty in accurately manipulating the screen cursor with the joystick, as compared to the tablet.

Interaction with the system is provided primarily through the tablet. By moving the pen accross the tablet, a user may draw or paint on the *AED* screen. An interactive on-screen menuing system is provided offering the user a range of palettes, and an interactive palette generation mechanism.

Selection of the various commands provided in the paint system may be effected through an on-screen menuing system, or by selecting a key code on the alphanumeric keyboard of the *AED*.

The system contains a wide range of graphic elements for a user to work with, including lines and circles of various thicknesses, squares of various sizes, grids, points, etc. The system allows these commands to be built up in various ways, allowing the development of complex graphic *macros*. For instance, a user may define a graphic element as being a series of concentric circles, in the range of colors of a palette. When used with a palette consisting of a smooth range of colors, this can give the effect of small spheres. The user may then draw with these on the screen, locating them with the cursor, and setting them by pressing down with the electronic pen.

Palettes and Color Mixing

A unique aspect of the *CMU-PAINT* system is the system of palettes and color mixing. A great weakness of most systems currently available is the difficulty of working with color. Those systems having on-screen color palettes tend to have matrices of tiny squares of colors, representing the full range of colors available to the artist. The weakness of these systems is that small squares, placed close together, do not allow an artist to accurately perceive a color. After numerous arrangements were tried, an optimum size was determined, allowing a palette of 16 colors across the top of the screen. To accomodate a wider range of colors, a "palette shifter" mechanism was designed, whereby an artist may select any of the palettes for use in graphic composition. Designed like a push-button phone mechanism, a user need only "push a button" to gain access to any of the nine palettes. The packaging of the palettes thus allows a user to group his colors as desired. He may, for instance generate shades of blue in palette 1 (which may be done with a single command), shades of green in palette 2, and so forth.

Another important innovation is the use of scale bars for color mixing. Just below the palette area are three *virtual potentiometer* scale bars allowing a user to interactively select the amounts of the *additive primaries*, red, green, and blue, or the *subtractive primaries*, cyan, yellow, and magenta. Since the width of a particular scale bar represents the quantity of

that primary within the composite color, the display offers an intuitively obvious, and visually oriented, means of color mixing, not dependent upon memorization of percentages, or references to printed color tables. Next to the scale bars, additionally, is a digital readout of the relative color primary quantities, so that colors may be digitally specified when desired. While some systems do allow scale bar color modulation, none to date offers the communicatively obvious analog representation presented here, where the size of the colored rectangles in the scale bars gives a direct *visual* representation of the quantities of the (additive or subtractive) primaries being used.

A very significant new feature, currently under under development, allows color mixing on the basis of *hue, saturation, and value* (HSV). While a number of systems feature this kind of mixing, work at the graphics lab has led to the development of a new algorithim for the conversion between the RGB primaries, and HSV, and a new mechanism has been devised for the selection of the HSV values, allowing a user far greater facility in manipulating the HSV parameters. Previous algorithms for this conversion [2] have been based upon a projection of the RGB color cube to a plane, resulting in a hexcone representation of hue, wherein red, green, and blue are equally spaced. This results in a wide range of greens and blues within the plane of hue, but a very narrow range of yellows and oranges. The new algorithm evenly spaces the hues, giving equal spacing to red, *yellow*, and blue, resulting in an even distribution of all hues. Due to the circular nature of hue, as defined in the Munsell system, the device designed is a virtual dial on the screen, wherein a person can "dial up" any hue. To provide feedback on the selection of hue, the face of the dial changes to the pure hue indicated by each movement of the hand on the dial. Scale bars appear on the side of the dial to indicate value and saturation.

Color Separations

CMU-Paint offers a facility to generate color separations of any composite image with a single command. This allows a designer not only to review the separations, but also to use the calculated separations as direct output to a digital scanning device, directly producing the separations required for reproduction by conventional printing means. This then eliminates the need

for the production of an intermediate photographic original.

FONDSY, a FONt Design SYstem

FONDSY is a program designed to work closely with, yet separately from, the *CMU-Paint* system. FONDSY is essentially a design and drafting tool, specifically tailored to the needs of the font and symbol designer. At the top of the screen appears a palette of sixteen colors, as in the paint system. Palettes may be composed using the paint system, and be subsequently read in by FONDSY on demand, thus allowing the same 16.8 million color possibilities. FONDSY was designed to provide a powerful tool to font designers that could be mastered with 15 minutes of instruction. In order to do this, all commands were placed within a hierarchical menuing system, organized by function, with text labels chosen to have obvious meanings. Under *point* functions, for instance, three choices appear-- *move, add*, and *kill*. These functions can be easily explained, that *move* will allow a user to move a point, *add* will allow a user to add a point between two points, and *kill* will allow a user to remove a point. With that instruction, the command names become obvious, whereas on many other systems, cryptic abbreviations such as *mp*, for *move point* are used.

To make the processes of the system clear to users, the system provides extensive graphic feedback. Upon selecting a command such as *move*, the system gives the user instant feedback-- the *move* "button" lights up in pink, and every point in the object he is designing appears as a dot, blinking from pale blue to white. Upon selection of a point with the cursor, the user again gets feedback that his selection is understood, by having the point appear as a red blinking rectangle. The user may then select a new location for the point, and press down on the pen, at which the character will be redrawn, reflecting the change.

The composition of the screen was devised to address the special needs of the font designer. Two work areas are provided, allowing the designer to take advantage of the similarities between characters of a given font. Thus he may create a character like a lower case *"h"* from a lower case *"n"* by simply modifying a copy of the character. Having created the *n* on the left screen, for instance, he would simply copy the *n* to the adjacent screen, and moving two points to create the *h*. Grids are provided for the convenience of

the user. The colors of the grids were carefully selected for the visual and psychological comfort of the user. Pale blue grid lines with pale pink delimiting lines have two advantages: They present an appearance of a working surface familiar to a font designer-- standard graph paper, and additionally, the closeness of saturation and value between the blue, pink, and white minimizes the blinking effect that would otherwise be irritating on an interlaced raster graphic display. Coarse or fine grids may be used, with an optional *"gravity field"* on them, which allows a user to draw lines exactly between grid line intersection points.

The system allows easy definition of curved forms, by providing a spline curve facility. A user may define a rough polygonal form, and then designate certain points on the polygon to define a curved region. This will effectively smooth any portion of a polygonal form. Unlike many other systems having spline curve capabilities, however, users may easily modify the curves he has defined. By moving the points of the original polygon he drew, that are within the curved area, he can *stretch* the curve in any way. The procedure for this is identical to the *move point* procedure outlined above. Currently the various forms of curve representation and computation are being evaluated to determine which is easiest for a font designer to work with.

The system allows fonts to be defined and stored in files on floppy disks for retrieval by FONDSY or composition systems that will compose text, and allow superimposition over other graphics. These files are stored at a resolution of over 64,000 lines, so that fonts defined on FONDSY may be scaled to any point size, rotated, or moved with virtually no degeneration of the character forms. These files, once created, may at any time again be accessed by FONDSY to update the fonts, or to create new fonts based on old.

Creating an Environment for the Continued Development of Fine Arts Systems and Software

In order to continue the development and use of electronic systems for design purposes, the College of Fine Arts is embarking on an ambitious program integrating computers into the undergraduate curriculum. This will include the advent of a studio course in art, working on the paint system, starting this fall. The following spring, a course will be introduced in the

design department, using the various computer aided design and drafting facilities developed on campus. Additionally, courses will be offered on computer graphics, both at a beginning *(survey)*, and advanced *(programming)* levels, ensuring continued integration of competent designers into the computing environment, both to aid in their day-to-day work, and to aid in the design and development of the systems themselves, thus enabling them to customize the systems for their own purposes.

In order to support this new direction, a new laboratory for computer graphics is now being formed. Under the direction of the author, the new laboratory will provide both a center for computer graphics research, and a production environment for students, professors, and staff. In addition to graphic arts applications, facilities are and will be developed for computer- aided architectural design and drafting, industrial design, and animation. It is hoped that by working closely with industry, the techniques and systems developed may be dissemenated for commercial applications.

Future Directions

The current orientation in the development of computer graphic composition systems at C-MU is toward the continued evolution of the current systems to provide a complete high resolution system for graphic composition, including not only hand drawn graphics, but also photographically entered, and computer-generated, images. Combining these with image processing and manipulation capabilities, the realm of image production capabilities and applications will be virtually unlimited.

One of the shortcomings of the current technology for computer graphics is the lack of a high quality, high resolution, low cost output device. While devices such as high resolution film recorders exist, and digital output to conventional scanners may be used to provide color separations, and conventional color proofs, fine arts applications would ideally be allowed a variety of substrates, and a variety of pigment types. C-MU researchers, including the author, are currently discussing the possibilities of joint research efforts in this direction with industry leaders.

REFERENCES

[1] Black, P.
Digital Art/Paint Systems: Are They Right for You?
Broadcast Management/ Engineering 18(2):67-74, Feb., 1982.

[2] Smith, A. R.
Color Gamut Transform Pairs.
In *Computer Graphics*, pages 12-19. ACM/SIGGRAPH, August, 1978.

[3] Sutherland, I. E.
SKETCHPAD: A Man-Machine Graphical Communication System.
In *SJCC*. Spartan Books, Baltimore, MD, 1963.