DIGITAL TRANSPARENCY APPLIED TO INTERACTIVE MAPPING

by

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abstract

This report documents research in computer generated transparency at the Architecture Machine Group. As background material a brief description of the study of phenomenal transparency is presented. Its implementation on a raster scan display system is described as are various applications in the context of mapping. These applications illustrate the use of transparency as a technique to display information with reduced clutter and improved continuity. The computer's computational power is also used to determine when transparency should be invoked as a response to the user's actions.

One result of this study is the beginning of a sketching system that can be used as a design tool. This latter application is similar to the medium of tracing paper and can aid in the generation of ideas through the gradual and cumulative process of design.

THESIS SUPERVISOR: Nicholas P. Negroponte

TITLE: Associate Professor of Computer Graphics

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12 May 1978

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"How'd yuh know deh was such a place," I says, "if yuh neveh been deh befoeh?"

"Oh," he says, "I got a map."

"A map?" I says.

"Sure," he says, "I got a map dat tells me about all dese places. I take it wit me every time I come out heah," he says.

And Jesus! Wit dat, he pulls it out of his pocket, an' so help me, but he's got it--he's tellin' duh troot--a big map of duh whole f--- place with all duh different pahts mahked out. You know--Canarsie an' East Noo Yawk an' Flatbush, Bensonhoist, Sout' Brooklyn, suh Heights, Bay Ridge, Greenpernt--duh whole goddam layout, he's got it right deh on duh map. ...

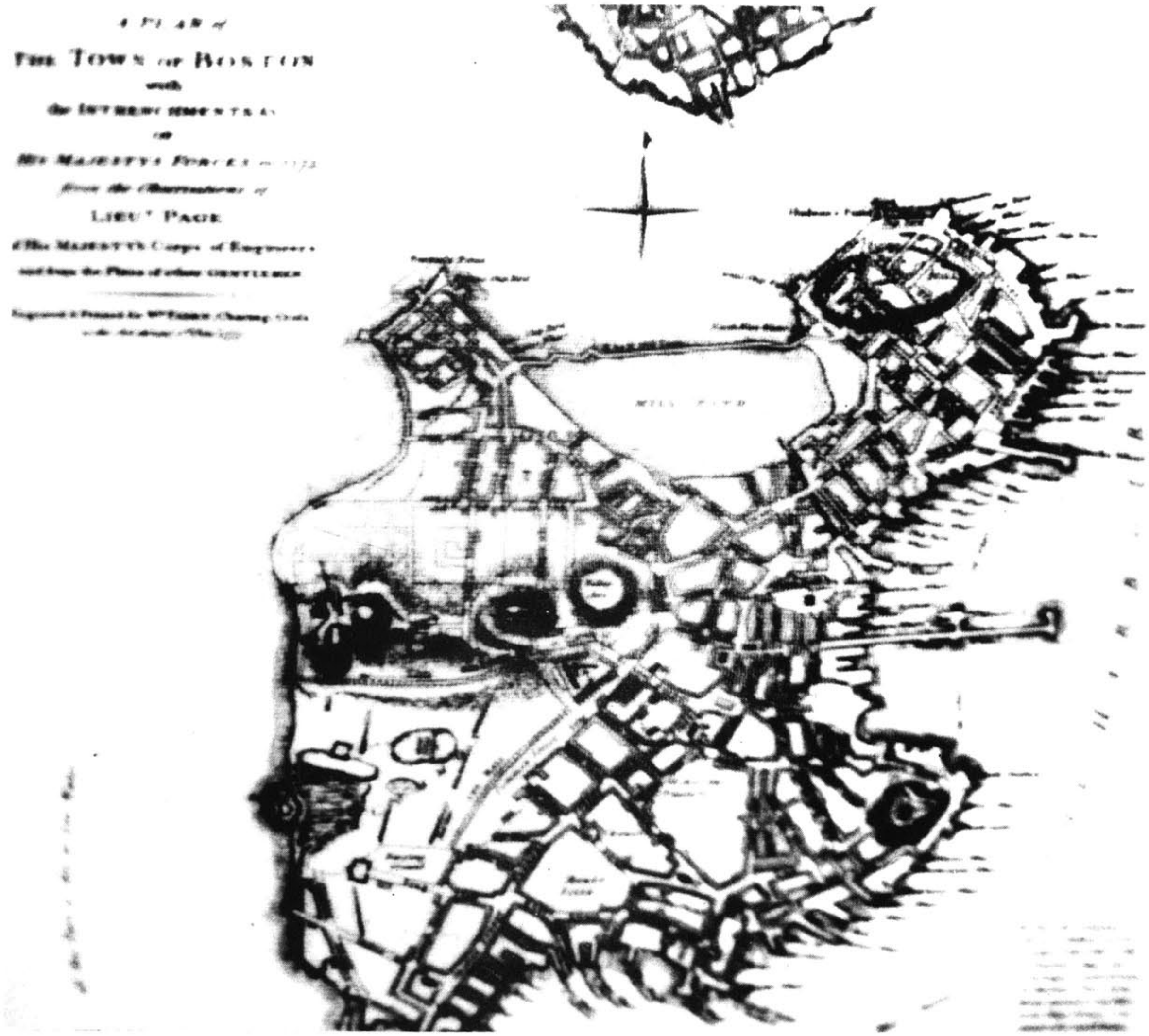
So den duh guy begins to ast me all kinds of nutty questions: how big was Brooklyn an' could I find my way aroun' in it, an' how long would it take a guy to know duh place.

"Listen!" I says, "You get dat idea outa yoeh head right now," I says. "You ain't neveh gonna get to know Brooklyn," I says, "an I don't even know all deh is to know about it, so how do you expect to know duh town," I says, "when you don't even live heah?"

"Yes," he says, "but I got a map to help me find my way about."

"Map or no map," I says, "yuh ain't gonna get to know Brooklyn wit no map," I says.

Wolfe, Thomas, <u>From Death to Morning</u>,
"Only the Dead Know Brooklyn," pp 93,95,
Charles Scribner's Sons, New York, 1963



1.0 INTRODUCTION

1.1 traditional vs interactive mapping

Traditionally, maps have been used as aids to orientation and way finding. They have never been able to present a complete description of an environment, forming a reliable image of that place.[1] The creation of this image has traditionally taken place between the observer and his environment. It is a two-way process in which the environment would suggest distinctions and relations while the observer would select, organize and give meaning to what he sees.[2] Ultimately a map could have this same image formation capability. Through the process of creating this image with a map, one could come to "know" a place without ever having been to the environment.

The limitations of conventional maps that prohibit this from occurring are related to the quantity of information that must be communicated and the way in which that information is now presented. Since legibility must be preserved, the amount of information on a single map is small. Multiple diagrams of the same area are necessary to adequately

[1]Kevin Lynch, <u>The Image of the City</u> (Cambridge: MIT Press, 1960), pp. 1-13.

[2]<u>Ibid</u>., pp. 123-139.

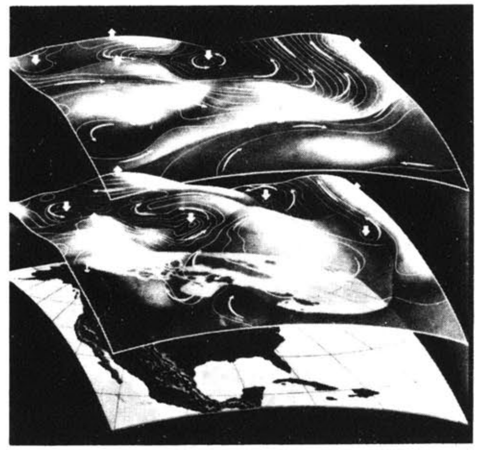
convey all aspects of that place. Continuity between the various maps then becomes a problem as one must relate information from one diagram to the next.

The only way in which to handle the large amounts of data and its presentation is through the use of an interactive computer based mapping system. Many of the problems with the volume of data can be resolved merely through the use of the computers great speed and storage capacity. A database management system could utilize high speed storage devices to provide quick access to an almost limitless database. This data could include all types of information necessary in the formation of a reliable image of a place including: maps, photographs, movies, written descriptions, sound, etc.[1]

The method of data presentation is also a very important characteristic of the system. One of the most critical features in this presentation is the capability for user interaction. In a highly interactive system the user gains insight and information

[1]Eric Teicholz and Julius Dorfman, Computer Cartography World-Wide Technology and Markets (Newton, Massachusetts: International Technology Marketing, 1976).

through the interaction itself.[1] Because of the quality of this interaction, the functions of map reader and map maker are no longer distinct. The user creates a personalized image of a place where the cartographer's schematic representation used to be.



Sophisticated display techniques can be employed by the system to further improve the overall communication of information by reducing the clutter and improving the continuity of the data. This thesis explores the use of transparency as one such technique. In the following sections various applications of this technique are described. These applications include:

1) pure transparent images,

2) fading,

3) cutaways-

   looking through one image to a corresponding image below,

4) logical transparency-

   objects having common attributes share similar transparent qualities

5) computed transparency-

   the computational powers of the computer are used to determine when

[1]Nicholas Negroponte, Christopher Herot, and Guy Weinzapfel, "One-Point Touch Input of Vector Information for Computer Displays," (Cambridge, Massachusetts: 1977).

transparency should be displayed as a response to user actions, and

6) a sketching system in which transparent sheets are simulated to produce independent overlays.

1.2 literal vs phenomenal transparency

To fully understand transparency one must realize that there are two different conditions under which transparency will be perceived. The first condition is called "literal" (physical) transparency.[1] Physically transparent objects are present in our everyday life - glass, plastics, etc. For one to perceive these objects as transparent, however, it is necessary for one to see not only the surface behind the transparent medium but also the transparent medium or object itself. Air and glass are not perceptually transparent unless fog and scratches or reflections make their respective medium visible.

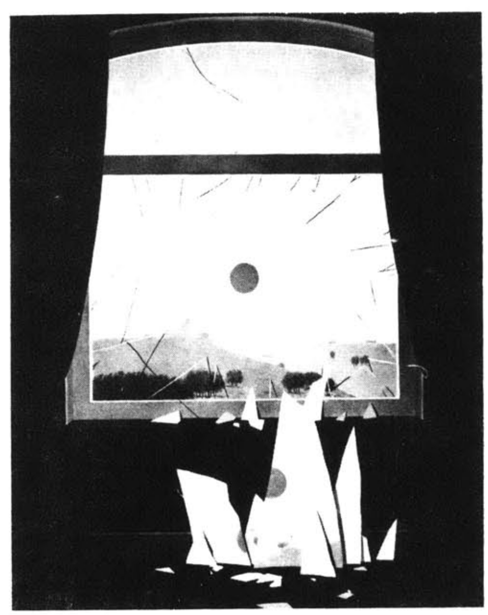
Physical transparency in itself does not guarantee perceptual transparency.[2] If a piece of transparent material is placed directly on top of a homogeneous background the material is no longer transparent and is seen as opaque. Women's nylon stockings, though physically transparent, are not seen as such because its color and texture merge with those of the leg. When the shape of a physically transparent

If one sees two or more figures partly overlapping one another, and each of them claims for itself the common overlapped part, then one is confronted with a contradiction of spatial dimensions. To resolve this contradiction, one must assume the presence of a new optical quality. The figures are endowed with transparency.

Gyorgy Kepes, Language of Vision p. 77.

[1] Colin Rowe with Robert Slutzky, "Transparency: Literal and Phenomenal," in The Mathematics of the Ideal Villa and Other Essays, (Cambridge: MIT Press, 1976).

[2] Fabio Metelli, "The Perception of Transparency," Scientific American, April, 1974, p. 91.



surface coincides with the shape of the background, no transparency is perceived.[1]

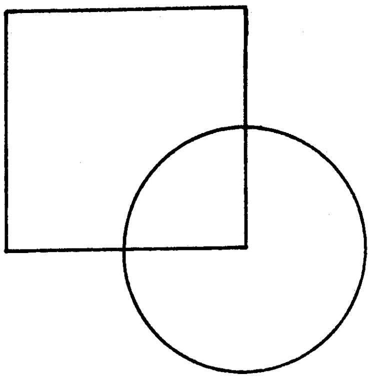


FIG. 1.1

It is possible, however, to perceive an object as being transparent when no physical transparency is present. This second condition is known as "phenomenal" transparency.[2] A basic law of perception states that any visual pattern will be spontaneously organized by the mind in such a way that the simplest interpretation will result. That is why an overlapping square and circle are seen as two instead of three distinct elements. Also a pattern will appear three-dimensional when it can be seen as the projection of a three-dimensional situation that is structurally simpler than a two-dimensional one.[3] This is the concept employed by artists limited to two dimensions to create the illusion of depth.

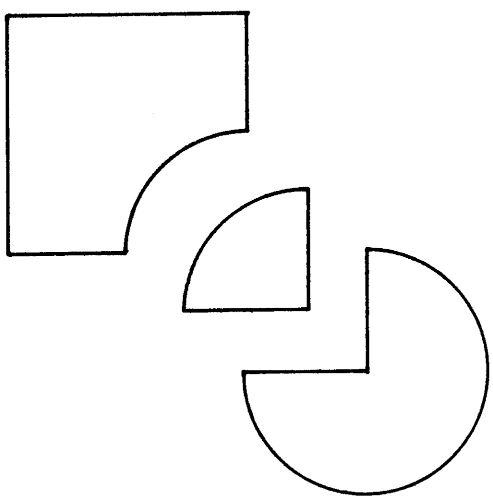


FIG. 1.2

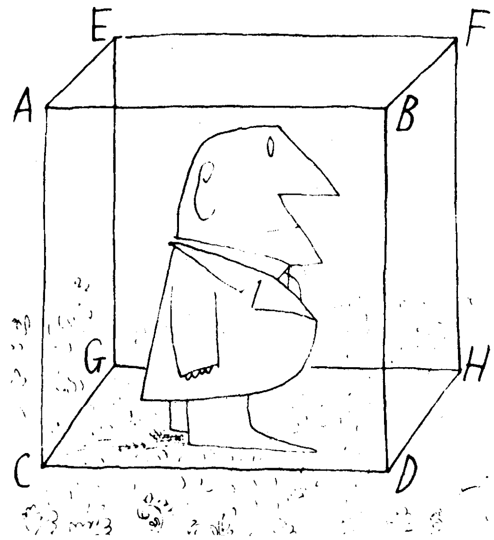
Because of the third dimension in architecture, physical transparency becomes a reality. There is no need to rely totally on perceptual transparency as in paintings. Therefore, most discussion about transparency in architecture is based exclusively on the

[1] Rudolf Arnheim, Art and Visual Perception (Los Angeles: University of California Press, 1974), p. 253.

[2] Rowe and Slutzky, "Transparency: Literal and Phenomenal."

[3] Arnheim, Art and Visual Perception, p. 248.

physical properties of materials themselves. Perceptual transparency, on the other hand, is a condition much more difficult to achieve.



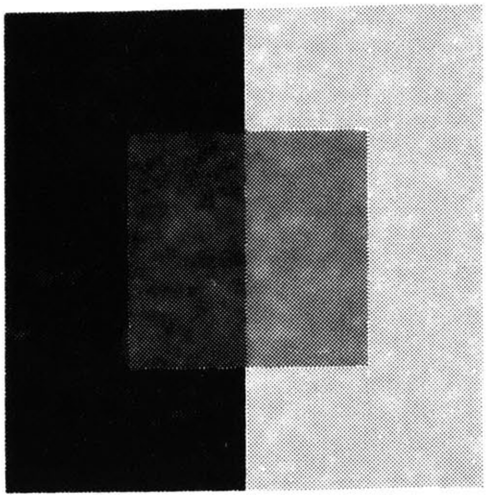


FIG. 1.3 OPAQUE MOSAICS PRODUCING PHENOMENAL TRANSPARENCY

1.3 the study of transparency

1.3.1 HISTORY

One of the first people to show that physical transparency was not necassary for perceptual transparency was Wolfgang Metzger of Munster.[1] He used opaque cardboard mosaics to give the illusion of transparency. By placing two sets of squares next to each other that do not appear to have any transparent qualities, a perceptual transparency can be experienced.

In the 19th century, Hermann von Helmholtz wrote a treatise on physiological optics and described the perception of transparency as "seeing through".[2] He used a device which superimposed two strips of paper of different colors by reflection and transparency. The two images were perceived one behind the other much like the image experienced looking through a window seeing both the reflected interior and exterior simultaneously.

Ewald Hering did not agree with Helmholtz. He argued that when light reflected by two different colors reaches the same retinal

[1]Metelli, "The Perception of Transparency," p. 91.

[2]Ibid.

region an intermediate or fusion color will be perceived. He observed that when looking only at the region where two color images overlapped, just one color, the fusion color was perceived.[1]

In 1923 W. Fuchs, a German psychologist, solved the Helmholtz/Hering controversy.[2] He showed that both colors are perceived only when the transparent object and the object seen through it are perceived as independent. If the region of overlap of the two objects is isolated, then only the fusion color is perceived.

Some other findings were made in the following years.[3] The fact that transparency on a totally homogeneous ground is not possible was discovered by Kurt Koffa and some of his students at Smith College. Another finding revealed that not only is the region of overlap of two figures important to the perception of transparency, but also is the region in which the background can be seen through the transparent surface. This was discovered in 1955 by Gaetano Kaniza at the University of Trieste. The fact that this

[1] Ibid.

[2] Ibid.

[3] Ibid.

had been neglected for so long indicates that transparency on a figure is much more evident than transparency on the background.

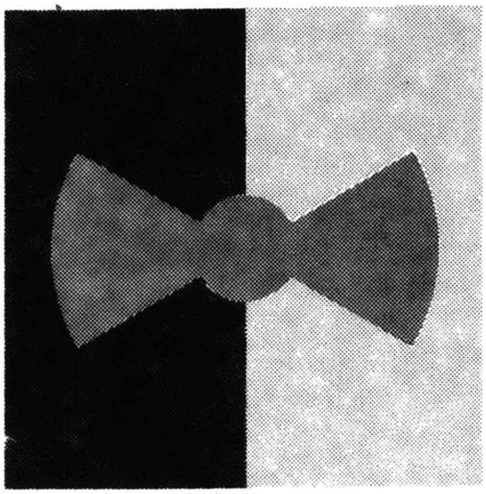


FIG. 1.4 STATIONARY EPISCOTISTER

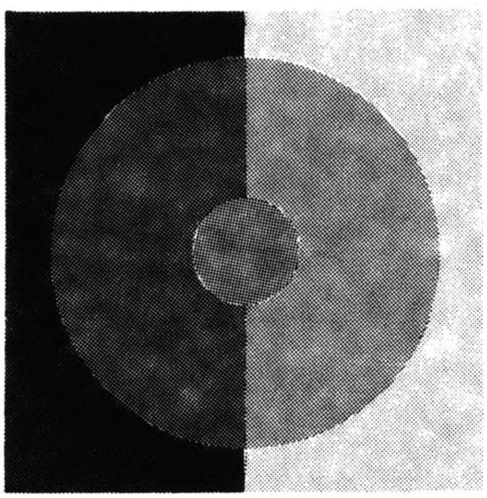


FIG. 1.5 ROTATING EPISCOTISTER

1.3.2 TECHNIQUES

Early investigations used filters or transparent objects, but after it became clear that physical transparency was not a criteria for perceptual transparency the use of physically transparent objects was generally abandoned.[1]

One technique was through the use of episcotisters, wheels with sectors cut out.[2] When the wheel is rotated at a high speed it would generate a strong impression of transparency. This technique would enable the investigator to independently vary the size of the missing sectors, which affects the degree of transparency, and the color of the remaining sectors, which determines the color of the transparent layer.

Another approach was to use the mosaic method that was developed by Metzger. This

[1] Ibid., p. 92.

[2] Ibid.

provided the experimenter with the most flexibility. Using this method one could independently vary the color, shape, and size of each region of a configuration. With this technique it is easy to demonstrate that transparency depends on form as well as color. Because this technique can be applied to raster scan display systems, it will be described in more detail.

1.3.3 MOSAIC METHOD

The following examples of mosaic transparency are for relations of "pure" achromatic conditions.[1] They deal with instances of balanced transparency where the perceived transparent layer is uniform in degree of transparency and color. Unbalanced transparency, where the perceived transparent layer varies in degree of transparency, and chromatic transparency are also possible.

The three main figural conditions for perceiving transparency using the mosaic method are:

[1] *Ibid.*, pp. 92-94.

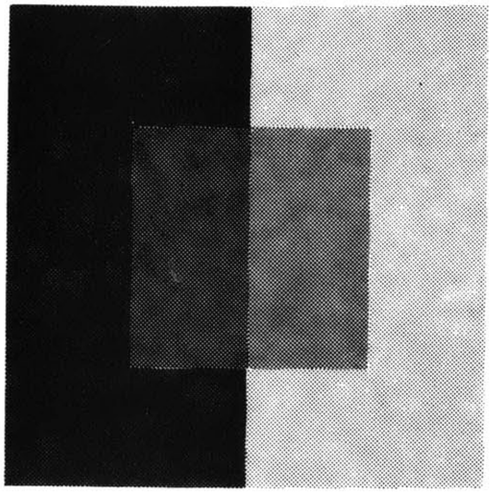


FIG. 1.6 CONTINUITY OF TRANSPARENT LAYER

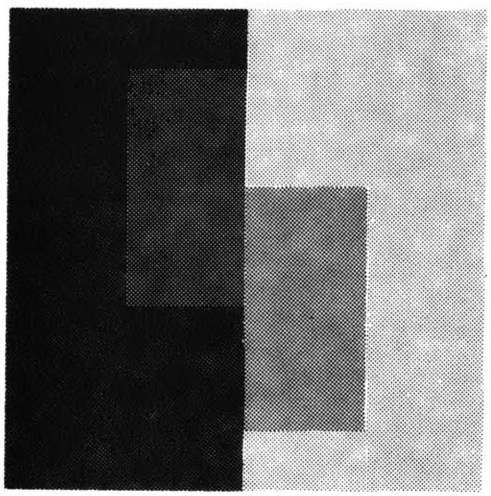


FIG. 1.7 LACK OF CONTINUITY

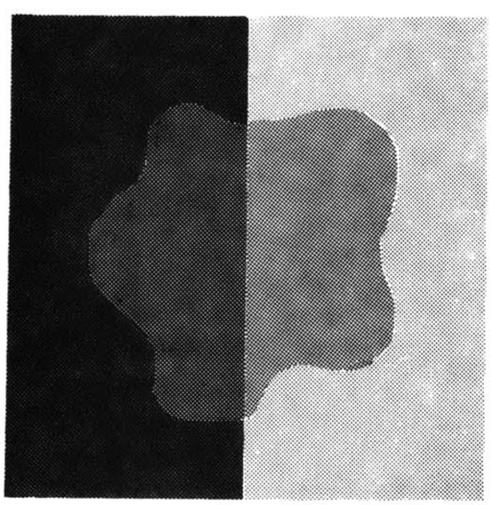


FIG. 1.8 CONTINUITY REGAINED

1) Continuity of the transparent layer,
2) Continuity of the boundary line, and
3) Adequate stratification.

CONTINUITY OF THE TRANSPARENT LAYER

Continuity of the transparent region (figural unity) must be preserved else the perception of transparency is lost. However, changes in the shape of the transparent layer do not destroy the illusion of transparency as long as there is continuity of that region. Continuity of the transparent region alone is not sufficient for the perception of transparency.

CONTINUITY OF THE BOUNDARY LINE

The line separating the background shapes must be perceived as belonging to those opaque regions. A break in the continuity of the boundary line where it intersects the transparent layer can destroy the perceived transparency. Abrupt changes in the boundary at points other than this intersection do not destroy the perception of transparency. This by itself is again not sufficient to guarantee the perception of transparency.

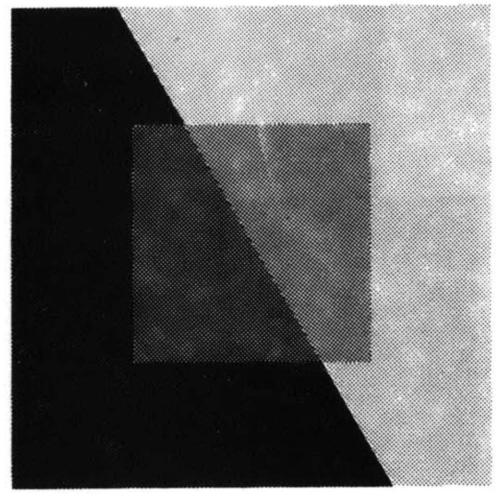


FIG. 1.9 CONTINUITY OF BOUNDARY LINE

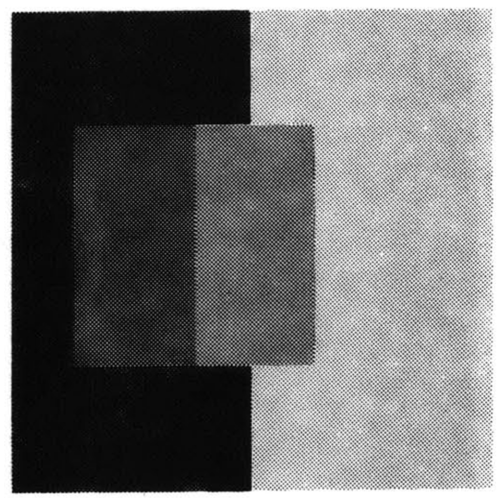


FIG. 1.10 LACK OF CONTINUITY

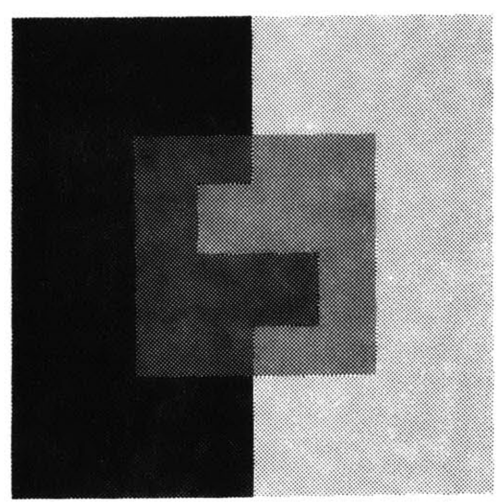


FIG. 1.11 CONTINUITY REGAINED

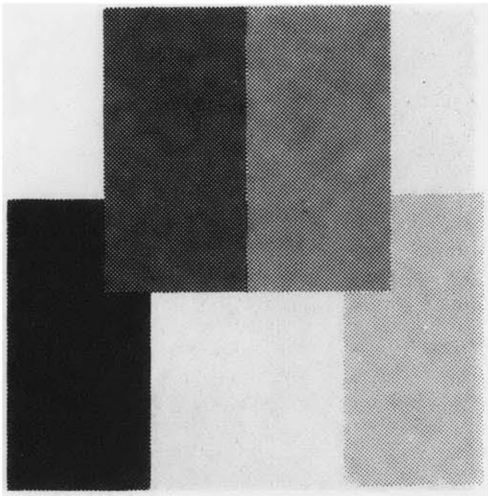


FIG. 1.12 UNDERLYING REGIONS FAIL TO MEET UNDER TRANSPARENT LAYER

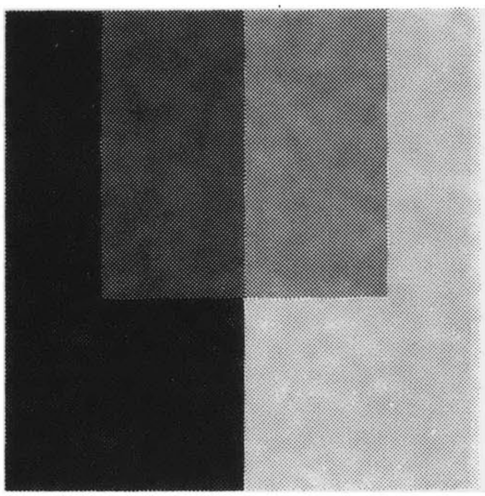


FIG. 1.13 ADEQUATE STRATIFICATION

ADEQUATE STRATIFICATION

The perception of transparency has been defined as seeing surfaces behind a transparent medium or object. This means the layer having the condition necessary to become transparent must be located on or above the opaque object. In order to create this illusion the underlying opaque regions must appear to meet under the whole of the transparent layer.

Separately these three conditions are not sufficient for the perception of transparency. They must all be present for this phenomena to occur.

1.3.4 PERCEPTUAL SCISSION

Perceptual scission is the phenomenon where two different shades of gray give rise to the same shade of gray in a perceived transparent layer.[1] With the perception of transparency the stimulus colors, the original shades of gray, split into two different colors. These colors are called the scission colors. One of the scission is perceived to be part of the transparent layer while the other is perceived to be part of the opaque layer below.

In 1933 Grace Moore Heider of Smith College formulated a hypothesis to show the simple relation between stimulus and scission colors.[2] The hypothesis stated that when a pair of scission colors are mixed, they will recreate the stimulus color. The law of color fusion allows us to predict what color will be perceived when two colors are mixed. Color scission is the reverse of this process and allows us, as Heider demonstrated, to describe the color scission that gives rise to transparency.

[1] *Ibid.*, p. 93.

[2] *Ibid.*

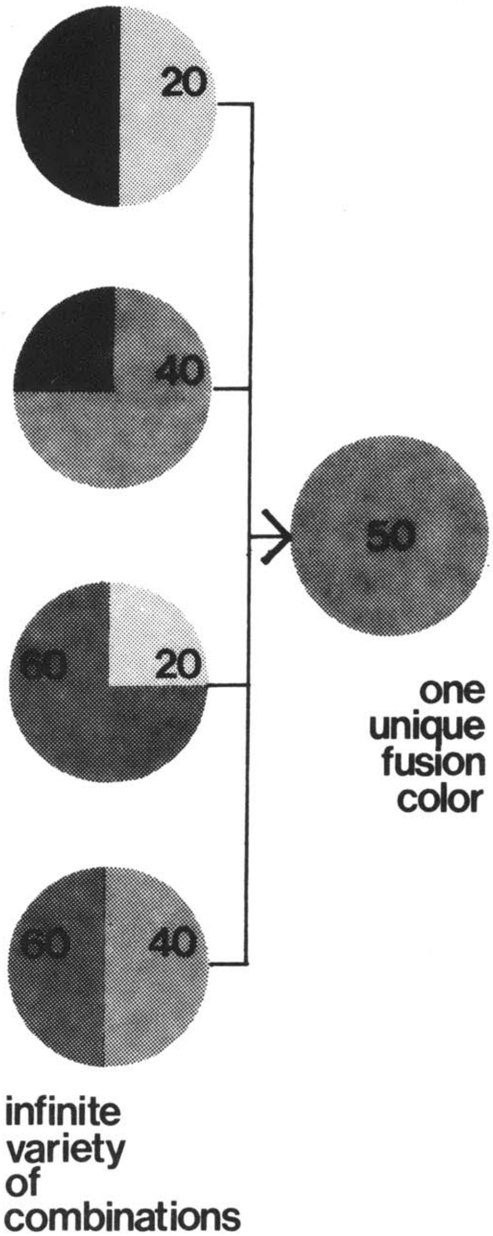


FIG. 1.14 COLOR WHEEL

The device used to study color fusion is the color wheel. Two or more colors are placed on the wheel which is then rotated rapidly. Depending on the proportions and colors placed on the wheel, a fusion color is perceived. With achromatic colors the resulting fusion color can easily be predicted. With color scission, however, there is an infinite number of ways in which the stimulus color can split.

In the figure, color fusion with achromatic colors is diagrammed. With relative reflectance levels represented by numbers, 100 being perfect white and 0 being perfect black, an endless number of combinations can be used to achieve the same shade of gray.

Transparency is perceived only when there is a separation of the stimulus color to both the transparent layer and the opaque background. The transparency varies directly with the proportion of color going to the underlying layer. If all the color goes to the transparent layer it becomes opaque. As more color goes to the underlying layer the more transparent it becomes until all the color goes to the background surface and the transparent layer becomes invisible. The proportion of color going to the opaque layer is described by an algebraic formula and can be used as an index to transparency.

When transparency is perceived, the areas P_1 and P_2 in the figure split and appear to consist of two surfaces equal in form and size but different in color. Since color scission follows the same process as color fusion, only in reverse, the proportion of the stimulus color going to each of the perceived surfaces can be described by Talbot's law of color mixture:[1]

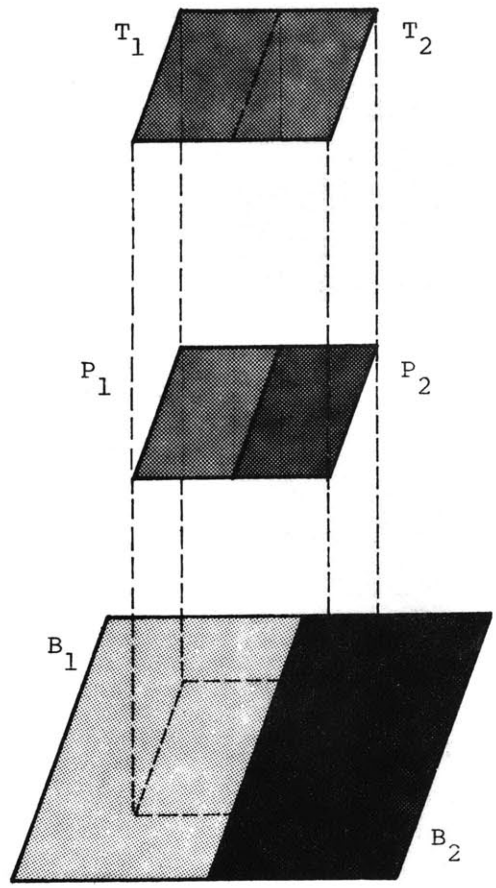


FIG. 1.15 COLOR SCISSION

$$P_1 = \text{alpha} * B_1 + (1 - \text{alpha}) * T_1$$
$$P_2 = \text{alpha}' * B_2 + (1 - \text{alpha}') * T_2 \qquad (1)$$

where: alpha and alpha' are the proportion of color which can very from 0-totally opaque to 100-totally transparent
P_1 and P_2 are the actual colors of the area
B_1 and B_2 are the perceived background colors
T_1 and T_2 are the perceived transparent layer colors

[1] Metelli, "An Algebraic Development of the Theory of Perceptual Transparency," Ergonomics, Vol. 13, 1970, p. 62.

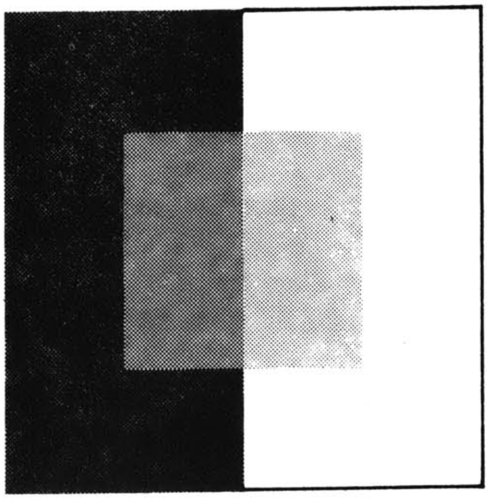


FIG. 1.16

The following are some other examples of conditions necessary for the perception of transparency. The first diagram is an example of a readily transparent configuration.

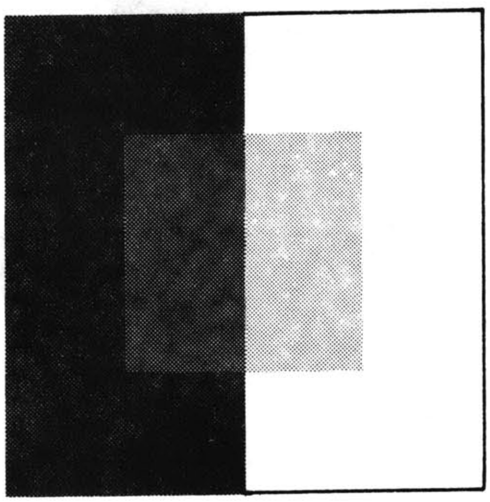


FIG. 1.17

Transparency increases when the difference between the dark and light gray regions is increased.

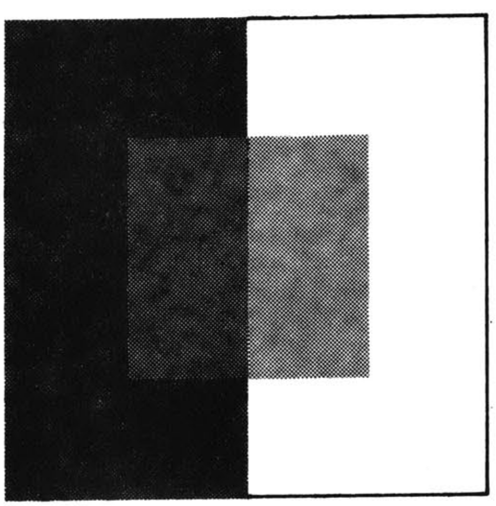


FIG. 1.18

Transparency decreases when the gray regions are similar.

No transparency is perceived when the gray regions are identical.

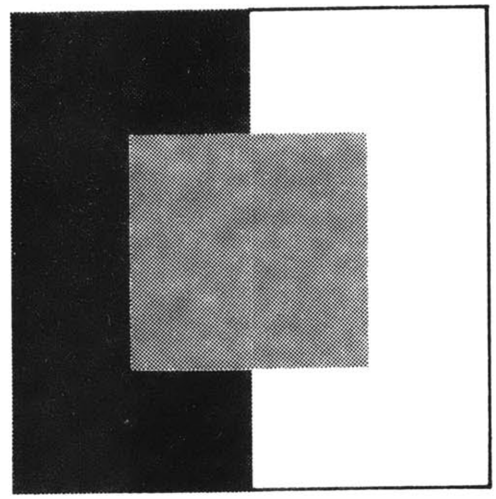


FIG. 1.19

Transparency is possible only when the darker gray square is on the darker underlying surface and the lighter gray square is on the lighter underlying surface. In this case there is no percevied transparency.

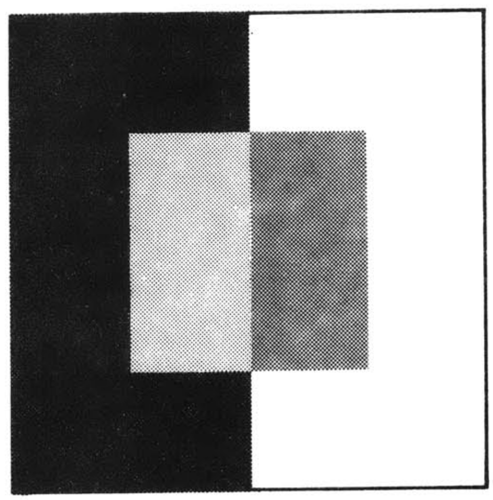


FIG. 1.20

The difference of reflectance of the colors in the transparent layer must always be less than the difference of reflectance of the colors in the unerlying layers. In this case there is no perceived transparency in the central region but the outer zone takes on transparent qualities.

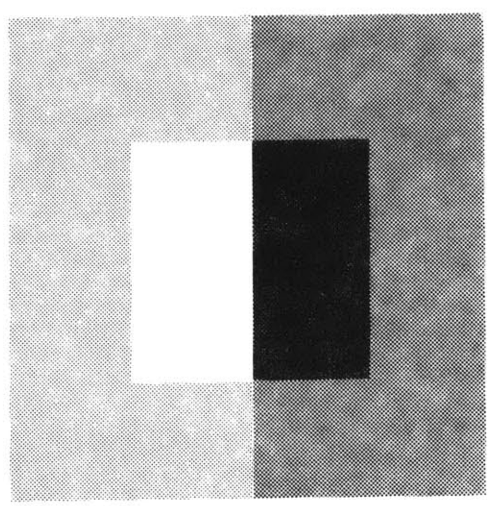
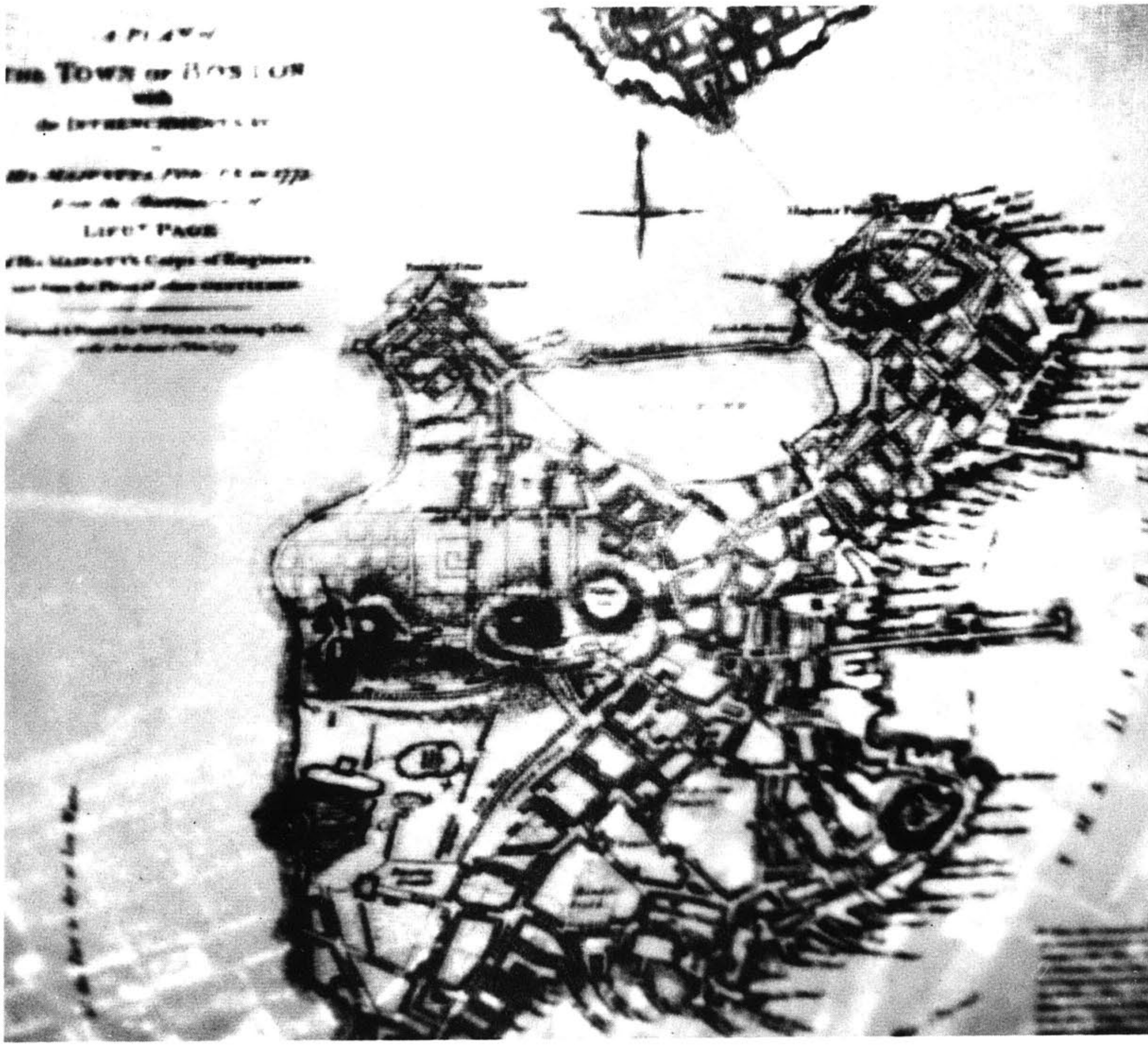


FIG. 1.21



2.0 IMPLEMENTATION

2.1 raster scan implementation

Raster scan display systems lend themselves to the study of transparency because of the ease in which colors and shapes can be created and modified. To better understand how the mapping techniques described in this report work, an overview of raster scan display systems in general, and the Ramtek RM-9300 in particular, is included.

Tristimulus colorimetry is a system of color analysis on which raster scan displays are based. All systems of tristimulus colorimetry have two fundamental principles in common. The first is that color is a three dimensional property of light: hue, saturation, and brightness. The second principle is that the amounts of the three color primaries to match an unknown color may be used as numerical dimensions to specify the color.[1] An additive color process of this sort can not reproduce all possible colors but is adequate for all colors of interest. The primary colors selected for color display

[1] G. Wyszecki and W. S. Stiles, Color Science (New York: Wiley, 1967); T. N. Cornsweet, Visual Perception (New York: Academic Press, Inc., 1970).

systems are highly saturated red, green, and blue. When separately controlled, these primaries can match the widest possible range of colors. In the display system these three primaries are generated by modulating the light emittances from independent red, green, and blue phosphers. Stated as an equation[1]:

$$\text{color} = r*R + g*G + b*B \qquad (2)$$

where: r, g, and b are integer numbers ranging from 0 through 255 controlling the display for each picture element.

There are three basic approaches to raster scan computer graphics:

1) on-the-fly scan conversion

2) run-length lists, and

3) n-bit-per-point veridical memories

but the latter is the most widely accepted.

> For every dot on the screen, there are some number of bits of memory (including zero). In the simplest sense, one can consider a 525-line television screen as a two-dimensional array of single bits 700 wide, because of the aspect ratio, and 525 high, so that, say, 1 is on/white and 0 is off/black.
>
> Given that both the computer and the video display processor can provide access to this array, we effectively have a storage tube with local

[1]Richard A. Bolt, Nicholas Negroponte, and Victor, "Color Transparency Effects from Mosaics of Opaque Color," (Cambridge, Massachusetts: 1977).

erase. Elaborating slightly, we can provide more than one bit per point to achieve gray-tone or color. Ultimately we can make the mappings of areas and tones programmable and incredibly variable.[1]

The image of the Ramtek display system is composed of an array of 640 x 480 independent picture elements, or "pixels". Each pixel has a numerical value associated with it, and it is this value that determines the pixel's color. This value is merely an index into a color matrix, or look up table. A separate color can be stored in the matrix for each unique pixel value. The size of this matrix (the number of unique addresses available) limits the effective pixel wordlength. In the Ramtek, there are 1024 color matrix addresses. This requires a pixel wordlength of 10 bits. As well as the 10 bits of picture data, there are two additional bits available per pixel. These two bits do not affect the displayed image but are useful for storing other data. For example, they can be used as flags independent of the image to distinguish boundary conditions.

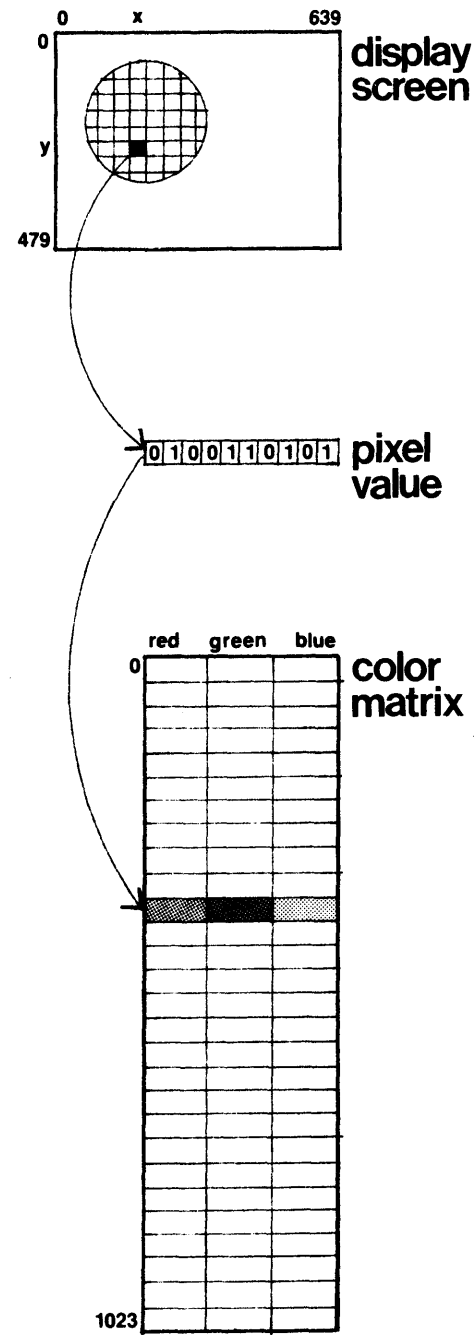


FIG. 2.1 PIXEL (X,Y) SHOWN WITH ITS EFFECTIVE 10 BIT PIXEL VALUE (0100110101) ADDRESSING A UNIQUE SLOT IN THE COLOR MATRIX

[1]Nicholas Negroponte, "Raster Scan Approaches to Computer Graphics," (Cambridge, Massachusetts: 1977).

Images for the display system were digitzed with the Vidicon camera. Through this digitization process, the Ramtek would receive only eight bits from the camera, a range of 256 gray levels. Because the transparency applications in this paper explore the combinations of more than one image, a variation of this process was used.

In order to store multiple images, one must compress the data from the Vidicon so as to create virtual layers. Any number of images up to eight can be stored via compression of the Vidicon data, but it must be remembered that the more images one stores, the fewer gray levels there are available per image. For example, if two images are digitized, one can split the eight bits into two four bit images both consisting of 16 gray levels (2^4) instead of the normal 256 levels (2^8).

I use this combination of two four bit images often in the applications and will refer to the image stored in the low bits (1-4) as the low order image, and the one stored in the high bits (5-8) as the high order image.

A useful feature of the Ramtek that is employed when storing more than one image is the software feature called the "subchannel mask". This option allows the protection of certain bits of the pixel value that contain important data. For example, when only one image is digitized no mask is necessary. However, when the second image is digitized one must shift the eight bits from the camera to the right in order that only the high order bits of the second image are stored. The mask must then be used in order that the bits containing the first image are not modified. The diagram graphically illustrates both the shift right by four bits and the use of the subchannel mask. This is just one example of how the subchannel mask can be used in protecting pixel data.

Normally with an eight bit image, one would want a grayscale loaded in the matrix with black mappingto 0 and white mapping to 255. However, when you want to display just one of many images that are stored, the color matrix must be loaded such that only those bits of the image to be displayed are significant in referencing unique colors.

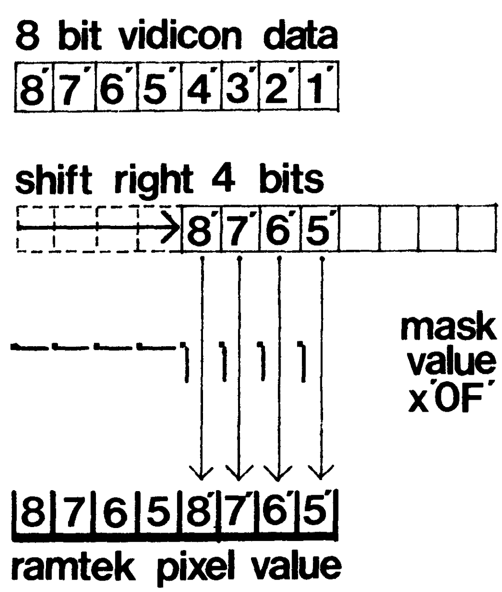


FIG. 2.2 GRAPHIC REPRESENTATION OF THE SHIFT AND MASK USED IN DIGITIZING IMAGES

For any arbitrary image stored, it is necessary to know:

1) the number of bits per pixel in the image,
2) the number of bits higher than the highest bit in the image, and
3) the number of bits lower than the lowest bit in the image.

In the example of two four bit images, these parameters for the low order image are:

number of bits/pixel	numl=4
bits higher	highl=4
bits lower	lowl=0

These parameters are then used to control the loading of the color matrix. The $2^{(numl)}$ or 16 colors are chosen and then loaded into the matrix such that each color is repeated $2^{(lowl)}$ or 1 time. This loading sequence is then repeated $2^{(highl)}$ or 16 times. The total number of entries loaded into the matrix will then equal $2^{(highl+numl+lowl)}$ or 256.

This loading procedure is generalized so that those bits lower than the lowest bit and higher than the highest bit of the image will not affect the color displayed at any one point.

The parameters for the high four bit image are:

num2=4

high2=0

low2=4

This means that each of the 16 colors for the second image would be loaded $2^{(low2)}$ or 16 times. However, the sequence is repeated only $2^{(high2)}$ or 1 time so that the total number of colors loaded is still 256.

2.2 digital transparency

One of the first objectives of this research was to simultaneously display two separately stored images. With this effect one image is perceived as transparent, thus revealing the second image below. One interesting characteristic of transparency is that the form of the data is independent of the technique. Whether the data is two-dimensional, three-dimensional, schematic, photographic, static, or dynamic, information can be displayed simultaneously without one "layer" obscuring the other. This section deals with the algorithm responsible for the generation of these images.

Conceptually digital transparency is easy to produce if one combines Talbot's law of color mixture (equation 1):

    P1=alpha*B1 + (1-alpha)*T1

with the fact that raster scan display systems uniquely specify a color by modulating the light from three separate phosphors, red, green, and blue (equation 2). For any one point, separate equations can be written for the pixel colors of both the background and transparent layers:

background_color=Br*R + Bg*G + Bb*B

transparent_color=Tr*R + Tg*G + Tb*B

Combining these equations results in three separate relationships, one for each of the primaries:

Pr=alpha*Br + (1-alpha)*Tr

Pg=alpha*Bg + (1-alpha)*Tg

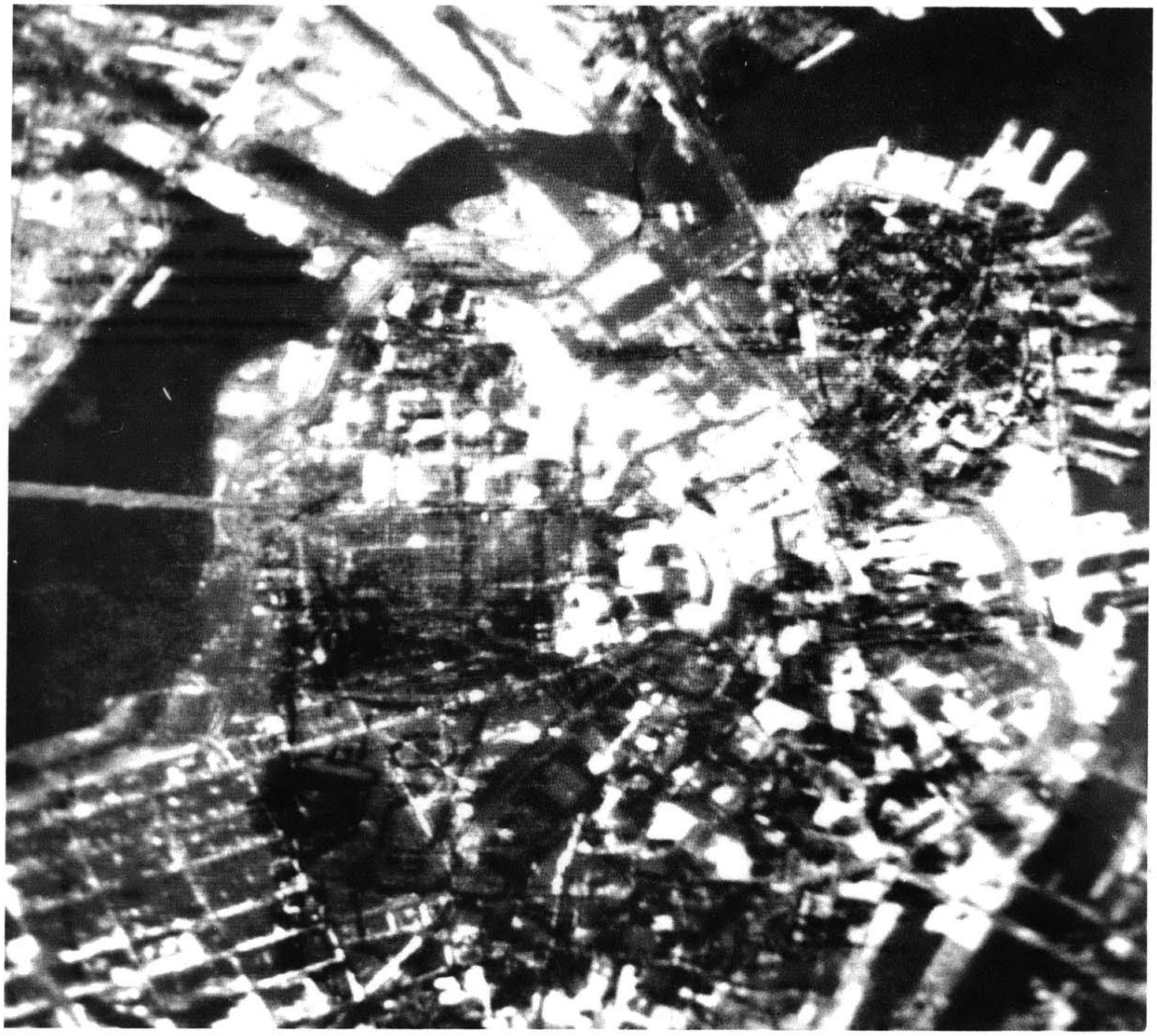
Pb=alpha*Bb + (1-alpha)*Tb

where: r,g,b represent components for red, green, and blue of the final perceived color (P), the color of the background layer (B), and the color of the top layer (T).

The new perceived transparent color can now be described by combining the perceived red, green, and blue components:

perceived_color=Pr*R + Pg*G + Pb*B

These equations are the same whether or not the images are in color or black and white. All subsequent routines that utilize the effect of transparency are based on these equations.



3.0 APPLICATIONS

3.1 transparent images

The first application of transparency illustrates the possibility for placing objects over an image such that the underlying image is not obscured. This technique, like many of the subsequent applications, utilizes a database of Fulda Gap, Germany that has been stored on disk. This database includes information on

1) land use,
2) soil types,
3) vegetation, and
4) elevation features.

It is stored in an 80 x 80 array and covers a 10 x 10 kilometer area. For more information on this data, on-line documentation exists in directory FULDA in the file DATA.doc.

Examples of simple transparency are shown in the two photographs. In the first figure, a black and white map of Germany is used as an underlay on which colored land use symbols have been placed. The routine that creates these symbols (program: USE) also generates transparent colors for each symbol. The user can determine the land use at any location by touching that spot by means of a tablet. The computer then accesses the database to display the appropriate symbol. The scale of the symbols change to correspond to the scale of the digitized map. This application can also be implemented with other display techniques, ie digitized sound, to increase the overall sensory input.[1]

[1]William D. Gooch, "Clutter Control Through Use of Sound in Computerized Interactive Maps," (Bach. of Sci. in Computer Science and Engineering, 1978).

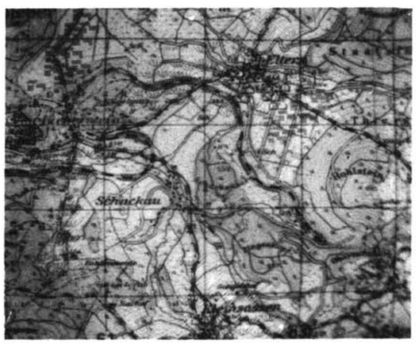


FIG. 3.1 TRANSPARENT SYMBOLS

The second figure illustrates the possibility for this data to be overlaid as multiple sheets of transparent colors. Here a colored layer of "urban" land use has been combined with colored layers for different soil types. The program (program: OVERLAY) can combine a total of six data types over a four bit digitized map.

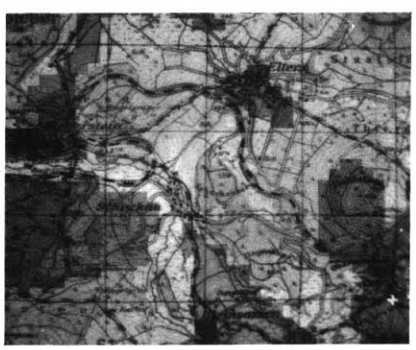


FIG. 3.2 TRANSPARENT DATA SHEETS

A problem occurs because the different overlays lie on the same grid pattern, and therefore do not follow the rules for perceptual transparency in mosaics. Transparency works in some areas, but in others the overlays lose their cohesiveness and new colors are perceived.

Another example of straight transparency is illustrated on the dividers to the five major sections in this report. The program that creates these transparencies (program: TRANSIT) assumes two four bit black and white images have previously been digitized. Then it generates a new color matrix in order to see the combination. The only difference that exists between these images is the percent of transparency. In this sequence the percentage changes from 0% to 100% in increments of 25%.

Because of the late implementation and considerable effort in digitizing color images, transparency utilizing two separate color images was never illustrated. Once two color images are stored in the Ramtek, however, it would be an easy task to simultaneously display both images since the same algorithms are employed.

3.2 fading

FIG. 3.3 A SUMMER'S NIGHT, AUG., 1956

FIG. 3.4 COMBINATION OF FIG. 3.3 AND FIG. 3.5

FIG. 3.5 A WINTER'S DAY, JAN., 1963

Transparency may also be used to provide smooth changes between images through the process of fading. This allows one to change from one data type to another keeping the continuity intact. The result of the transition may be just to change the detail of information, or may be to change the scale, of the diagram, or may even be to reveal a completely new topic. In any case, the smooth fade allows for a more subtle and interesting transition.

The fading technique is achieved by creating a series of transparent images incrementing the coefficient "alpha" in equation 1 from 0 to 1 (or vice versa). The greater number of steps in the fade, a slower yet smoother fade will result. This technique also assumes two images are stored in the Ramtek. In this routine (program: FADEIT) the user must indicate the number of steps in the fade, the number of bits per point for each image and the direction of fade (from low bit image to the high bit image or vice versa).

The example shows two images from Jörg Mülller's

"The Changing Countryside" in which the display fades from a summer's night in August 1956, to a winter's day in January 1963. The middle step is 50% of both the starting and ending images.

3.3 transparent gels

A technique which demonstrates the flexibility in creating multiple overlays is a program that generates transparent rectangular gels. These gels also illustrate the possibility of highlighting areas by controlling the brightness of the overlay. Relating certain areas with one another is also possible using transparent gels of similar hues.

One extension of this technique is provided when the rectangular gels are given mobility. Interesting conditions then occur when two or more rectangles overlap. In these situations multiple color combinations are needed to diplay a realistic illusion of physical transparency.

If the rectangles were moved by erasing and redrawing the entire shape, the resultant figure would be flickering constantly. The system cannot redraw the rectangle fast enough without the eye detecting the subtle changes. In order to avoid this undesirable effect, the technique of frame coherence is applied. This technique assumes the shape is coherent throughout. Then by erasing and redrawing only what is necessary in any movement, the major portion of the object remains unchanged. This allows a smooth, flicker free movement of the rectangles across the screen.

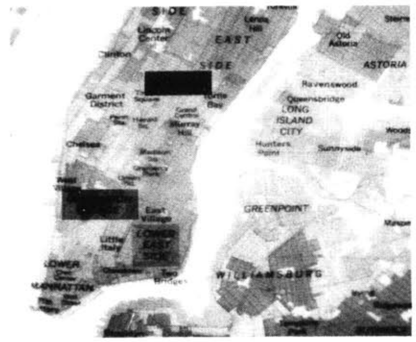


FIG. 3.6 TRANSPARENT GELS

There are two options for creating and moving these rectangles. One (program: SQUARE) allows the user to create from one through nine rectangles over a black and white image. Each rectangle requires one unique bit of the pixel value for storage. Since there are a maximum of eight bits needed for a digitized image, there are immediately two bits free. For every rectangle greater than two, however, a bit must be taken from the image data. In order to do this, the image is shifted to the right one bit. The low order bit is thus discarded allowing a high order bit to be freed. This can occur until there remains only one bit (two colors) for the image and nine bits for nine separate rectangles.

FIG. 3.7 TRANSPARENT GELS

FIG. 3.8 TRANSPARENT GELS

The second series of routines (program: CSQUARE) allows one to create a maximum of two rectangles but they move across an eight bit colored image. Both series of routines requires the user to specify the red, green, and blue components of the transparent gels. The percent of transparency is also required before a new color set can be generated.

3.4 cutaways

Another technique that utilizes two stored images is a routine that allows one to look through the "top" image to a different image "below". This technique is useful in correlating not only two-dimensional information, like aerial photographs and schematic maps, but also three-dimensional information. The ability to look through a building to see what's behind it is only one such application. This example of "x-ray" vision is most effective when there exists similar information on both images that can be aligned.

FIG. 3.9 "UPPER" LAYER

FIG. 3.10 "LOWER" LAYER

The technique becomes interactive when the cutaway area is given mobility. The user can then move the window across the screen using frame coherence. Whenever the user points to an area, that portion of the second image is revealed.

FIG. 3.11 CUTAWAY LOOKING THROUGH UPPER LAYER

In order to create the "window" effect the 9th and 10th bits of the pixel value are used to reference different quarters of the color matrix. The first quarter of the

FIG. 3.12 MULTIPLE WINDOWS - CLEAR

FIG. 3.13 MULTIPLE WINDOWS - TRANSPARENT

matrix can be loaded with an appropriate color set to display the first image while the second quarter can be loaded to display the second image. A clear window can then be drawn if the 9th bit of the pixels within the window is "on" (referencing the second quarter of the matrix) while those pixels outside the window are "off" (referencing the first quarter of the matrix).

There are many parameters to the basic windowing program making it a very flexible routine (program: EWINDOW). The window may reference any one of the four sections of the color matrix. It may remain visible at all times or just when the tablet is being touched. It's size is variable and its path can remain visible. If a small window whose path is visible has been defined, one can "erase" the top layer revealing the second image below. Applying the transparency algorithm and loading the appropriate color set into the matrix, the window can take on any level of transparency desired. The fading technique can also be applied to the quarter of the matrix that is referenced wihtin the window allowing only the window to fade from one image to the other. A final variation of this routine (program: PWINDOW) displays a window that dynamically varies its transparency. The various degrees of pen-tablet pressure is utilized to determine the transparent quality of the window. A clear window is displayed when maximum pressure is applied.

FIG. 3.14 "ERASED" WINDOW - CLEAR

The window in this application bears no relation to any specific area of the screen. Mobility is its greatest asset. This feature could be enhanced if the movement of the window could be directed by information in a database. Vector data (roads, railways, and rivers) exists for Fulda Gap, Germany but its use in connection with this technique has not yet been explored.

FIG. 3.15 "ERASED" WINDOW - TRANSPARENT

3.5 logical transparency

The concept for logical transparency is a direct refinement of the windowing technique of the previous section. The window described in that section did not show any relation to the image that was displayed. An arbitrarily sized window would be created sometimes eliminating important image data or written descriptions. The window would then have to be redefined to include the appropriate information. Logical transparency is an effort to make the window somewhat "intelligent" in relation to the displayed image (at the expense of mobility).

In order to do this, a database must accompany the image. This data base is now generated on-the-fly for the set of digitized images. Different groups of windows are defined and linked together as are the individual windows within groups and the points within each window. Every set of windows can be of arbitrary length while each individual window can be arbitrarily shaped.

Once the database has been defined, one can display individual windows or a set of similar windows by simply pointing to an object via the tablet. The display routine will then search until the window pointed to was located. It would then be displayed by flooding the irregularly shaped window. If a set of windows is to be displayed the routine starts with the one that is pointed to and searches the list of related windows until all of them are displayed. When there are many windows or they become very large, the speed of the flood routine is extremely frustrating. The flood routine takes many seconds to complete and the responsiveness of the program is destroyed (program: UPSET).

FIG. 3.16 ONE LOGICAL WINDOW

FIG. 3.17 MULTIPLE WINDOWS OF SIMILAR TYPE

The three examples of logical transparency are illustrated with two images, an aerial photograph and diagram, of Stockholm, Sweden. The database was created to display different building types. The first figure shows a single cutaway of one of the museums, the National Museum. The second illustration shows the entire set of museums in the database. The final figure shows a completely

FIG. 3.18 MULTIPLE WINDOWS OF DIFFERENT TYPE

separate set of building types, governmental. Notice that every window not only includes a diagrammatic sketch of the building but also includes the building's name.

This routine utilizes the Ramtek's additional 11th and 12th bits to draw boundary lines for the flood program. It uses these two bits so that the image will not be altered when the boundaries are allocated.

Instead of basing the "logic" for transparency on a constructed database, there are two other directions one could pursue. First, the database for Fulda Gap, Germany could be further explored, using various combinations of the different data types as requirements for transparency.[1] Another method not yet investigated would use the pixel values themselves as the database. Each point with a similar characteristic would have the same pixel value, pointing to the same location in the color matrix. Eventhough some pixels may have the same color, they could point to separate locations in the matrix. This difference could then be used for invoking a new "logical" window.

[1]William Porter, "The Development of Discourse: A Language for Computer Assisted City Design," (Ph.d. dissertation, MIT, August, 1969).

3.6 computed transparency

Up till now, the computational ability of the computer has not been utilized to determine when transparency should be invoked. This technique explores the use of that power.

One application in which the computer can use this ability is in the computation of sightlines. Using the previously described database for Fulda Gap, Germany, this technique displays land use data as transparent overlays if that **point** can can be seen from a given starting point. Input for this routine (program: SEEK) in addition to the starting point includes the viewers height above ground (in meters) and a maximum range of visibility.

As one follows a radial path from the starting point, the maximum height to distance ratio is stored. For each new point a new ratio is calculated. If this new ratio is greater than the old ratio, then the new point can be seen. The new ratio is then saved as the maximum and the

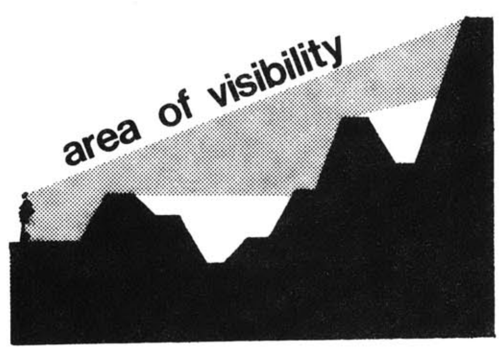


FIG. 3.19 SECTION OF A RADIAL SIGHTLINE

FIG. 3.20 GRAPHICAL REPRESENTATION OF FULDA GAP ELEVATION DATA

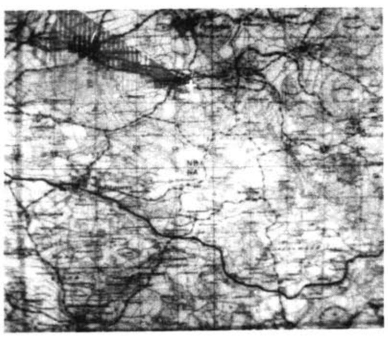


FIG. 3.21 DIRECTED VIEWING AREA

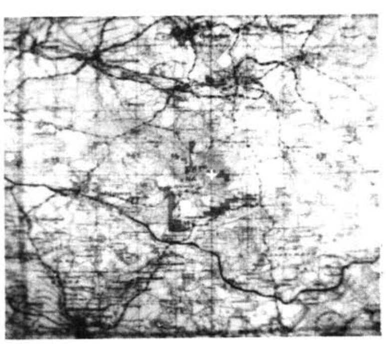


FIG. 3.22 360° VIEWING AREA

land use data at that point is displayed.

The first figure is a graphic representation of the elevation data for Fulda Gap. The white areas represent high points while the black areas reprsent valleys. The second figure shows just a segment of the total sweep of a field of vision. The viewpoint is 200 meters above ground and the land is relatively flat. That is why most of the land use data is being displayed. In the third figure the complete circular viewing pattern is shown. The viewpoint is only 40 meters above ground and sightlines are limited. The cursor's position indicates the viewpoint in both illustrations.

Many variations of computed transparency are possible now that the database for Germany is available. Also a simple refinement of this program would display information on those areas that are hidden from ones view.

3.7 transparent sketching

Computer based sketching systems provide artists with a wide range of drawing techniques beyond traditional methods. Transformations of color and size can be made with simple indications to the computer. Areas can be flooded with a particular color or even by a self-defined "texture".[1] One technique usually omitted from these systems, however, is the ability to draw on separate layers. With the ability to generate transparent images, a sketching system could provide a working environment similar to the designer's world of tracing paper.

The beginnings of such a system were investigated as another application of techniques in transparency. Although constraints did not allow for a full implementation, a skeletal system is operational. It demonstrates the ability to define "levels" or "sheets" on which to work. There are eight bits available for level definition so a range from one 8 bit layer to a maximum of eight 1 bit layers is possible. The user can define the transparent quality of each

[1] PAINT, Computer Program developed at the Architecture Machine Group at MIT.

layer and indicate which layers are to be displayed at any given time. Flipping through the layers individually is also possible. At all times the number of levels activated are displayed while only those "on" or writable are lit up.

In this sketching system there are three major areas of manipulation. They appear in menu format and are color coded. From left to right they are:

DATA INPUT/OUTPUT (red)

1) Digitzing an image
2) Disk I/O
3) Tablet input

DATA MANIPULATION

4) Copying picture data from one level to another
5) Moving picture data on a level

LEVEL MANIPULATION

6) Adding or deleting levels
7) Flipping through the levels displaying any one level individually
8) Defining the transparency of each level

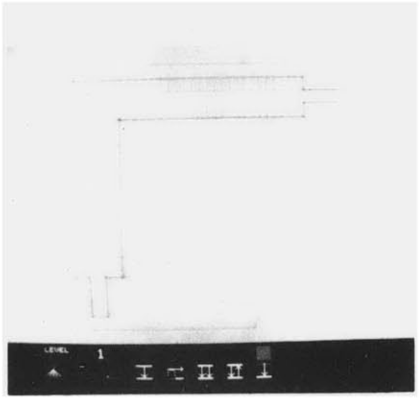


FIG. 3.23 ONE LAYER (8 BITS)

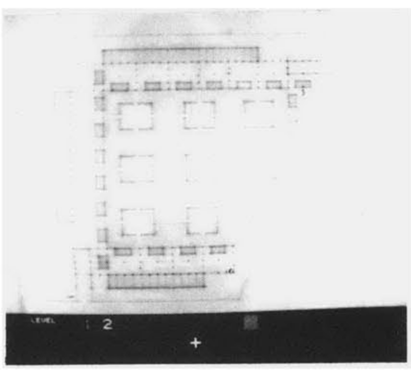


FIG. 3.24 SECOND LAYER ADDED (4 BITS)

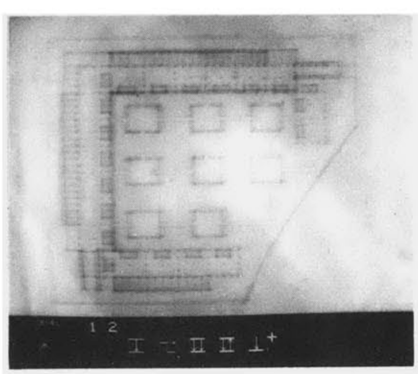


FIG. 3.25 TRANSPARENT IMAGE OF LAYERS 1 AND 2

The first series of figures illustrates the addition of layers using digitized images. Initially an eight bit image is stored on level one. When a new layer is added, the maximum number of bits per point is cut in half. The next figure shows a four bit image on the second level. The third figure illustrates the transparent image of the two layers. A third layer is added in the next sequence and each figure displays an increasing number of levels. The final illustration of this system shows a detail in which an area has been copied (twice) onto another level and then moved on that level. This technique allows one to move image data without destroying other data on separate levels. With a transparent image, one can see both levels simultaneously permitting accurate placement of the copied area to occur.

Some interesting refinements of this system would permit logical transparency and logical copying to occur between levels. Layers could be made for "read only" mode. This would enable important drawings or maps to be used as underlays without being modified.

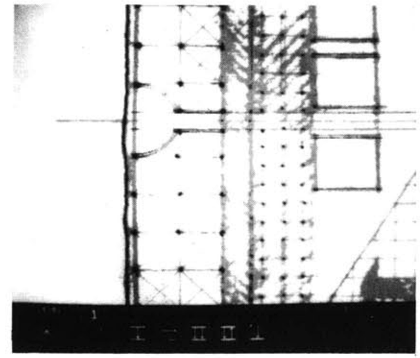


FIG. 3.26 1st LAYER (2 BITS)

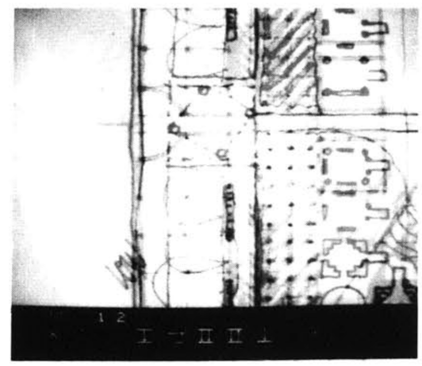


FIG. 3.27 1st & 2nd LAYERS DISPLAYED SIMULTANEOUSLY

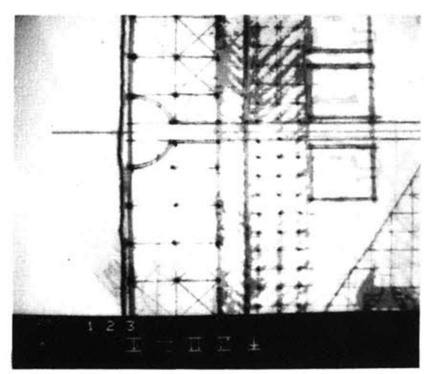


FIG. 3.28 1st, 2nd, & 3rd LAYERS DISPLAYED SIMULTANEOUSLY

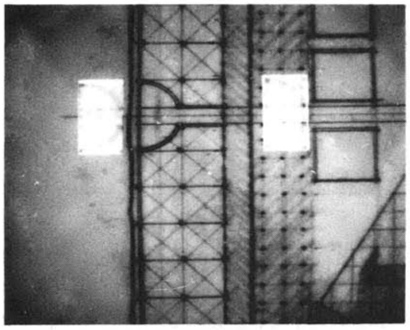
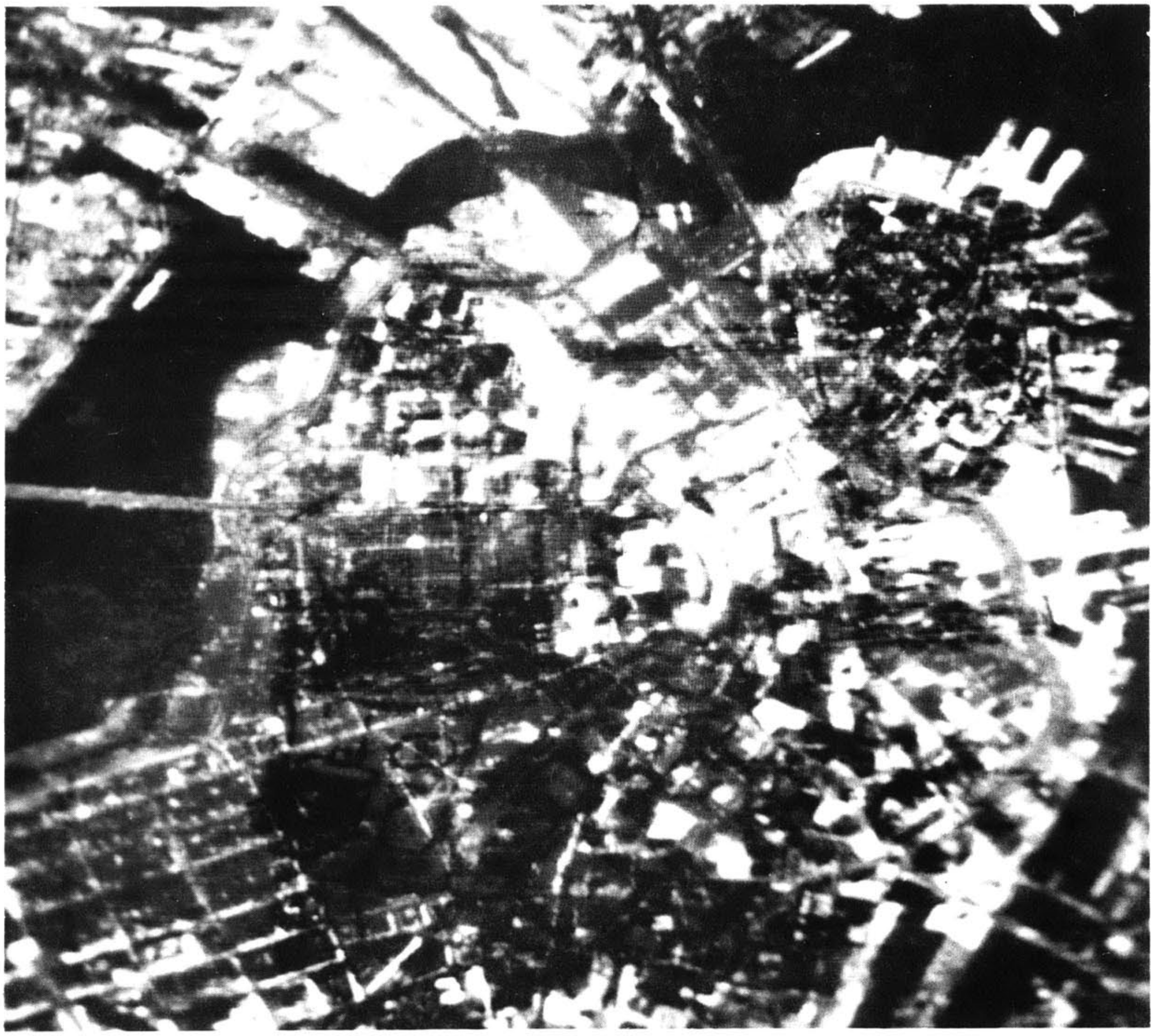


FIG. 3.29 SEMI-CIRCULAR AREA COPIED TWICE ONTO ANOTHER LAYER

Writable sheets could then be added on which personalized or temporary data could be marked.



4.0 APPENDIX

4.1 hardware environment

When dealing with computer generated transparency, it is necessary to have the ability to vary colors and shapes easily. To provide this flexibility the hardware that was used in this project was the Ramtek RM-9300 image display system. It is a full color raster scan display system which is microprocessor controlled. The system stores its image in 4k random access memory refresh in binary. All of the programs described in this report are written in terms of this display system. Image data was digitized into the system using the Sierra Scientific Corporation's standard high resolution video CCTV camera. For a more detailed description of this hardware configuration and its relation to the software techniques see section 2.1 Raster Scan Implementation.

The Ramtek display and Vidicon camera are linked to the Architecture Machine Group's MAGIC system via an Interdata Model 7/32 192 k-byte mini-computer. This processor is linked to a common shared bus which is controlled by another Interdata Model 7/32 mini-computer.

For the duration of this research, all disk access has been through the common shared bus. For this reason images were not stored on disk. Instead, new images were digitized from the Vidicon camera for each working session. Recently a 2314 m-byte disk has been connected directly to the processor controlling the Ramtek. Images can now easily be stored providing greater flexibility to the entire system.

The Architecture Machine Group is a unique environment for man-machine interaction. Although the techniques described in this report have not yet been implemented on some of the labs more sophisticated hardware, touch sensitive,[1] pressure sensitive,[2] and large scale "media room" display systems.[3] Current research is now working in this area to allow the user to physically become more a part of the mapping process.

The machines used in this report can be seen in relation to the total AMG's hardware environment in the diagram on the facing page.

[1] Richard A. Bolt, "Touch Sensitive Displays," (Cambridge: 1976).

[2] Negroponte, Herot, Weinzapfel, "One-Point Touch Input of Vector Information for Computer Displays," (Cambridge: 1977).

[3] Nicholas Negroponte, "Large Format Displays," (Cambridge: 1977).

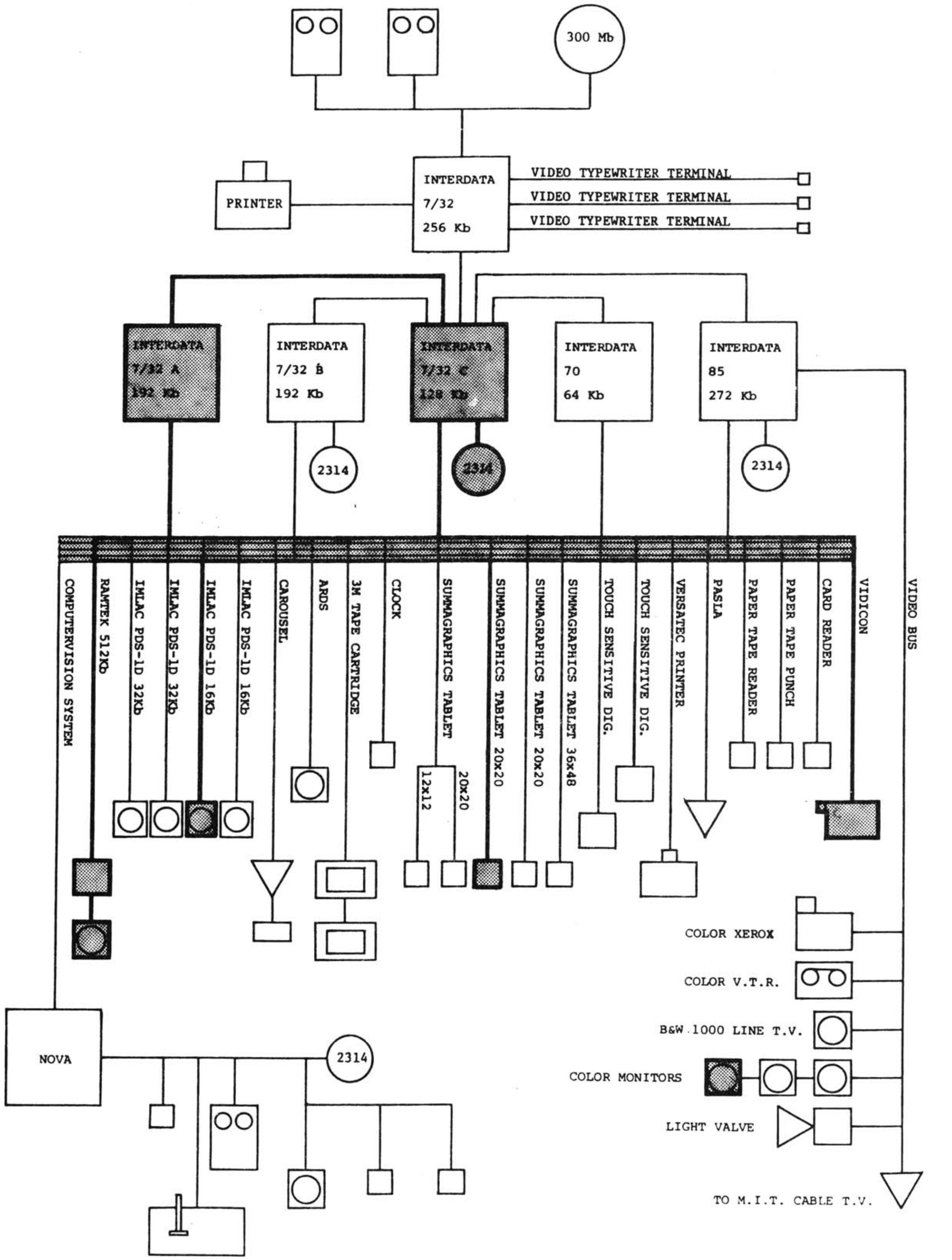


FIG. 4.1 HARDWARE ENVIRONMENT

4.2 programmer's manual

This section is an alphabetical list of those routines used to illustrate the various applications described in this report. Each routine is accompanied by:

1) a brief description of the program,
2) a list of those programs that call the routine,
3) a list of those programs it calls,
4) the correct format for using the routine (the declare and call statements), and
5) the name of the main routine in which it is utilized.

A more detailed explanation exists for each routine in its PL/1 file.

ACCENT

This routine displays the Fulda Gap elevation data. It reads in the data from the FULDA directory and displays high points (the highest being 800 meters) as white and low points (the lowest being 300 meters) as black.

called by: none

calls: none

application: GENERAL

ADD

This routine changes the value of NLEVEL, either adding or deleting levels to be used. FMASK is called to determine the new mask value.

called by: BUM

calls: CLEVEL, FCOLOR, FMASK, GETPT, LCOLOR

```
dcl add entry;
call add;
```

application: TRANSPARENT SKETCHING

AGEE

This routine displays the symbol for "other agriculture". The structure INFO includes the display start point plus a scale factor allowing the symbol to correspond to the size of the underlying map.

called by: USE

calls: none

```
dcl agee entry ( );
dcl 1 info,
      2 x      fix,
      2 y      fix,
      2 scale  fix;
call agee (info);
```

application: TRANSPARENT IMAGES

BUM

This routine initializes the Ramtek for the transparent sketching technique. The color matrix is loaded and then a loop is entered which calls the various subroutines.

called by: none

calls: ADD, CLEARMENU, DIGL, FLEVEL, FLIP, GETPT, LMENU, MENU, TRANSP

application: TRANSPARENT SKETCHING

CINTER

This routine is called to determine a new 24 bit color between a starting color (FROM) and an ending color (TO) given a percentage (PERCENT). The red, green, and blue components are separately interpreted.

called by: MAKESQ

calls: UNCOL

```
dcl cinter entry (bit(24),bit(24),fix) returns (bit(24));
new_color = cinter (from,to,percent);
```

application: TRANSPARENT GELS

CITY

This routine displays the symbol for a city (see AGEE).

called by: USE

calls: none

```
dcl city entry ( );
call city (info);
```

application: TRANSPARENT IMAGES

CLEARMENU

This routine is used in the transparent sketching system to clear the menu area. Either the entire menu or just the lower half may be cleared.

called by: BUM

calls: none

```
dcl clearmenu entry (fix);
call clearmenu (x);
```

application: TRANSPARENT SKETCHING

CLEVEL

This routine is called when levels are added or deleted to clean out unused bits. Olevel is the value of the number of levels before any additions or deletions.

called by: ADD

calls: none

```
dcl clevel entry (fix);
call clevel (olevel);
```

application: TRANSPARENT SKETCHING

COLORINT

This routine is called to determine a new 16 bit color between a starting color (FROM) and an ending color (TO) given a percentage (PERCENT). The red, green, and blue components are separately interpreted.

called by: TRANSPARENT

calls: UNCOLOR

```
dcl colorint entry (bit(16),bit(16),fix) returns (bit(16));
new_color = colorint(from,to,percent);
```

application: TRANSPARENT IMAGES

COPY

This routine copies pixel data from one level to another depending on what levels are "on".

called by: BUM

calls: CORNER, FLEVEL, GETPT, WINSET, WREAD, WWRITE

```
dcl copy entry;
call copy;
```

application: TRANSPARENT SKETCHING

CORNER

This routine checks the values x1, y1 and x2, y2 to make sure that they represent the upper left and lower right corners of a rectangle. If not, it substitutes the correct values.

called by: COPY, EWINDOW, MOVE

calls: none

```
dcl corner entry (fix,fix,fix,fix);
call corner (x1,y1,x2,y2);
```

application: GENERAL

CROP

This routine displays the symbol for croplands (see AGEE).

called by: USE

calls: none

```
dcl crop entry ( );
call crop (info);
```

application: TRANSPARENT IMAGES

CSCREEN

This program writes "0" into the bits of every pixel as described by the mask argument.

called by: OSOIL, OUSE, OVEG OVERLAY, USE

calls: none

```
dcl cscreen entry (bit(16));
call cscreen (mask);
```

application: GENERAL

CSQUARE

This routine is the main calling routine to create colored transparent rectangles and then move them over a colored image.

called by: none

calls: MAKECSQ, MOVESQ

application: TRANSPARENT GELS

DIGG

This routine digitizes an image from 1 to 8 bits of resolution. The program takes three arguments:

1) the quarter of the matrix which is to be displayed while the digitization takes place,
2) the shift right argument (0-7), and
3) the subchannel mask.

called by: none

calls: VIDIGS, VIDSET

application: GENERAL

DIGL

This routine is used in the sketching system to digitize an image using the external variable LMASK as the subchannel mask. The shift is determined by the number of bits per level and the first level that is "active"

called by: BUM

calls: VIDIGS, VIDSET

```
dcl digl entry;
call digl;
```

application: TRANSPARENT SKETCHING

DIG2

This routine digitizes two 4 bit images. The first image is stored in bits 8-5 (counting from the right) while the second image is stored in bits 4-1. This program runs slightly faster than two DIGG's would because the parameters are already set and the first digitization does not require a shift.

called by: none

calls: VIDIG, VIDIGS, VIDSET

application: GENERAL

DRAWPTS

Given a pointer to an "object" that has already been allocated by UPSET (cp), this routine draws the outline of the object as points are allocated in a linked list. Flood is used to fill the object with the image stored in bits 8-5.

called by: UPSET

calls: GETPT, RAMSET

```
dcl drawpts entry (ptr,fix,fix);
call drawpts (cp,x,y);
```

application: LOGICAL TRANSPARENCY

EWINDOW

This routine displays a "window" from one 4 bit image to another. It assumes the color matrix has previously been loaded for the desired effect (colored images, transparency, clear windows). It can be displayed continuously or only when the pen is touching the tablet. The windows path can remain visible "erasing" one image to display the second.

called by: none

calls: none

application: CUTAWAYS

EXTVAR

This assembly language routine defines the external variables used in the transparent sketching system.

- NLEVEL - number of levels
- ACTIVE - levels that are "on" are active
- ORDER - the order for transparency of "on" levels
- PERCNT - percent of transparency for a given level
- LMASK - subchannel mask depending on NLEVEL and ACTIVE
- COLORS - array of 640 colors for all levels
- DISPLY - indicates what image will be displayed if that quarter of the matrix is referenced

application: TRANSPARENT SKETCHING

FADE

This routine is similar to TRANSPARENT. The only difference is that instead of a percentage of the two images this program takes the number of steps in the fading process as input. The color matrix is loaded for each step from the beginning image through the ending emage.

called by: FADEIT

calls: COLORINT

```
dcl fade entry (bit(16),bit(16),fix,bit(1),fix);
call fade (old_cm,new_cm,nplanes,direction,steps);
```

application: FADING

FADEIT

This routine fades from one 4 bit image to another 4 bit image stored in the Ramtek. Input includes

1) number of steps in the fading process
2) starting image - "1" low bit image
"0" high bit image
3) number of bits per point

called by: none

calls: FADE

application: FADING

FCOLOR

This routine will return a matrix (0:15) filled with those colors for a particular level (n) using the external variable COLORS

called by: FLIP, ADD, LTRANS

calls: none

```
dcl fcolor entry ( ,fix);
call fcolor (matrix,n);
```

application: TRANSPARENT SKETCHING

FINDED

This routine finds the first point along the extreme edge of visibility for SEEK to use in starting its sweep. It uses the external variables TOPX, TOPY, BOTX, BOTY that are set up in SEEK.

called by: SEEKS

calls: none

```
dcl finded entry (fix,fix,fix,fix);
call finded (x1,y1,x2,y2);
```

application: COMPUTED TRANSPARENCY

FINDMASK

This routine is used to find the subchannel mask for a particular transparent gel before moving it. NSQUARE is the total number of squares, and I is the number of the square in question.

called by: MAKESQ

calls: none

```
dcl findmask entry (fix,fix) returns (bit(16));
mask = findmask(nsquare,i);
```

application: TRANSPARENT GELS

FINDOBJ

Given a starting point (x,y), this routine uses the pointer to the beginning of the first list of objects (cp) to see if the point falls within any object's boundaries. If so, it returns a pointer to that object. If the point does not lie within any object, a null ( ) value is returned.

called by: S

calls: none

```
dcl findobj entry (ptr,fix,fix) returns (ptr);
objptr = findobj (cp,x,y);
```

application: LOGICAL TRANSPARENCY

FINDSQ

This routine searches through the list of existing rectangles and returns a pointer (sqptr) which points to the rectangle that was chosen. If (x,y) does not fall within any rectangle a null( ) value is returned.

called by: MOVESQ

calls: none

```
dcl findsq entry (ptr,fix,fix) returns (ptr);
sqptr = findsq (sptr,x,y);
```

application: TRANSPARENT GELS

FLEVEL

This routine is used in the sketching system to determine which level the user wants writable from those levels previously chosen. That number is then lit up.

called by: BUM, FLIP

calls: FMASK

```
dcl flevel entry (fix);
call flevel (x);
```

application: TRANSPARENT SKETCHING

FLIP

This routine is used in the sketching system to display individual layers by choosing the level number, turning it "on" or "off". The external variable DISPLY keeps track of what has been loaded in the color matrix. If the correct color set is already loaded it references that quarter, otherwise, a new color set is calculated and loaded into the matrix.

called by: BUM

calls: GETPT, FCOLOR, FLEVEL, LCOLOR

```
dcl flip entry;
call flip;
```

application: TRANSPARENT SKETCHING

FMASK

Using the external variables NLEVEL and ACTIVE, this routine calculates what the subchannel mask should be.

called by: FLEVEL

calls: none

```
dcl fmask entry;
call fmask;
```

application: TRANSPARENT SKETCHING

FULDA GAP DATA

These are four data files arranged in an 80 x 80 array with (0,0) corresponding to the upper left corner. Each point corresponds to a cell that is 125 meters by 125 meters on the map of Fulda Gap, Germany. For more complete documentation see the on line explanation in DATA.doc in directory FULDA.

LAND USE
VEGETATION
SOIL TYPE
ELEVATION

GETPT

This routine calls DEFCWS and TABLU to get a point from the tablet. It waits until the pen has been lifted from the surface of the tablet before returning the x and y values.

called by: ADD, BUM, FLEVEL, FLIP

calls: none

```
dcl getpt entry (fix,fix);
call getpt (x,y);
```

application: GENERAL

LCOLOR

This routine is used by the sketching system to fill the variable MATRIX with an appropriate color set to display the image on level N. STARTC is a matrix of starting colors.

called by: ADD, FLIP, LTRANS

calls: none

```
dcl lcolor entry ( , ,fix);
call lcolor (matrix,startc,n);
```

application: TRANSPARENT SKETCHING

LMENU

This routine will display that part of the menu used in the sketching system to be used in determining which levels are "active" and which are "on" or "off".

called by: BUM

calls: none

```
dcl lmenu entry;
call lmenu;
```

application: TRANSPARENT SKETCHING

LTRANS

This routine is used in the sketching system to determine a combination color matrix to display a transparent image for those levels that are "active".

called by: BUM

calls: COLORINT, FCOLOR, LCOLOR

```
dcl ltrans entry;
call ltrans;
```

application: TRANSPARENT SKETCHING

MAKECSQ

This routine creates a list of rectangles and returns a ptr to that list. The red, green, and blue components and percent for each rectangle are parameters defined by the user.

called by: CSQUARE

calls: CINTER

```
dcl makecsq entry (fix,ptr);
call makecsq (nsquare,sqptr);
```

application: TRANSPARENT GELS

MAKESQ

This routine creates a list of NSQUARE rectangles (1 to 9) and returns a pointer to that list. Each rectangle has a red, green, and blue component and percent that is defined by the user.

called by: SQUARE

calls: CINTER, FINDMASK SHIFT

```
dcl makesq entry (fix,ptr);
call makesq (nsquare,sqptr);
```

application: TRANSPARENT GELS

MAPDATA

This routine is used to map the database (USE, SOIL, VEG, ELEV) onto a digitized image of the Fulda Gap area. The origin is the location of the upper left hand corner of the database in pixel coordinates. The scale is the number of pixels required for each data point.

called by: OVERLAY, SEEK, USE

calls: none

```
dcl mapdata entry (fix,fix,flt,flt);
call mapdata (xorigin,yorigin,xscale,yscale);
```

application: GENERAL

MEADOW

This routine displays the symbol for a meadow (see AGEE).

called by: USE

calls: none

```
dcl meadow entry ( );
call meadow (info);
```

application: TRANSPARENT IMAGES

MENU

This routine puts up the main subroutine symbols to be used by the sketching system.

called by: BUM

calls: SYMADD, SYMCPY SYMDIG, SYMDRD SYMDRW, SYMFLP SYMMOV, SYMQUT SYMTRN

```
dcl menu entry;
call menu;
```

application: TRANSPARENT SKETCHING

MOVE

This routine moves a rectangular region of pixel values on a given level in the sketching system.

called by: BUM

calls: CORNER, FLEVEL, GETPT, WINSET, WREAD, WWRITE

```
dcl copy entry;
call copy;
```

application: TRANSPARENT SKETCHING

MOVESQ

This routine searches through the list of rectangles pointed to by SQPTR and then moves them around the screen using frame coherence.

called by: SQUARE

calls: FINDSQ

```
dcl movesq entry (ptr);
call movesq (sqptr);
```

application: TRANSPARENT GELS

NEXTPT

This routine is called by seek to determine the progression of radial sight lines. The point x2, y2 is on the extreme edge of visibility and CLOCK is the clockwise or counter-clockwise direction. The program uses the external variables TOPX, TOPY, BOTX, BOTY.

called by: SEEK

calls: none

```
dcl nextpt entry (fix,fix,bit(1));
call nextpt (x2,y2,clock);
```

application: COMPUTED TRANSPARENCY

NSFCON

This routine displays the symbol for a coniferous non-state forest (see AGEE).

called by: USE

calls: none

```
dcl nsfcon entry ( );
call nsfcon (info);
```

application: TRANSPARENT IMAGES

NSFDEC

This routine displays the symbol for a deciduous non-state forest (see AGEE).

called by: USE

calls: none

```
dcl nsfdec entry ( );
call nsfdec (info);
```

application: TRANSPARENT IMAGES

OFFSET

This routine is used in the sketching system to return a shift right value depending on the particular level (N).

called by: DIGL, FMASK, LCOLOR

```
dcl offset entry (fix) returns (fix);
shift = offset(n);
```

application: TRANSPARENT SKETCHING

OSOIL

This routine displays the soil data as transparent overlays on top of a four bit map of Fulda Gap. (see OUSE)

called by: OVERLAY

calls: COLORINT, CSCREEN

```
dcl osoil entry ( );
call osoil (info);
```

application: TRANSPARENT IMAGES

OUSE

This routine displays the land use data as a transparent overlay on top of a four bit map of Fulda Gap.

called by: OVERLAY

calls: COLORINT,CSCREEN

```
dcl ouse entry ( );
dcl 1 info,
      2 xorigin       fix,
      2 yorigin       fix,
      2 xscale        flt,
      2 yscale        flt,
      2 next          fix,  /* the next plane
                               open for new
                               data    */
      2 temp(0:1023)  bit(16);
                            /* copy of the
                               color matrix */
```

application: TRANSPARENT IMAGES

OVEG

This routine displays the vegetation data as transparent overlays on top of a four bit map of Fulda Gap (see OUSE).

called by: OVERLAY

calls: COLORINT, CSCREEN

```
dcl oveg entry ( );
call oveg (info);
```

application: TRANSPARENT IMAGES

OVERLAY

This routine allows one to overlay the different layers of data (USE, VEG, SOIL). It first calls mapdata to set up the coordinates, and then calls the individual display routines. Since four bits are used for the base map, only six levels of data can be displayed at any one time.

called by: none

calls: CSCREEN, MAPDATA, OSOIL, OUSE, OVEG

application: TRANSPARENT IMAGES

PWINDOW

This is a variation of EWINDOW. The routine assumes that there are two four bit images stored in the Ramtek. It also assumes that the second quarter of the matrix is loaded to display the high order image while the third quarter of the matrix will display a combination of both images. Then one can use the pressure of the tablet pen to display the various levels transparency.

called by: none

calls: none

application: CUTAWAY

S

S is the search routine in logical transparency that finds any object or set of objects and displays them. CP is the pointer to the top of the list of all objects.

called by: UPSET

calls: FINDOBJ

```
dcl s entry (ptr);
call s (cp);
```

application: LOGICAL TRANSPARENCY

SEEK

This routine displays the Fulda Gap land use data that can be seen from a starting point, given a viewing height and maximum radius. The program uses the elevation data to determine if a point can or cannot be seen.

called by: none

calls: CSCREEN, FINDED, GETPT, MAPDATA, NEXTPT, WWRITE

application: COMPUTED TRANSPARENCY

SFCON

This routine displays the symbol for state forest coniferous (see AGEE).

called by: USE

calls: none

```
dcl sfcon entry ( );
call sfcon (info);
```

application: TRANSPARENT IMAGES

SFDEC

This routine displays the symbol for a deciduous state forest (see AGEE).

called by: USE

calls: none

```
dcl sfdec entry ( );
call sfdec (info);
```

application: TRANSPARENT IMAGES

SHIFT

This routine shifts the pixel values of the image to the right one bit by using the arithmetic mean instruction.

called by: MAKESQ

calls: none

```
dcl shift entry;
call shift;
```

application: GENERAL

SQUARE

This routine is the main calling routine to create colored transparent rectangles and then move them over a black and white image.

called by: none

calls: MAKESQ, MOVESQ

application: TRANSPARENT GELS

STREAM

This routine returns the x and y values from the tablet as soon as it is touched.

called by: USE

calls: none

```
dcl stream entry (fix,fix);
call stream (x,y);
```

application: GENERAL

TOWN

This routine displays the symbol for a town (see AGEE).

called by: USE

calls: none

```
dcl town entry ( );
call town (info);
```


application: TRANSPARENT IMAGES

TRANSIT

This routine displays a transparent image based on two four bit images previously stored in the Ramtek. The program asks for a percentage from 0% (low bit image) to 100% (high bit image).

called by: none

calls: TRANSPARENT

application: TRANSPARENT IMAGES

TRANSPARENT

This routine loads the color matrix with an appropriate color set to display a transparent image of two original images. The arguments are:

1) a starting color set (old_cm),
2) an ending color set (new_cm),
3) the number of bits/point (nplanes),
4) an indication of which image is the starting image ("1" low bit image "0" high bit image),
5) the percent of the original and final images.

called by: TRANSIT

calls: COLORINT

```
dcl transparent entry (bit(16),bit(16),fix,bit(1),fix);
call transparent (old_cm,new_cm,nplanes,direction,percent);
```

application: TRANSPARENT IMAGES

TWOGRAY

This routine loads the color matrix with two gray scales assuming two four bit images will be stored in the Ramtek.

called by: none

calls: none

application: GENERAL

UNCOL

This routine returns the individual red, green, and blue components of a 24 bit color value (RGB).

called by: CINTER

calls: none

```
dcl uncol entry (fix,fix,fix,bit(24));
call uncol (r,g,b,rgb);
```

application: GENERAL

UNCOLOR

This routine returns the individual red, green, and blue components of a bit 16 color value (RGB).

called by: COLORINT

calls: none

```
dcl uncolor entry (fix,fix,fix,bit(16));
call uncolor (r,g,b,rgb);
```

application: GENERAL

UPSET

This routine is the main program in creating and then using a database for logical transparency. It allocates the elements while the subroutine DRAWPTS completes the database.

called by: none

calls; DRAWPTS, S

application: LOGICAL TRANSPARENCY

USE

This routine displays the Fulda Gap land use data when a point has been touched on the tablet. Various transparent symbols are displayed for the different use types. The symbols change in size to reflect the scale of the map.

called by: none

calls: AGEE, CITY, CROP, CSCREEN, MAPDATA, MEADOW, NSFCON, NSFDEC, SFCON, SFDEC, STREAM, TOWN, VILLAGE

application: TRANSPARENT IMAGES

VIDIGS

This assembly language routine digitizes an image into the Ramtek. A shift right instruction is used making this a flexible routine. An error code is returned and should be equal to 0 or 3.

called by: DIGG, DIGL, DIG2

calls: none

```
dcl vidigs entry (fix,fix);
call vidigs (error,shift);
```

application: GENERAL

VIDSET

This routine should be called to initialize the Ramtek before digitizing an image. A subchannel mask is the only argument passed.

called by: DIGL

calls: none

```
dcl vidset entry (bit(16));
call vidset (mask);
```

application: GENERAL

VILLAGE

This routine displays the symbol for a village (see AGEE).

called by: USE

calls: none

```
dcl village entry ( );
call village (info);
```

application: TRANSPARENT IMAGES

WINSET

This routine will reset the Ramtek's window to the arguments that are passed (upper left, lower right).

called by: COPY, DIGL, MOVE

calls: none

```
dcl winset entry (fix,fix,fix,fix);
call winset (xtop,ytop,xbot,ybot);
```

application: GENERAL

WREAD

This routine will either read a rectangular window from or write a rectangular window to the Ramtek. MATRIX is a one-dimensional array of pixel values and MASK is the sub-channel mask used with the write option.

called by: COPY, MOVE

calls: none

entry point: WWRITE

```
dcl wread entry ( ,fix,fix,fix,fix);
dcl wwrite entry (bit(16), ,fix,fix,fix,fix);
call wread (matrix,xtop,ytop,xbot,ybot);
call wwrite(mask,matrix,xtop,ytop,xbot,ybot);
```

application: GENERAL

5.0 BIBLIOGRAPHY

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