COMPUTER ROTOSCOPING WITH THE AID OF COLOR RECOGNITION

by

Rebecca Allen

BFA (Film Animation)

Rhode Island School of Design

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Signature of the Author ____________________

Department of Architecture
February 12, 1980

Certified ____________________

Nicholas Negroponte
Associate Professor of Computer Graphics
Thesis Supervisor

Accepted by ____________________

Professor Nicholas Negroponte
Departmental Committee for Graduate Students

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Submitted to the Department of Architecture on February 11,1980, in partial fulfillment of the requirements for the degree of Master of Science.

Abstract

Rotoscoping is explored as a computer animation technique. The optical videodisc serves as the image storage and input source. Image processing and tablet painting routines are applied to digitized frames.

"Color Recognition", the exploitation of digital color information, enables the tracking of objects, from frame to frame, based on their color. This system allows for semi-automatic, <u>selective</u> processing of images.

Thesis Supervisor: Nicholas Negroponte

Title: Associate Professor of Computer Graphics

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I.0 INTRODUCTION

Film animation continues to have mass appeal though the economics of production time often prohibits the use of traditional techniques. This thesis explores the use of rotoscoping as a technique for computer animation. Rotoscoping is defined in the film industry as an Animation and Special Effects technique. A Computer Rotoscoping system has been designed and implemented. An Optical Videodisc serves as the input source for frames to be rotoscoped. These frames are processed and painted, creating animation sequences.

A major aspect of the Computer Rotoscoping system is "Color Recognition." Color Recognition is based on the premise that if a computer could recognize a shape by its color, a tracking system could be implemented that would follow that shape from frame to frame. The color area being tracked could serve as a template or matte, allowing the area under the template to be processed and colored.

Processing, Coloring and Color Recognition software is described, as well as additional uses for this system.

2.0 Rotoscoping as an Animation Technique

The animator, Max Fleisher, devised a method of filming live actors and using the results as a guide for animation. (8.) A sequence of live footage is projected, frame by frame, and the artist traces the movements of a subject. The motion information is then transformed into a stylized animation environment. This technique, known as rotoscoping, is especially helpful when animating complex movement such as human characters.

The standard animation process, 'cel animation,' uses the key pose or key frame technique. The animator will first draw the salient poses of a character, mapping out the movement, and later, the interlinking or 'in-between' frames can be drawn, completing the action. (13.)

Though some form of a model is needed to design any type of animated movement, the use of live action as a model has always been controversial among animators. "Live action should only be used as a 'library' of information and should never be traced," says Art Babbitt, a long-time Disney animator. (21.)

There appears to be a fine line in the rotoscope controversy based on the amount of interpretation the artist exercises when drawing from live action models. During the production of Disney's first full length feature, Snow White and the Seven Dwarfs, rotoscoping was deemed necessary to inject a certain realism into the characters of Snow White, the Prince, and the Queen. (The dancer, Marge Champion, acted as the rotoscoped model and hence personality of Snow White). The Disney animators would employ a kind of 'gentle caricature,' so that gestures and poses become slightly exaggerated. As reported, "this system served the animators well, and they continued to use it in later movies." (10.) It seems that this technique of 'gentle caricature' justified their initial use of rotoscoping.

In any case, the animator must become proficient at simulating movement. For the dedicated, conventional animator, this can be accomplished by spending countless hours memorizing the visual effects of the laws of motion and extrapolating characterizations from this knowledge. But, by using the technique of rotoscoping, the animator needs only to conceive of the necessary movements, record them, or access them from existing live-action footage, and use these movements as the basis of the animation. In a sense, this concept is similar to that of the Bauhaus Theater where the actors and dancers were "reduced to motors for the costumes." (12.)

The process of animation, that of creating a discreet image for each instant of represented time, has imposed restrictions on artistic style. The exaggerated style of cartoons has evolved out of function. The gesturing parts of the body--legs, arms, hands, feet and especially the head--often demand enlargement as well as simplification for two reasons. One, because these parts will most obviously portray a character, but a more important reason is a result of the structured organization of an animation studio. The need for drawings in huge numbers has required the formation of an intelligent assembly line-production system. Because a drawing may pass through many hands; some form of graphic economy, through the simplification and exaggeration of certain characteristics, is essential. (13)

John Halas and Roger Manvell proclaim, "As the animator draws away from naturalism the powers of his medium increases; there is nothing but the limits of imagination and his technical resources to hold him back." (13) But in practice, one's imagination is severly limited by the monumental task of the animation process.

Rotoscoping, as a time-saving technique, allows the artist additional time and effort towards the rendering and detailing of the imagery.

3.0 ROTOSCOPING AS A SPECIAL EFFECTS TECHNIQUE

A more technically oriented use of rotoscoping is applied in the area of Special Effects animation. The technique of rotoscoping is often linked to the matting process, especially the travelling matte. (For a more detailed description of Special Effects processes, refer to (9, 5)).

A lamp house and prism assembly, which attaches to an animation camera, allows for the projection of master positive film. This unit is often referred to as a "Rotoscope," and the projection process, as "Rotoscoping." (9)

Live action footage is rotoscoped in order to provide guide points when matting in an image. A scene, (live action or animated) can be traced, frame by frame, providing a plot or graph which enables artwork and moves to be planned together. This technique can be used, for example, to superimpose a title or credits on a moving object.

Another example of its use was during the production of The Miracle Worker. A rough road caused an unacceptable jiggling of a dolly shot. To smooth out the shot, each frame was rotoscoped onto an alignment chart, plotting the changes in image position due to the jiggling. (9)

Travelling mattes grew out of a need for a "type of matte which changes in position, size, and configuration from frame to frame." (9)

'Hand drawn animation provides what is both the most versatile and the most tedious method for the production of a travelling matte." (9)

Travelling mattes can also be produced photographically. This is accomplished by taking advantage of the film's ability "to record different colors which are intentionally produced in foreground and background areas during the original photography. (9) The most basic method is the blue-backing' system, though additional techniques capitalize on color filtering. These include the Infra-Red, Ultra-Violet and Sodium-Vapour processes.

The above sections have described the use of rotoscoping in an Animation and Special Effects environment. These areas correspond to the respective categories of Processing/Coloring and Color Recognition in a Computerized Rotoscoping System, (described in the following sections). Processing/Coloring software allows for the modification and painting of images. Color Recognition software enables the tracking of objects, from frame to frame, based on their color.

4.0 ROTOSCOPING IN A COMPUTER GRAPHICS ENVIRONMENT

The implementation of a rotoscoping system in a computer graphics environment was justified for a number of reasons:

-- As a graphic designer/film animator, struggling in a computer graphics lab, I was groping for a thesis topic that would utilize my previously acquired skills.

-- The interfacing of Computer Graphics with the Optical Videodisc was appealing.

-- There was an immediate application of rotoscoping, involving two research efforts at the Architecture Machine Group.

4.1 The Optical Videodisc as a Motion Library

The use of the Optical Videodisc as an inexpensive storage device is a major concern at the Architecture Machine Group. The videodisc is capable of storing 108,000 frames (54,000 frames per side.) The disc playing speed varies between single frame mode and 30 frames per second (fps). These frames can contain one hour of a motion picture at 30 fps, single frame stills, or any combination of the two. A fast scan mode enables scanning of the disc from first frame to last in approximately five seconds. This feature, and the fact that each videodisc frame is encoded with a number, creates a random access device, able to operate under computer control.

If one's rotoscoping source material is stored on a videodisc linked to a computer, then a videodisc system would become a library of motion segments, including a data base. This data base would contain a list of motion segment descriptions and their associated frame numbers. With such a library, it could be possible to locate, for example, an aerial view of a football tackle, or an underwater shot of a shark swimming, eliminating the need to generate the original footage.

4.2 Preliminary Procedure

As a first attempt at rotoscoping from a videodisc, a frame from the disc was superimposed on the computer's display monitor. Using the computer's tablet and paint programs, I simply traced and stylized those areas of the frame to be animated. These drawings were loaded onto an Eigen magnetic videodisc (a Slo-Mo device), and replayed at a variety of speeds.

4.3 Applications at the Architecture Machine Group

Two research projects stimulated the development of a rotoscoping technique:

1. The Aspen Movie Map Project has, on videodisc, live footage of the buildings and streets of Aspen, Colorado, including front facades of each building in the town. There is also computer generated animation of Aspen, using a limited number of polyhedra

to represent actual building types. Because the polyhedra lack enough identifying detail, simplified, rotoscoped caricatures of building facades can be mapped onto the front of the appropriate polygon, providing more specific visual location cues.

2. The Personalized Movies Project concerns the display of instructional information, in this case, bicycle maintenance and repair, in the most effective format for each user. Certain perspectives are available through live-action footage, but a form of animation is needed for a number of reasons:

   a) As an alternative style of visual presentation. Earlier research on image perception determined advantages to various degrees of image degradation such as simplification and loss of detail. (11, 14, 20, 23, 26)

   b) Coloring can be done arbitrarily, therefore allowing subdued or bright tones, highlighting of a particular area, or unnatural coloring.

   c) By providing levels of detail, important features can be highly detailed, less important areas, less detailed or deleted.

   d) Rotoscoped animation is especially appropriate for instructional use. Much information is conveyed through "real" motion, making high resolution movement an important factor. In the case of bicycle maintenance, the movement conveys touch or "feeling." (How much pressure is exerted when screwing or unscrewing? How heavy is a tool or part?) "Real" motion also supplies temporal information. (How many rotations are needed? How long does a particular task take?)

e) The existing bicycle videodisc contains a large amount of cyclic movement. For example, a 20 frame sequence of one rotation of a wrench is repeated 40 times using 800 videodisc frames. When transferring the rotoscoped animation onto a disc, only the first cycle is necessary. This will save large amounts of videodisc real estate.

4.4 Rotoscoped Animation for Instructional Use

Further elaboration on rotoscoped animation for instructional films (or videodiscs) should include a statement by Halas and Manvell (13). "It has been proved by experience that the shorter the film the more effective the instruction is likely to be . . .. Animation can often help to shorten the footage of the instructional film without loss of content . . .. The element of design in the graphic style of the film can itself be an aid to memory through the use of striking shapes and colours . . .. The key moments in the animation of mechanisms and processes can easily be isolated" (or emphasized). Though rotoscoping may start with "real" motion, it is possible to alter pacing by eliminating frames or extracting only key frames from the live footage.

5.0 IMAGE PROCESSING

In order to link Rotoscoping to Computer Graphics it became apparent that Image Processing techniques could be utilized. The science of digital image processing involves the analysis and manipulation of scanned (usually photographic) images. This can be accomplished through the use of convolving kernel filters based on mathematical transformations. (2) The process is often used for enhancing and extracting detail information in a photographic image, but is also capable of performing countless variations of photomechanical processing techniques.

5.1 The Artist as Image Processor

The traditional role of a visual artist is that of an image processor. What distinguishes the art of image processing from the science of image processing is the type and level of interpretation that occurs.

At present, image processing hardware/software systems provide an effective interpretive tool for the artist. This tool is destined to find its place in the Art World if, for example, one observes the techniques of Pop Artists or Hyperrealists. (4, 19, 22)

6.0 THE COMPUTER ROTOSCOPING SYSTEM

When rotoscoping from live footage, the animator will often select key frames to use when developing the overall style and color. Once the 'look' has been determined, the tedious job of transforming each frame begins. From my own experience, this task inevitably brings about the desire for a method of coding the style and color transformations of the various subjects in a drawing. If this information was coded, one could hope to automatically apply these changes to the appropriate areas in the rotoscoped image. The following sections describe the first phase of a computerized rotoscoping system, capable of performing such a task.

6.1 The Input Process

6.1.1 Hardware

The MCA Model PR7820 Videodisc Player serves as the storage and input source.

Digitized images are stored in a Ramtek 9300 frame buffer. The Ramtek color, raster scan display system generates RGB signals with 640 x 480 pixel resolution. Though capable of displaying 2^{24} colors, its 9 bit planes allow only 512 colors to be displayed at one time. The host computer is an Interdata 7/32.

6.1.2 Software

Programs are accessed from a number of different directories and sub-directories, therefore a directory change will be noted next to the program name. Program names are in capital letters.

Using the program

DIG in directory: >u>paul>color

A single frame from the videodisc is digitized (converted from analog to digital information) in three passes. The first pass converts the blue information, the second and third pass does the same for green and red information.

DOODLE

Indicates the IMAGE program the pixels to be used for color sampling.

IMAGE

Samples the image to find the 256 most frequent colors and uses them for the color matrix of an 8-bit color image. When complete, the user has an 8-bit color reconstruction of the videodisc frame.

SAVEPIC

Saves the 8-bit color image in an image file.

B&W

Converts the RGB values to black and white (intensity) values, creating a black and white version of the image. This image is also saved using SAVEPIC.

A number of key frames in a motion sequence can be stored. The black and white (B&W) version of these frames can be used as references when deciding the overall style (i.e. the processing and coloring) of an image sequence. The reconstructed color version can be used as key frames when teaching the system various color areas (i.e. color recognition).

7.0 PROCESSING/COLORING PROGRAM DESCRIPTIONS

As stated at the end of section 3.0, the computer rotoscoping software is divided into two major categories. The first category, Processing/Coloring, includes a series of programs which allow the animator to modify and paint an image. The second category, Color Recognition, includes programs which enable the tracking of objects, from frame to frame, based on their color.

7.1 Image Processing Programs

These programs initially use the digitized 8-bit B&W reference images.

SHIFT in directory: >u>pt>roto

Shifts the most significant 4 bits of the 8-bit image into the 4 least significant bits of the Ramtak. This creates a 4-bit B&W reference image. The remaining 5 bits are used for color data (as described in section 7.2).

A low pass filter program can be applied for smoothing contours or blurring edges. A high pass filter program can be applied for edge outlining (detection).

The image can be processed further through the TONE programs.

TONE in directory: >u>pt>roto>tone

Interactively generates a transformation, mapping the bits in the reference image (4 lsb's of the Ramtek) to various gray levels. Contrast, brightness and exposure effects are all possible as well as the simulation of a 1 to 4 bit image.

TONE functions inclued:

- -BITS varies the bit levels from:
  - 1-bit -a black and white, high contrast image
  - 2-bit -4 gray levels (including B&W)
  - 3-bit -8 gray levels
  - 4-bit -16 gray levels
- -CONTRAST varies the contrast levels from low to high contrast.
- -OFFSET varies the lightness or darkness by shifting the gray levels towards black or white.
- -GRADIENT alters the gray levels while blacks stay black
- -PICK displays only a particular, chosen gray level as an impulse function.
- -PRINT accesses and displays the current values from the parameter file in READPARAM (described below).
- -GRAPH calls the program, GRAPH, to display the current plot.
- -UNGRAPH calls the program, UNGRAPH.

GRAPH in directory: >u>pt>roto

Plots and displays a graph of the various TONE functions, mapping the bits in the 4-bit reference image to the appropriate gray levels. As the TONE functions are changed the graph display is altered. This graph is overlayed on a small section of the reference iamge, providing a visible plot of the gray level alterations occuring in the image.

UNGRAPH

Removes the overlayed graph.

7.1.1 Image Information Files

Aside from the graph display, a file is created which contains a list of pertinent information for each sequence of frames.

CREATEPARAM in directory: >u>pt>roto>utility

Creates a parameter file which stores such statistics as frame numbers, sequence numbers, number of bits, and the color matrix number. In addition it contains the current values of offset, gradient and contrast.

READPARAM

Rreads the parameter file.

7.1.2 Tablet Driven Image Processing

The above programs use a keyboard as the interface between the artist and the manipulated image. The following programs create a graphic menu display. The artist is able to quickly and easily modify an image, using a tablet and stylus to point to various functions displayed on the screen. This menu is located in the area below the visible portion of the screen, but can be shifted to the visible area when needed.

TONEG

A tablet driven TONE alteration program. It calls TONEMENUE with the present x,y and returns the functions requested and the variables selected. The menu is hidden in lines 479-511 in the Ramtek, so this program reorigins the Ramtek to make the menu visible. TONEMENUDRAW is the program that draws the menu.

7.2 Coloring Programs

A specialized painting program was implemented which allows the artist to paint the B&W reference image, using a "brush" that recognizes the various gray values of the image it is painting.
As stated earlier, our Ramtek Graphic Display is 9 bits per pixel. Since 4 bits are being used for the reference image, this leaves a color palette limited to 32 colors. Therefore, colors must be chosen easily and accurately. As one solution, the RGB color space was transformed into IHS space (Intensity, Hue, Saturation) for a more intuitive color selection.

CHOOSECOLORS in directory: >u>pt>roto>cm
Calls all color related programs.

To paint in a particular object, for example, a person's jacket, one would want a brush capable of recognizing the highlighted and shaded areas. A color selection program was implemented that can, first of all, pick colors from any existing color matrix or from a display of the IHS color space.

The color selection program

CHOCOLATE

Accesses a color table that stores the RGB components of the initial and final colors in a color wipe. A color wipe, also referred to as a wash, includes the intermediate colors of a transition between two color values.

MAKECM

Creates a color matrix from the information in the color table. It executes a linear wipe between each initial and final color of the 32 color blocks in the color table.

The color matrix will contain 32 color blocks with a 16 color (4-bit) wash between the first and last colors in each block. These color washes correspond to the 16 gray levels of the 4-bit reference image. So if the first color in the color block is brown, and the last color is yellow, all black areas in the reference image will be painted brown, all white areas yellow, and the inbetween grays correspond to the color tones in the brown to yellow transition. A color wipe can be a dark to light value of a color, a wipe between two different colors (blue to pink), or a solid color. As well as having shaded brushes, this system allows more color values than a standard 32 color palette.

NCOLORING

The coloring program, is a modified version of our standard painting program with flooding capability. The color palette is displayed at the bottom of the reference image, and a tablet and stylus are used for painting. There are two basic brush types. One will paint over the various gray levels with the appropriate color values. This brush quickly covers large areas of an object. The second brush type paints only a selected gray level, again with the appropriate color value. This brush is especially good for quickly outlining the border of an object, or for coloring small intricate areas, because it will not paint into adjacent but different gray levels.

The color on the brush can also be modified by the TONE functions. This proves to be an interesting link. For instance, the contrast of a color can be altered by changing the CONTRAST value, or the tones of colors can be lightened or darkened by varying the OFFSET. Of particular importance, is the ability to alter the detailing of a painted object by changing the BIT level. This enables one area of a painted image to be detailed (4 bits), while another area, less so (perhaps 2 bits).

7.3 Checking Image and Motion Consistency

LUNATIC in directory: >u>paul>ram>warp

Allows a sequence of images, up to 64, to be displayed on the monitor and checked for consistency. The sequences can also be set in motion, in forward or reverse, at various speeds, so as to observe motion accuracy and pacing.

7.4 Superimposing Images

COLLAGE in directory: >u>jkess>cap

Combines two images by inserting the second image in the unpainted areas of the first.

8.0 COLOR RECOGNITION

8.1 Why Color Recognition?

Though the Processing/Coloring programs enable the animator to quickly create and paint a new image, she or he is still repeating this task for every frame. Processing over an entire image, such as low or high pass filtering can be performed automatically by the computer, but the computer cannot recognize objects. The most it recognizes in a reference image are the various gray levels. Yet, often, in a scene, two or more objects can contain the same gray levels though they have been painted different colors.

The development of an intelligent machine, capable of recognizing objects or analyzing data in a scene, is an area receiving more and more attention and research. This research generally concentrates on pattern, shape or texture recognition.

In the case of rotoscoping, the shape of a subject in live footage usually varies from frame to frame; because it is moving in three-dimensional space, and because of motion blur on the recorded image. These factors, combined with the shape complexity of most subjects, eliminates the use of traditional scene analysis techniques. (Not to mention the fact that they are tedious and time-consuming processes, which would have to be applied to hundreds of frames.)

Even if it were possible to identify a shape, such as a human form, the artist might want to paint the skin green and the clothing blue. This would require further recognition and segmenting techniques.

Therefore I focused on the exploitation of the color information in a scene to define the shapes of objects.

Most efforts in scene analysis and picture processing have concentrated on monochromatic images. But since the advent of faster scan graphisc, as well as videodiscs, images are no longer restricted to monochromatic information. (An interesting aside is Kodak's recent announcement of a large price increase for all black and white film. This may move the black and white photo into the area of antique processing.)

Color is an important property of objects and plays a large role in human perception and recognition. As Berthold Horn (15) points out, "Colors are so immediate, and seldom depend on one's interpretation of the scene. Colors will be seen even when the picture makes no sense in terms of previous experience. Also, color is seen at every point in an image." If a computer could recognize the shape by its color, a tracking system could be implemented that would follow that shape from frame to frame. The color area being tracked could serve as a template or matte, allowing the shape under the template to be reprocessed and recolored.

8.2 Color recognition Program Descriptions

8.2.1 Learning the Colors of a Color Image

The 8-bit reconstructed color version of a frame is loaded into the Ramtek and displayed on the monitor.

The computer must be taught the various colors of objects in that frame. This is done using the program

LEARN in directory: >u>pt>roto>cr

Using the tablet, the artist circles an area within an object. Pressing down the stylus inside the circled area causes a flood algorithm to find its boundary. A seemingly, single colored object actually contains a number of discreet colors and shades. Because of this, the flooded area should include a good representation of the overall color of the object. This can be accomplished by circling more than one area in an object. A count of the frequencies of each color found is tabulated and stored under the object name in a data base. Each object's data base includes:

1. the name of the object
2. the color set (learned colors) of an object
3. the new color the object is to be painted
4. the TONE functions coded in the new color

Once the colors of the objects have been taught, SHOW is used.

8.2.2 Displaying and Editing Learned Colors

SHOW

Requests an objects' name and displays the learned colored set in its data base. SHOW will also list the colors found using their position number in the color matrix and display a plot of those colors. Using DISPLAY, the artist is able to see if the objects' color has been learned correctly. If not, an editing program can be used to eliminate unwanted colors. This is done either by a yes-no answer to each color in the color set, or the tablet can be used to point to areas outside of the object where colors are to be deleted. Except for the editing, no changes are made to the data base.

Once satisfactory color data bases are created, they should be checked with additional digitized color frames. If, for instance, a color data base identifying a blue jacket has been created, this data base should be checked with additional color frames to make sure the blue jacket will be consistently identified.

8.2.3 Generating a Template

At this point, the second frame of a sequence can be displayed on the monitor.

ROTOPAINT

Uses the 9th bit plane as a template or matte. The animator points to an object in the image and the computer decides what the object is and displays its name. It will then flood, with a solid color, over the object it has found, filling in wherever it finds the colors in the color set of the object's data base. The flooding of a contiguous area is one of the key advantages of this system. Take the previous example of the blue jacket. ROTOPAINT will flood over the jacket as a contiguous area. There may have been some 'blue jacket color' pixels elsewhere in the image, but because they are not touching the jacket shape, the flood will not find them. The flooded area becomes the template the the random pixels are ignored. An averaging filter can be run over the template to make the template a smooth, solid shape.

8.2.4 Using the Template for Automatic Coloring and Processing of Sequential Frames

ROTOPAINT then applies the previously selected new color and TONE functions (coded in the color) to the area underneath the template. These are third and fourth items in object's data base. For instance, the blue jacket could now automatically become a red, 3-bit jacket. This process occurs for the remaining frames in a sequence.

TRACK

Designed to eliminate the need for the animator to point at objects to be flooded. Incomplete at this time.

8.3 Summary

This is the design of the system at present. To simply summarize through an example, a hand registers a "flesh" hue and the "flesh" hue boundaries determine the hand shape. As the frames in this sequence are displayed, the hand is changing shape and position but for each frame the "flesh" hue is mapped to its new color and corresponding TONE changes. The result being a sequence which imitates the image modifications that the animator created in the first frame.

This system, in effect, allows for semi-automatic, selective processing of images.

8.4 Research Survey of Color Picture Processing

Though no previous research was found pertaining directly to this thesis, there was evidence of work involving the exploitation and applications of color information in picture processing.

Yachida and Tsuji (28) published one of the earlier reports, describing algorithms for color perception and applications of color information to visual perception. In their study, solid color blocks were described by their color and boundary points, using a straight-line fitting routine. They concluded that "normalized color is constant as long as the color temperature of the illuminating sources remain the same. This makes fast processing of visual information possible."

Tennenbaum (24) argues that we must avoid the simple "blocks" world, and "learn to cope with the complexity of real-world scenes by capitalizing upon their natural redundancy and contextual constraints." His approach relies heavily on multi-sensory (i.e. color and range) data to locate objects. These simpler descriptions are favored over more complex attributes (e.g. shape and texture), because of economy, reliability, and, most important, the ability to find complex objects (like trees) which can be impossible to describe. According to Tennenbaum, "it is . . . easier to interpret a set of brightnesses . . . as a color . . . than to interpret a set of gray-scale intensities as a shape or texture."

Horn (15) basically agrees with the importance of using color as low-level processing.

Ito (18) discusses the importance of "computer-oriented chromatics", emphasizing the need to modify the traditional field of "chromatics" or "color science" to include procedures for computer analysis of color information. He concludes, through analysis, that, compared to monochromatic pictures, color pictures contain a large amount of information which should be utilized.

Underwood and Aggarwal (25) describe an interactive computer system that measures the color of individual trees to detect the presence of insect infestation. An aerial infra-red photograph is used as the input.

Ali, Martin, and Aggarwal (1) describe a three-dimensional normalized color space used for segmenting color scenes. Both color (independant of intensity) and total intensity information can be accessed. Aerial color photographs in the form of 35 mm transparencies are used as input.

9.0 OUTPUT FACILITIES: RECORDING ON VIDEOTAPE OR FILM

The automatic recording of frames as they are completed must be capable on a high quality medium. The Architecture Machine Group has access to an Eigen magnetic videodisc which can store up to 300 frames and input these frames onto videotape at a variety of speeds.

We also have access to the Matrix Color Graphic Camera and are in the process of modifying the Matrix to accept a 35mm Mitchell movie camera as a recording device. This unit is being designed to automatically record sequences of animation frames from the Tamtek. With the capability to automatically input videodisc frames to be digitized, an input/processing/output system is complete.

10.0 ADDITIONAL APPLICATIONS OF COMPUTER ROTOSCOPING USING COLOR RECOGNITION

10.1 Color Recognition as an Intelligent Chroma-Key

Methods of electronic inlay and overlay, sometimes referred to as keying or chroma-keying, are employed in the television broadcasting industry. These are techniques similar to film matting (discussed in Section 3.0), where one image is inserted in or overlayed on another. With monochromatic television, a black or peak white backing is used behind a subject. A switching circuit allows the insert of a second input when it receives the signal from the appropriate shade of black or white. This created problems with 'black' shadows on the subject or 'white' reflected highlights such as perspiring foreheads. The second input would leak into these areas. With the advent of color television, the industry utilized the cameras' ability to read color information. This cuased the development of the Chroma-Key system which allows the camera to key on a particular color. This color activates the switching circuits and inserts a second input. A blue of specific hue and intensity was chosen as the primary keying color because blue is basically not found in human flesh tones, and because this blue produces the highest response in the blue channel of the camera. (27)

A form of digital color recognition could be exploited as a more intelligent keying system. Less sensitive to uneven coloring, it is, therefore, capable of keying on a larger variety of colors and on colors in scenes that were not initially designed for keying purposes.

10.2 Other Applications

Digital color recognition could be used to track moving objects in the same way that rotoscoping is used as a Special Effects technique to superimpose a title on a moving object. (Refer to p.10.)

Color recognition, if accurate enough, could be used to create travelling mattes. (Refer to p.11.)

Because Color Recognition is in the digital computer domain, it may combine with other numerous computer graphics and image processing capabilities.

11.0 CONCLUSIONS AND FURTHER DEVELOPMENTS

Color Recognition will be most effective with simple scenes. The more differentiated the color areas, the better. A few tests with textured objects and patterned clothing have been surprisingly successful. This implies that it is not necessary to apply color recognition to only solid color objects.

The next step should be the development of an assiduous evaluation method, devised to measure and analyze the variables appropriate to this use of color information.

More favorable interaction between the animator and the system would occur through increased speed of the processes. If the ROTOPAINT routines were coded in assembly language for a frame buffer processor, the speed of these programs could be drastically increased. Or, for instance, real-time image processing facilities, currently on the market, could allow the animator to observe a large number of processing variations in a very short amount of time.

Each medium possesses its own characteristics. Charcoal pencil does not give the same effect as oil paint or emulsion on film. The artist using this system should allow this medium to affect the style and reveal its characteristics, rather than force a style previously conceived.

Using color recognition alone, as a low-level processing technique with no higher-level understanding of the image, will not create the same results as a human artist using ink and paint. Though this is a first step, the system, at its present state, should be exploited and appreciated as a creative tool.

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