A Design for an Interactive Color Program

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Introduction

Recently, there has been a movement within the SEP to improve the graphics capability of our computer system. The prime motivation for this movement was the realization that seismic data sets were really multi-dimensional data sets. Paper can only show two-dimensional functions: the horizontal and vertical directions on the paper are the two dimensions; the variable area of the traces is the magnitude of the function. This method is inadequate for the new three dimensional data sets because it is impossible to display all three dimensions on one sheet of paper. For example, seiscrop sections are made from three dimensional data sets for making isographic maps of subsurface features. These maps would be difficult to make and interpret if three dimensional data sets were stored on several pieces of paper. Through the use of movies, geophysicists have been able to view three dimensional data by using time as the third dimension. The geophysicist projects an image onto a table and draws the contours for that time point. After a particular time is plotted, the geophysicist moves to the next time image.

The students in the SEP have developed several methods for displaying three dimensional data. Rick Ottolini has been the prime innovator for improving the user's control of movies on the AED (see his article in this volume). Through Ottolini's movie program, the user has increased control of all the data's three dimensions. The only other element left to change is the intensity and the colors on the screen. To complement this increased control of movies, I have expanded the user's control of the AED graphics terminal color table.

Non-linearity

The AED graphics terminal has three primary colors available: red, green, and blue. All other colors are created by mixing these three colors together in different ratios. For example, white consists of equal parts of all three colors, while purple requires equal amounts of red and blue, without any green. The amount of the three primary colors present in any color is determined by a number from 0 to 255 inclusive. For a bright purple, red and blue would each have a value of 255, while green would have a value of 0. Thus, the number of different colors available on the AED is 16,777,216. However, the internal memory of the AED allows the storage of only 512 colors at a time. The memory is limited because each pixel on the screen is controlled by eight bits. Each value of a pixel byte corresponds to one of the 512 colors. The user is confronted with the problem of which of the more than 16 million colors to use and how to arrange them.

The standard method of making a color table is to divide the color table into two parts. The colors in registers 0 to 255 of the color table will correspond to the negative values of the data. The colors in registers 257 to 511 of the color table will correspond to the positive values of the data. Register 256 is the color of the zero value of the data. Three different colors chosen by the user are assigned the positions of negative (0), zero (256), and positive (511). For example, our grey scale has the following assignments:

Primary Color	Color Table Registers		
	Negative (0)	Zero (256)	Positive (511)
red	0	128	255
green	0	128	255
blue	0	128	255

The intermediate colors between the three main colors are chosen by linear interpolation. For the case above, color table register 128 would have the intensity level 64 for all three colors, which corresponds to a dark grey. This algorithm works well for the grey scale, which varies linearly from black to grey to white. When colors are included, trouble occurs because the human perception of color is non-linear. An example of this is a color table with the following assignments:

Primary Color	Color Table Registers		
	Negative (0)	Zero (256)	Positive (511)
red	255	0	0
green	0	255	0
blue	0	0	255

Even though the intensity of each color is the same, the blue appears to be darker, and the green appears to be brighter. Since the intensities are scaled linearly between the three main values, the overall sum of intensities in the color table remains constant at 255. When this color table is displayed in a test pattern, the area between the green and the edges appears darker. Therefore, any attempt to build a color table that has constant numerical brightness will fail to appear constant because the eye does not function linearly. By adjusting the values at 0, 256, and 511 in the color table, the user builds a color scale which appears uniformly bright across the screen:

Primary Color	Color Table Registers		
	Negative (0)	Zero (256)	Positive (511)
red	235	0	0
green	60	200	60
blue	0	0	255

Previously, the only way to find the proper ratios for a uniformly bright color table was through trial and error. The advantage of an interactive color program is that it allows the user to find new color schemes quickly which appear linear. To accomplish this, the user puts a test pattern on the screen, and then the user manipulates the intensities of the three primary colors to find a suitable color table. This manipulation is done with a joystick or on the keyboard. The change in the picture is almost instantaneous.

Gain

The default method of interpolating between the main colors is to use linear interpolation. There are other methods of interpolation available that can still produce different color tables. For example, the user may want to emphasize the high amplitudes by giving them a by giving them a wider range of colors or making them brighter. This has the effect of adjusting the gain of the data. For a gain greater than one, the high amplitudes are emphasized. For a gain less than one, the amplitudes around zero are emphasized. An example of how the intensities for different gains is shown in figure 1. The gain is controlled by the position of a joystick on the AED terminal. The color program reads the position of the joystick and interprets this as the gain. It recomputes the color table and loads it into the AED. We have found that a logarithmic function of the joystick gives the user a better "feel" of controlling the gain. Gain has been used most often to observe the high amplitude events on the AED. By manipulating the color table instead of the data, the user can examine a section in more ways with less computational time.

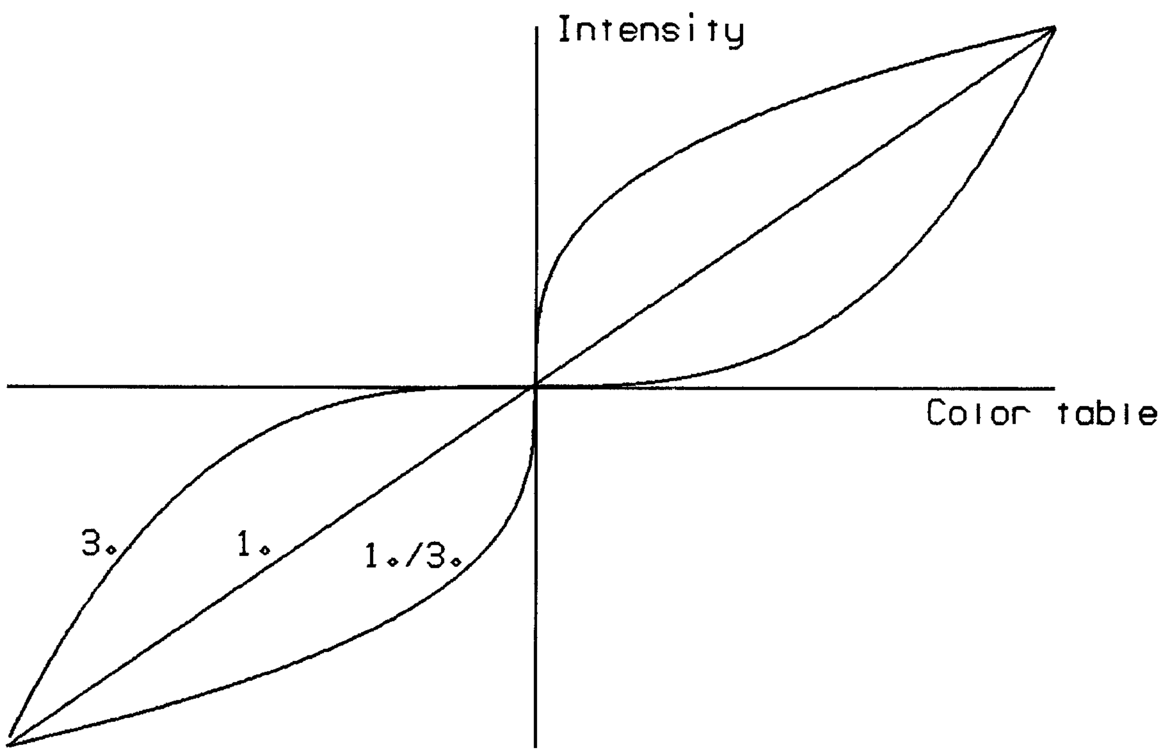

FIG. 1. The variation of intensities through the use of different values of gain. The numbers near the curve are the gain values.

Uniformity

There is one major problem involved with allowing all the users to chose their own color table for displaying their data. If some standard color rules are not established, then there will be confusion about what each data set shows. For example, one data set may show positive magnitudes as green and negative magnitudes as red. Another data set may show positive magnitudes as red and negative magnitudes as blue. A user looking at both data set would be confused about which colors represent which magnitudes. This situation is corrected in a way similar to the policy of oil companies to set rules on the colors that are used for marking seismic sections. For example, red lines mark faults and yellow lines mark the basement. Likewise, there should be rules governing color tables of graphic terminals to insure that there is some uniformity in the color tables. At the SEP, red generally stands for negative magnitudes and blue stands for positive magnitudes. The colors between these two endpoints are chosen by the user.

Two of the more used color tables have the following assignments

Primary Color	Color Table Registers		
	Negative (0)	Zero (256)	Positive (511)
red	255	0	0
green	0	0	0
blue	0	0	255

Primary Color	Color Table Registers		
	Negative (0)	Zero (256)	Positive (511)
red	255	0	0
green	255	255	255
blue	0	0	255

The first color table presents a dark image which emphasizes the high amplitude events. The second color table presents a brighter image where the low amplitudes are more evident. The most used color table used at the SEP is the plain grey scale shown in the first table.

This color table has two advantages. First, a grey scale produces a better linear scale in brightness which the eye can interpolate more easily. Second, a black and white picture shows more information to the eye than a color table. This may sound contrary to comparisons between color televisions and black and white televisions, since a color television shows far more information than a black and white television. However, a typical television image is not a two dimensional function where the amplitude determines the color. A television picture is a combination of three two-dimensional functions. Each function corresponds to the brightness of a primary colors. For seismic data, there is only one function which controls the color. Some informal studies done here within the SEP have shown that the average person can distinguish about 50 shades of grey. When color is used, a person can see between 30 and 40 shades of color, depending on the color table used. Therefore, a black and white image shows more information than a color image can to the human eye.

Merging Two Images

A seismic data set requires about four bits of data to be shown on the AED screen with no apparent loss of information. This leaves four bits of each screen pixel unused. One possible use of these extra bits is to display another image superimposed on the seismic data or two other types of pictures could be combined. One picture, such as seismic data set, would control the upper four bits. The other picture, such as some axis or labels, would control the lower four bits. The choice of dividing each pixel into two four-bit numbers is arbitrary. The division could be three and five bits to have more colors. Yet another possibility is to separate the eight bits into three fields. The upper bits would control the intensity, the middle bits would control the color, and the lower bit would be assigned some pen color that the other bits would not produce. The user could then combine a seismic section, a velocity map, and labels on one screen. By controlling the color table, each image can be individually controlled.

There are two methods for showing two pictures. The first method is to show the seismic data with some color scale and the second image with some different color, like yellow. The combined image would appear on the screen as a seismic section overlain with a yellow line drawing. This method is suitable for showing axis, labels, and numbers on a seismic picture because the seismic data is replaced by the second image. In other words, either the upper half of the pixel byte is easy or the lower half of the byte is empty. The second approach is to let the upper four bits determine the intensity value of each pixel and let the lower four bits determine the color. This approach can be used to show a seismic section with a velocity map superimposed in color. The second method differs from the first method in that all the bits of each of the pixels are used. Through manipulation of the color table, the second method can yield an identical image of the first method. The choice of method depends on the user.

Displaying the two images now requires the ability to control the gain in two dimensions. One dimension controls the intensity of the upper four bits, and the other dimension controls the color of the lower four bits. A two-dimensional joystick is ideal for the user to control the two gains.

Conclusions

There are still many applications of color which I have not explored. These include using color for contouring and finding different methods of assigning colors in the color table. As the possibilities increase, the control by the user must increase to allow easy use of all the options. To make a contribution toward this end, I have developed an interactive program. The program presents a list of options on the screen along with a list of one key codes that will activate them. For example, by pressing G, the user could change the color table of the AED to the grey scale. I am interested in new approacheds and ways of using color.

The use of color in seismic processing has been restricted to producing nice pictures. The cost of producing a paper output for a different gain or color table has prevented thorough exploration of color's uses. As color graphic terminals become more available, geophysicists will find more uses of color. We would like to hear about new ideas or applications for color.

1. The first two natives are knights, and the third is a knave.

2. There can be none. If all ten digits were present, then the number must be divisible by nine.

3. No. The cube which is cut from the center of the large cube must have six cut sides.

4. He is looking at a picture of his son.

5. He is looking at a picture of his father.

6. Three. 7. Four.

8. When the man left his house, he started the clock and jotted the time it showed. When he got to his friend's house, he noted the time when he arrived and the time when he left. Thus, he knew how long he was at his friend's house. When he got back home, he looked at the clock, so he knew how long he had been away from home. Subtracting from this the time he had spent at his friend's house, he knew how long the walk back and forth had been. Adding half of this time to the time he left his friend's house, he then knew what time it really was.

26. Clockwise, beginning at 12 o'clock, they are: Harry Tews (pilot), Loretta Van Allen (photographer), Ed Delane (teacher), Renee Collins (jeweler), Tyrone Van Allen (doctor), Mary Jane Tews (author), George Collins (salesman), and Betty Kay Delane (lawyer).

27. December 31. Two days ago (December 30) I was 28. Today (January 1) I am 29, and at the end of this year, I will be 30. So next year, I will become 31.

28. queueing

29. Al Gainor, the Englishman, wore yellow and won the tournament with three games. Bob Farley, the American, wore white and won two games. Carl Harkness, the Frenchman, wore blue and won no games.

30. Starting, staring, string, sting, sing, sin, in, I.

31. If the first letter of each word is removed, a new sentence is formed.

32. sequoia

33. $36. The price is determined by multiplying by 2 the location in the alphabet of the first letter of each name.

34. 33. The difference between each number is twice the difference of the two numbers before it.

35. 72. Each number is multiplied alternately by two and three.

36. 207. The difference between each successive number is three times the difference of the two numbers before it.

37. −2. The left column is the sum of the of the numbers in the first two columns. The last row is the sum of the numbers in two rows above.

38. The blouse costs $60. The price is ten dollars per letter in its name.

39. 6. The difference between each number increases by one as the string continues.

40. Arrangement of the houses: Lanes Whites Carsons Reeds.

41. typewriter