

# Color-Composite Image Generation on an Eight-Bit Graphics Workstation

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**ABSTRACT:** While a university or college may not possess sophisticated color-graphic image-processing systems with the three eight-bit image planes necessary for producing and displaying false-color composite images, they often have smaller, less-expensive engineering-oriented workstations with only one eight-bit graphics plane. It is possible, using simple techniques of image-data compression and contrast-stretching, to produce satisfactory color-composite images useful for a number of applications.

## INTRODUCTION

COLOR COMPOSITES are clearly useful in image analysis when digital processing remotely sensed data. Both false-color and true-color composites allow on-screen representation of considerably more information than a black-and-white image and, therefore, visual interpretation of the screen image is facilitated (Gonzalez and Wintz, 1977; Schowengerdt, 1983; Lillesand and Kiefer, 1987).

A typical method for construction of color composites involves a digital system with three image planes representing red, green, and blue images, respectively (Jensen, 1986). The gray values (or digital numbers) associated with each image are sent to respective color guns, and a standard color-composite image is produced (Figure 1). For images of 512 by 512 picture elements and an eight-bit gray scale, the necessary memory should be 512 by 512 by 8 by 3 bits for color composites when the standard scheme depicted in Figure 1 is employed. It is possible, though, to produce useful color displays with computer systems not configured in this manner.

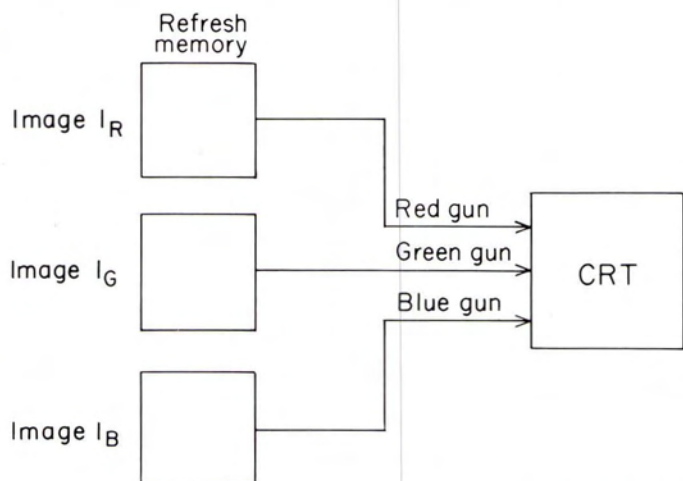


FIG. 1. Schematic illustrating digital construction of standard false-color composite.

The DEC VAXstation II/GPX\* system is an engineering-oriented computer-graphics workstation with useful capabilities, including windowing and mouse-driven drawing. However, there are limitations for image display as normally used for remote-sensing applications in that the GPX provides only an eight-bit color-display system; more specifically, an 864 by 1024 by 8 by 1 bit refresh memory. Therefore, if the CAD/CAM capabilities of the GPX are to be augmented with image display, certain programming variations must be implemented.

When using the GPX system for image processing, the gray values comprising an image must be used as "indices" linked to a color look-up table. From this table, the output values of the three components of red, green, and blue are obtained and sent to the respective color guns of the CRT display (Figure 2). In the color look-up table, each color has an eight-bit scale; so a total of 256<sup>3</sup> colors are ideally possible. However, the refresh

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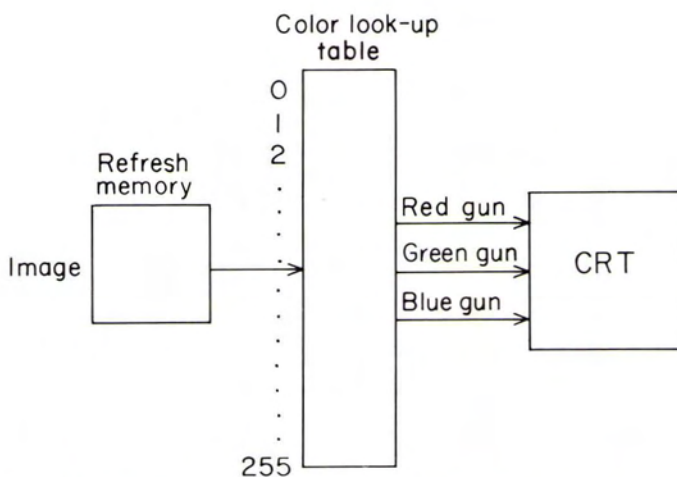


FIG. 2. Schematic illustrating the concept of a mapped color display.



memory is only eight bits per pixel. Thus, the possible colors for display on the GPX are only 256 for a screen image (Digital Equipment Corporation, 1986). Clearly, it is impossible to display standard false- or true-color composites on a GPX by using the scheme depicted as Figure 1. This paper discusses a simple method for constructing color composites on GPX and similar systems with eight-bit displays.

### METHOD

To construct color composites on the GPX, the red, green, and blue images must be composed in refresh memory. Because the possible number of gray values for the GPX is only 256, the three original images must be compressed to one eight-bit plane of refresh memory. Thus, each image has a mere  $256^{1/3}$  or six gray levels (the cube root of 256 is 6.349, but this must be rounded to 6 for display purposes), so the total number of possible composite values is  $6^3$ , or 216.

Clearly, when images are compressed from 256 to six gray shades, they experience a loss of detail both in a spatial and a spectral sense. This unfortunate circumstance is offset, to some extent, by the 1024 by 868 screen resolution in the case of the GPX. To minimize the loss of detail, a histogram-equalization compression has been implemented preceding the compositing process with our software. Histogram equalization converts the 256 gray values to six.

Following the compression process, the three images are composed in refresh memory using the formula:

$$I_c = I_r + 6 * I_g + 36 * I_b \quad (1)$$

where  $I_c$  represents the digital numbers of the composite image to be sent to refresh memory; and  $I_r$ ,  $I_g$ , and  $I_b$  are the gray values corresponding to the three images which will be displayed as red, green, and blue, respectively. The minimum and maximum values of  $I_r$ ,  $I_g$ , and  $I_b$  are 0 and 5, so the minimum and maximum values of  $I_c$  are 0 and 215.

The VAXstation II/GPX uses the pixel values of refresh memory as a mapped color value and they correspond to an actual color value located in a hardware color look-up table or hardware color map (Digital Equipment Corporation, 1986) (Figure 3). Therefore, the input pixel value may be considered an index to entry into the color map, and each has a corresponding output value for color display.

The original value of each pixel is the hardware color-map index of a color-map entry containing the actual color value for display. The pixel displayed on the GPX screen is coded using

this computed color value. The GPX RGB color values are in the range 0.0 to 1.0. Therefore, in order to produce color composites, we assign the darkest color value (0.0) a gray value of 0 in images  $I_r$ ,  $I_g$ , and  $I_c$  and the brightest color value (1.0) a gray value of 5. Because there are six levels of gray for the R, G, and B images ( $256^{1/3}$ ), the step size (or increment) of the color values is 0.2. The R, G, B components of 216 color-map entries are constructed as follows:

$$\begin{aligned} R(i) &= 0.2 * (i, \text{mod } 6) \\ G(i) &= 0.2 * ([i/6], \text{mod } 6) \\ B(i) &= 0.2 * [i/36] \\ i &= 0, 1, 2, \dots, 215. \end{aligned} \quad (2)$$

where  $R(i)$ ,  $G(i)$ , and  $B(i)$  represent red, green, and blue components of the  $i$ th color-map entry. Actually, value  $i$  of Equation 2 is the pixel value of the composite image  $I_c$ .

When a gray value of a composite image is sent to the color look-up table, the values of R, G, and B components will have been located in the corresponding entry of the table which is filled with RGB values calculated from Equation 2, and a color is composed. Comparing Equation 1 with Equation 2, it is concluded that the R, G, B components of image  $I_c$  produced by the color look-up table are proportional to the pixel values of image  $I_r$ ,  $I_g$ , and  $I_b$ . Then, the image on the display monitor is the color composite of image  $I_r$  (red), image  $I_g$  (green), and image  $I_b$  (blue).

For three images, there are 3! or six color-composite images. To produce a second composite (once the  $I_c$  image is obtained), it is not necessary to re-calculate the  $I_c$  image, which is computationally intensive. Actually, there is a very convenient way to obtain subsequent color-composites in near-real time; merely exchange the color components of the color look-up table. For example, when we want to display image  $I_r$  as the green image and image  $I_g$  as the red image, all we need to do is to exchange the 216 red components of the color look-up table with the 216 green components.

### IMPLEMENTATION

We have developed a module (GPXD), which is linked to both the ELAS (Junkin *et al.*, 1981) and LAS (Goddard Space Flight Center, 1987) software packages, to display black-and-white, color-composite, pseudo-color, and color-coded images on a GPX graphics workstation. This module also provides for histogram

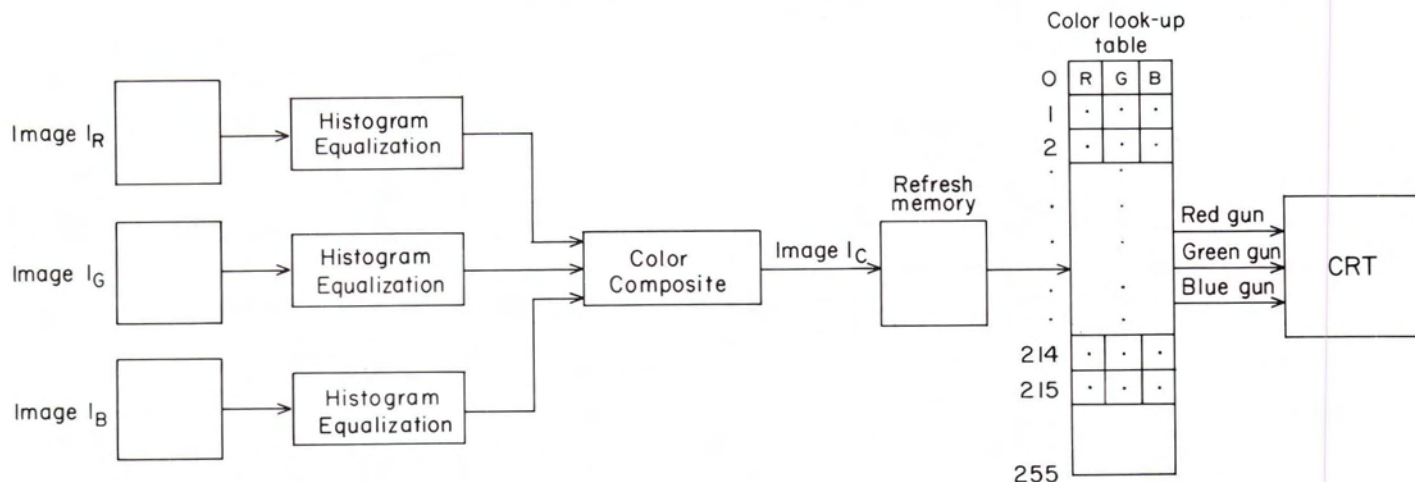


FIG. 3. Schematic illustrating digital construction of false-color composite using one eight-bit graphic plane.



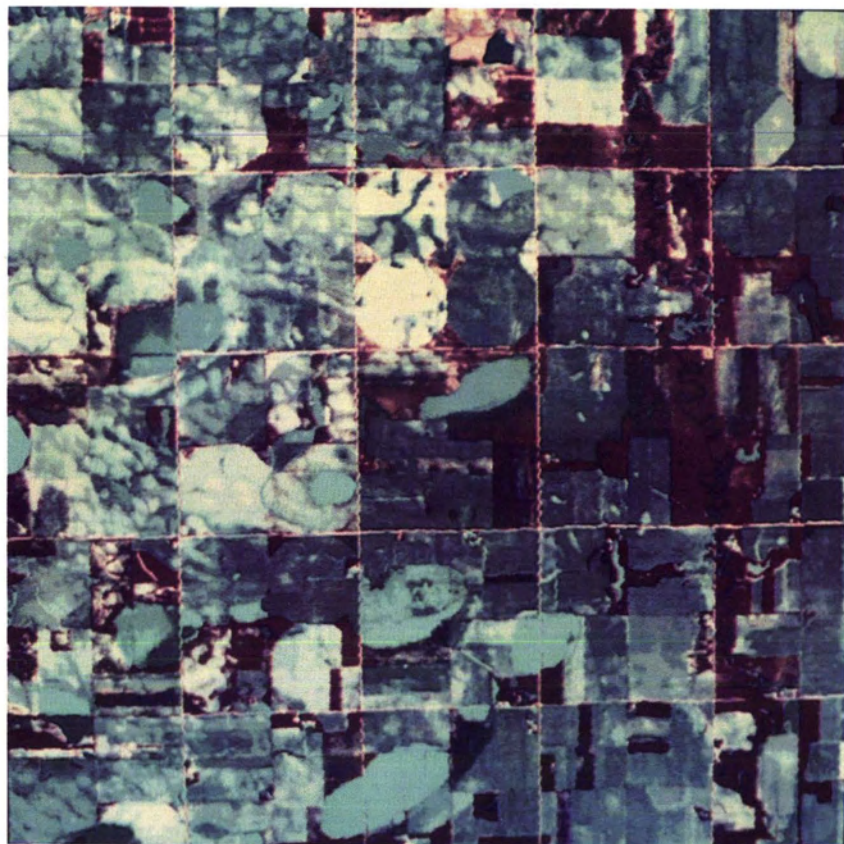


PLATE 1. Airborne-MSS false-color composite displayed using one eight-bit graphic plane.

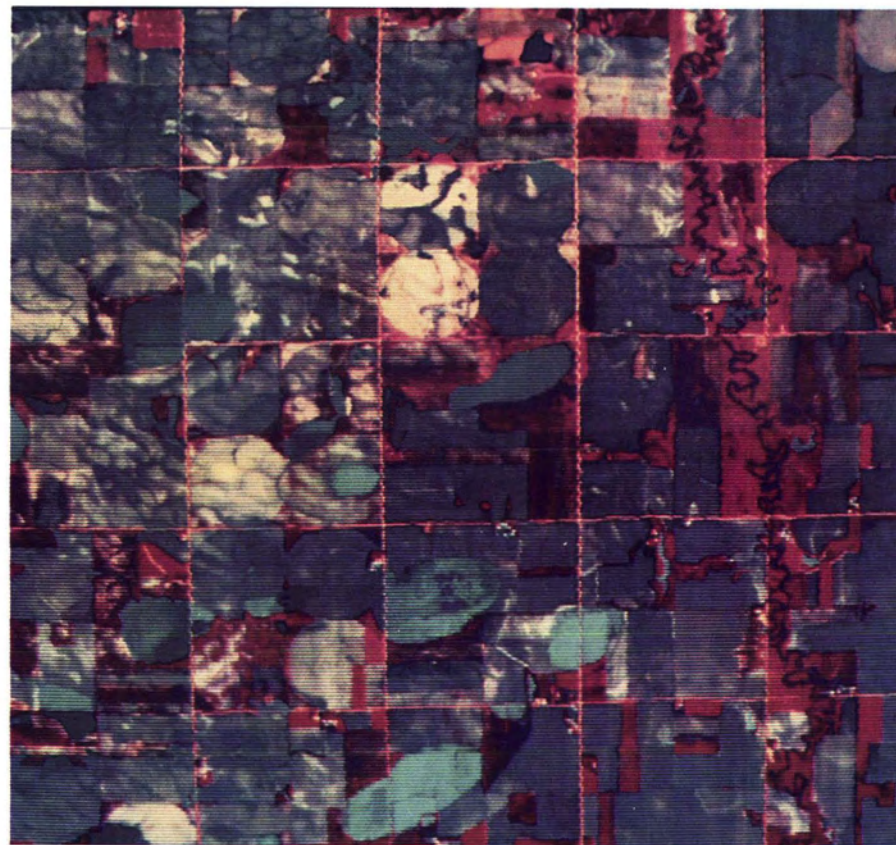


PLATE 2. Airborne-MSS false-color composite displayed using three eight-bit graphics planes.



equalization, linear-contrast enhancement, histogram display, profile display, zoom, and other conventional image-processing functions in near-real time. The mouse and windowing capabilities of the GPX, incorporated in our software, have proven very useful in executing these enhancements.

Plate 1 is a color composite, derived from airborne scanner data (Daedalus AADS-1260 acquired on 20 May 1984 over Clay County, Nebraska), as displayed on the GPX by program GPXD. The array size of the composite image is 512 by 512. Plate 2 is the same imaged area as Plate 1 but is displayed on an ERDAS system which uses Figure 1 as its compositing scheme (i.e., it has three eight-bit image planes). Comparing Plates 1 and 2, one can detect some difference in color tone. The red, green, and blue tones in Plate 1 are not quite as bright and sharp as in Plate 2, and it may not be possible to make subtle color distinction in the former case. We feel, however, that the quality of the composite generated with only one eight-bit graphics plane is reasonably good and that it serves a useful purpose. Note that Plate 1 possesses slightly less detail because of image compression. Although each GPX image has been compressed to a mere six gray levels, histogram equalization insures retention of essential image information. It seems that the loss of some detail can be tolerated in many applications.

### CONCLUSIONS

The simple technique outlined here allows one to produce acceptable color composites on graphics workstations typically used for engineering applications. Our software procedures al-

low the user to undertake image processing while still retaining the CAD/CAM potential of a system like the VAXstation II/GPX. Other graphics devices with similar hardware features, often found on college campuses, may also be programmed to conduct image-processing analyses using the concept presented in this paper.

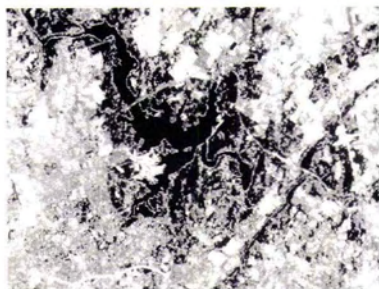
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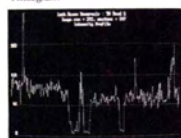
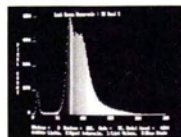
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