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Remote Sensing on a Shoestring

A practical additive color viewer can be constructed for less than $20.

INTRODUCTION

SHORTLY AFTER the first Earth Resources Technology Satellite was sent into orbit, many of us sent in our money and got the four Multispectral Scanner band images of our area in the form of black-and-white photographic prints. Once these were received we probably looked at them, then compared each of the different images to the others, then the prints were most likely filed away and only brought out thereafter to show to people.

ABSTRACT: *Although Landsat imagery is available at low cost, the information it contains is not easily extracted, and standard false-color composites are not satisfactory for every application. There are two kinds of color presentation: additive and subtractive. These methods seem capable of giving equivalent results, but there is some evidence that the eye sees additive color much more flexibly than it sees subtractive color. There are a number of additive color viewers on the market, but they are expensive and complex. However, an inexpensive additive viewer can be easily constructed using readily-available parts. In this viewer, the observer sees two different images at once through two differently-colored filters. The result is a colored composite image with adjustable color balance. For additive color viewing, it has been found that two colors are entirely adequate for most purposes, which means that Landsat imagery can be viewed in natural color.*

Some of us went farther and rephotographed the prints onto slide film and experimented with additive color using two or more filter-equipped slide projectors. The project was usually abandoned after that because of the difficulty in setting up and taking down, and the need to tie up two or more projectors. The method was mainly used for demonstrations and the operation usually was performed on only one set of images.

There are easier ways to get color imagery. Perhaps the easiest and most popular method involves ordering a standard false-color composite image, which shows healthy vegetation as red and everything else in various hues and shades of green, blue, grey, and black. If you are one of those researchers who can relate his study to vegetation, this method will probably be good enough to show you where the grasses and trees are and aren't.

But if you are studying a treeless, grassless desert region, a standard false-color composite probably won't do you much good. The reason for this is mainly related to the way we perceive color; on a false-color image the easily-distinguished colors red, yellow, and green are transformed to green, blue-green, and blue, which especially increases the difficulty in telling the colors apart when they are blended together as they are on color imagery.

All color can be categorized as belonging to either of two systems, additive or subtractive. The additive system is composed of the colors red, green, and blue. When these colors are superimposed their sum total is white. When any two of these colors are

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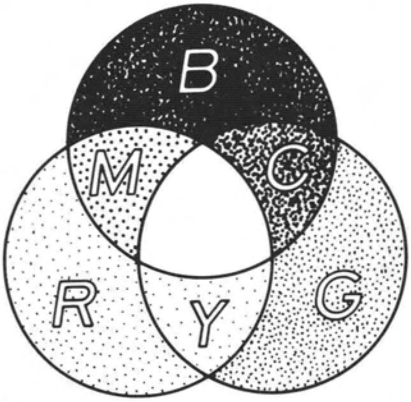

FIG. 1. The additive primary colors, and also the subtractive colors that are formed when they overlap. Colors are identified by a letter symbol:

Additive Colors	Subtractive Colors
B = blue	Y = yellow
G = green	M = magenta
R = red	C = cyan

mixed, subtractive primaries are formed in the blending area (Figure 1). This can only be done by mixing colored light. Subtractive primaries behave in a way that is exactly the opposite of additive. When they are superimposed the sum total is black, and any two of the subtractive primaries when overlapped will form an additive primary. Anyone who has mixed watercolors has had experience with subtractive color.

It should be noted that, although in additive color the red image of a photograph is viewed in red light, when it is subtractively printed, as in a color illustration for a magazine, the red image appears in minus red or cyan ink. The green image is printed in minus green or magenta; the blue image is printed in minus blue or yellow.

While writing to a graphic arts audience, Schlemmer (1966) gave a good explanation detailing the physical differences between additive and subtractive color: "The physicist and the artist/printer are dealing with two different aspects of color. The physicist is concerned with *light*; the artist/printer with *pigment*. The physicist *adds* color, proceeding from black (no light) to white. The artist/printer *subtracts* from the white of the paper, superimposing color upon color until he finally achieves black (no light), indicating that he has *subtracted* all of the light that the paper is capable of reflecting. The process of mixing pigment on paper (assuming for the purposes of this explanation that the paper is white) is an example of the *subtractive process*."

Although subtractive color is essentially taken at face value, a major advantage of additive color is the ability of the eye (or more likely the brain) to adapt quite flexibly to it. Examples of this are all around us but we usually don't notice them due to the eye's ability to adapt rapidly to unusual lighting conditions. For instance, if you are reading this page in the shade of a green leafy tree, in blue skylit shade, in the red light of a sunset, or even by the yellow light of an incandescent bulb, the page is being illuminated by colored light, but somehow the eye manages to adjust and make the page look white. However, if the page were printed on tinted paper the eye would manage to continue to see the tint through a whole range of colored light imbalances.

Additive methods are the only ones that will allow us to play with the image in order to get it to reveal what we are searching for (this method is called *image enhancement*, which involves altering the color balance in the image with hope of bringing out certain features). The reason for this is subtractive methods use filtering to remove colors, and once the color image is made, the pigment density can't be changed. Color balance is not so critical with additive color as it is with subtractive, since the balance can be adjusted simply by adjusting the illumination. This can only be done with light and as a result requires special equipment, which is usually expensive.

Though there are a number of optical additive color instruments on the market, they all seem to use the principle of multiple-projection in which two or more images are projected onto a screen by two or more lantern-slide projectors. This requires the use of black-and-white positive transparencies and some complex technology to allow for consistent illumination and registration of the separate images. Homebuilt arrangements following this principle are further limited by the size of imagery available from the EROS Data Center, because most home slide projectors can't handle 70mm sized film transparencies.

A SIMPLE MULTISPECTRAL VIEWER

This paper describes a much simpler instrument that can be constructed by the reader for less than $20, and that has the additional advantage of using black-and-white photographic prints of any size. Information can be annotated directly onto one of the prints.

Figure 2 illustrates the principle under which the instrument operates. As the observer looks through the device at photo A,

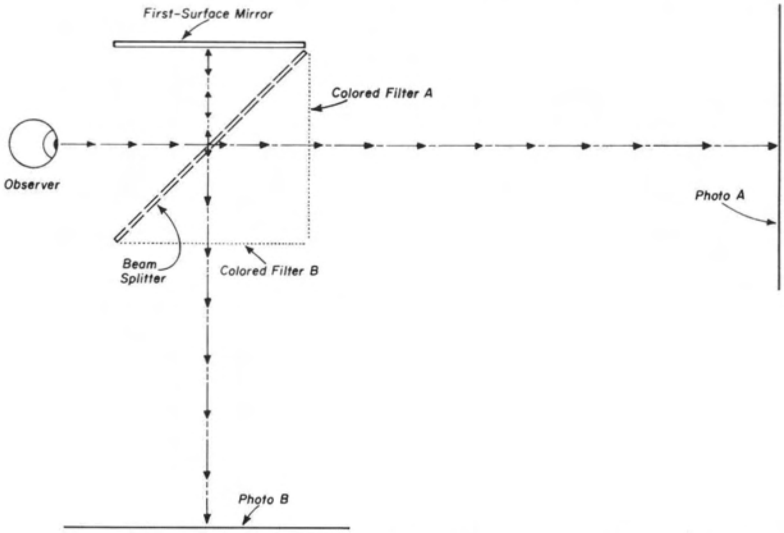

FIG. 2. Diagram illustrating how the multispectral photo viewer works.

which is fastened to the wall, his line of sight passes through the beam splitter mirror and colored filter A (which can be red). At the same time he sees photo B through colored filter B (which can be green), which has been seemingly superimposed over photo A by a double reflection.

Usually the two images will seem to be at different distances from the observer. By shifting the viewer unit either towards or away from himself, he can stereoscopically place the two virtual images at an equal distance. Then, by shifting the position of photo B, the observer can easily combine the colored images of photos A and B.

On Landsat imagery a grey scale is printed along the margin of each image. If the filters being used are red and green, then the illumination should be regulated so that the grey scale is illuminated with yellow light (see Figure 1).

The color balance can be regulated by varying the amount of light each image receives. There are a number of ways this can be done. The simplest is to illuminate each image with a 75-watt reflector floodlamp from a 45° angle (to eliminate reflections) and move the lamps towards or away from each image until the proper color balance is reached. More complicated alternatives can include the use of simple diaphragms, neutral density filters, cross-polarizing filters, variable intensity switches, etc. The lighting system you select depends on what you have or can find. For example, my viewer uses a model train transformer to regulate the voltage of 12-volt auto lamps, which are mounted in old camera flashbulb holders.

Figure 3 illustrates the basic construction of the instrument. The device is essentially an erecting camera lucida that is much larger and is oriented differently. Not shown in Figure 3 are the colored filters, which can be either inserted into slots, taped, or held with magnets on the bottom and far side of the viewer unit. The light sources are also not shown.

Looking into the viewer, the eye sees both images superimposed with the light areas of each seeming to be the color of its filter. The image resting on the base is shifted until it registers with the image that is taped to the wall. Varying the amount of light to each print regulates the color balance.

Though not all of these are essential, some tools which will be useful in constructing the viewer are—

- a saw that can cut reasonably straight lines;
- a screwdriver;
- an electric drill to provide starter holes for the wood screws;
- a countersink to allow the heads of the wood screws to go flush with the wood surface;
- a combination square to help in measuring, marking, and cutting the wooden components; and
- a right angle corner clamp to hold the parts in the correct angular position while being drilled and until the screws are driven.

The base is made from 3/4 or 1/2 inch Formica, plywood, or particleboard.

The viewer is supported above the base by cast-iron plumber's pipe, which is fastened to the wooden components by floor flanges secured by wood screws. It is a good idea to

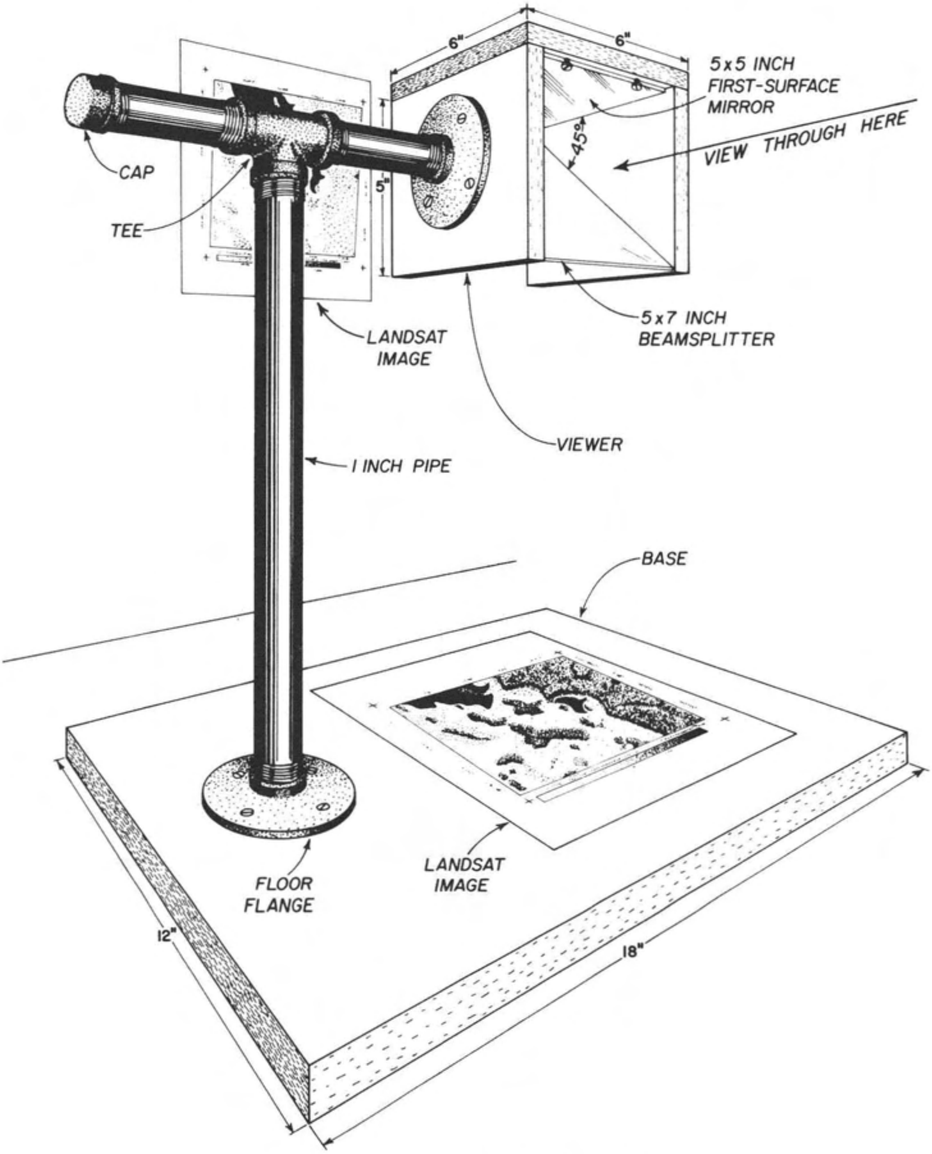

FIG. 3. The multispectral photo viewer.

screw the pipes tightly into the fittings and mark their positions on the wood surfaces before drilling and fitting the components into place.

For closer viewing of the imagery, an elevated stage can be constructed to support the base image above the base. The wall image needs no accessories since shifting the viewer adjusts its distance.

The viewer unit is constructed from 1/2 inch plywood or particleboard, with 1/4 inch thick wood strips forming slots to hold the mirrors in place. The unit can be constructed to allow removing the mirrors and filters for cleaning. The beamsplitter is held in its slot by gravity; the first surface mirror can also be held in a slot, but it should also be held in place at the ends by screws to prevent the mirror from falling out if the unit is tipped.

An inexpensive beam splitting mirror (called a "transparent mirror" in the catalogs) can be purchased for about $4.00 from either Edmund Scientific Company, Edscorp Building, Barrington, New Jersey 08007, or A. Jaegers Optics, 691 Merrick Road, Lynbrook, New York 11563. These have 50 percent reflection and 4 to 8 percent transmission. If you would like a higher quality

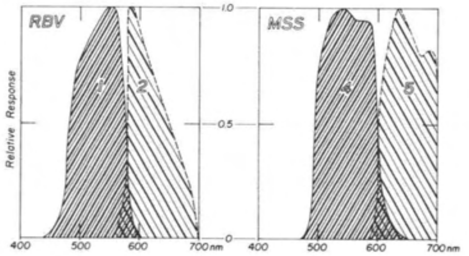

FIG. 4. Relative spectral response of the visible sensors (green and red) of the Landsat I Return-Beam Vidicon (RBV) and the Multispectral Scanner (MSS). Adapted from Albertz and Kreiling (1975).

beamsplitter, the Edmund catalog lists one with 30 percent reflection and 70 percent transmission for about $10.00.

Jaegers lists a 5 by 5 inch first-surface mirror priced at about $4.00.

The beamsplitter and the first-surface mirror should be mounted so the silvered side of each faces the other at an angle of 45°.

Figure 4 is a pair of graphs showing the relative spectral response of the visible bands (green and red) for Landsat 1's Return Beam Vidicon and Multispectral Scanner. If you want to use your viewer on Landsat imagery, you may wish to select colored filters with similar performance.

Colored acetate is an inexpensive material that can be purchased from the Edmund catalog or from art and stationery stores. It seems to do very well in the viewer, though the shorter wavelength colors often leak some red (see Figure 5a) and the filter color quality is not carefully controlled.

If you are concerned about matching the spectral response more closely, it would be wise to invest in Kodak Wratten gelatin filters. Figure 5b shows the performance of Wratten filters 58 and 25A. They each cost about $8.00 for the 5 by 5 inch size and can be sandwiched between thin glass or acrylic plastic that is taped together to protect them from moisture and dirt. Then they can be inserted into slots constructed in the bottom and on the far side of the viewer.

The outside of the viewer can be painted any color you prefer, but the inside should be painted flat black to reduce internal reflections in the optical system.

While the instrument is not in use, a plastic garbage sack can be used as a dust cover.

Owing to the simplicity of its design, the multispectral photo viewer can be used for a number of other purposes in addition to composite viewing. It can be used for image enhancement and change detection; also aerial or terrestrial photographs can be viewed in either anaglyphic or (using polarizing filters) polaroid stereo. The unit can also be used to proof color separations and map overlays and as a 1:1 ratio camera lucida for tracing onto opaque surfaces.

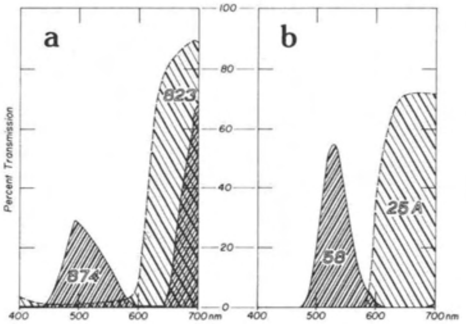

FIG. 5. (a) Spectral performance of Edmund acetate filters: No. 874 (Medium Green) and 823 (Medium Red). Adapted from Anonymous (no date). (b) Spectral performance of Kodak Wratten gelatin filters No. 58 (green) and 25A (red). Adapted from Smith (1968).

IS THREE A CROWD?

The design described above is for two-color viewing, but the same principle can be used to make viewers for three or four colors, though this is not necessary. Colvocoresses (1975) described an experiment in which he was attempting to determine the value of the green image in a false-color composite as follows: "ERTS offers a unique and widespread opportunity to look at the color problem since we start with four separate waveband records which register perfectly when properly handled. We have taken ERTS images of New Jersey, Florida, and Arizona and tested our concepts by combining only bands 5 and 7 (red and IR) and comparing them with the conventional three-color combinations of bands 4, 5, and 7. In each of our experiments the two-color approach resulted in a colored image of equal or better informational content than the three-color approach. To maintain color balance, band 5 was used to activate two of the subtractive colors (yellow and magenta) while band 7 activated cyan. These results would seem to imply that band 4 is of little or no value, but such an implication is obviously not true. On band 4, water tones, though subtle, are real and are not found on the other bands. . . . We have to find out if two generally meaningful signatures in the visible spectrum can be obtained from space, and it may be that we will have to use a completely different portion of the spectrum, such as the thermal wavelengths, before we can fully apply three colors to an image of the Earth that has been sensed through the atmosphere."

In reproducing Landsat imagery in color using subtractive techniques, a natural color presentation is not possible, since the process requires red, green, and blue, while most remote sensing imagery includes only red and green. It is interesting to note that if an attempt were made to print just the red and green bands in cyan and magenta, the finished print would seem to have an overbalance of blue.

Additive color can get along very well with just the green-red portion of the spectrum, since it doesn't require three colors, and since most earth colors concentrate in that region of the spectrum anyway (yellow is a mixture of green and red light). Very few natural objects that are large enough to be seen from space are blue, cyan, or magenta.

Land (1959) demonstrated that the eye is capable of seeing a full range of color when viewing a pair of multispectral images through filters of two spectral wavelengths, through one band and a white light source, and even using two closely-spaced portions from a monochromatic spectrum. Although in some of these cases the composite image was lacking in color intensity, the full range of color was there. These experiments led him to conclude that the eye is capable of seeing full color when only two records are available, as long as one image was exposed to longer wavelengths than the other.

The fact that this flexibility of the eye is not easy to notice without careful experiments is a strong testimonial to the efficiency by which it works, and defines some clear advantages of additive over subtractive color. It is hoped that the availability of the multi-spectral viewer that is described in this paper will give additive color the popularity it deserves.

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Short Course on Remote Sensing Technology & Applications

The Purdue University Laboratory for Applications of Remote Sensing, LARS, is offering a one-week Remote Sensing Short Course. The course, which will be held the first full week of each month, provides a series of workshops on the analysis of multispectral data from Landsat and, in addition, includes an introduction to and background of remote sensing, multispectral scanner systems, spectral characteristics of earth surface features, and pattern recognition as the basis for data analysis techniques, and optional specialization in radiation theory and instrumentation, design of data processing systems, remote sensing applications, and data processing and analysis. For further information regarding the Short Course, please contact

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