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Object Detection Enhancement

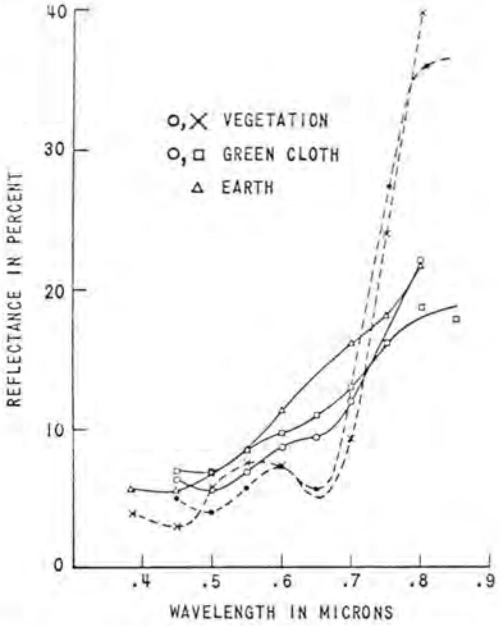

FIG. 1. Aerially determined reflectance curves of some objects in the scene of Plate 1.

The inherent spectral properties of a scene are utilized through the application of a negative (bi-band) mask on color photographs.

(Abstract on page 556)

INTRODUCTION

THE USE OF FALSE COLOR imagery to detect spectral differences between objects has generally been an empirical procedure. The purpose of this paper is to describe a procedure in which the known salient spectral features of objects and backgrounds are used to prescribe the manner in which the photographs should be taken and processed in order to suppress the background and to exaggerate the object. For purposes of illustration, the background consists of normal vegetation and the objects of interest may include disturbed vegetation.

METHOD

Narrow band† ($\sim 0.05\mu$) spectral photography was used to determine the spectral reflectances of environmental features in the spectral region between $0.385\ \mu$ and $0.875\ \mu$. Figure 1 represents some typical data and illustrates the unique properties of objects and vegetative backgounds in the bands centered at $0.65\ \mu$ and $0.8\ \mu$, namely, objects generally have higher reflectance than vegetation in the $0.65\ \mu$ region, whereas the reverse is true in the $0.8\ \mu$ spectral region; however this is not always true. Figure 2 presents additional data that indicates that these two spectral bands allow the separation of objects and vegetative backgounds regardless of whether or not reversal occurs. In the figure, the axes are the product of the reflectance and solar irradiance at the indicated wavelengths for a large number of objects and vegetative backgounds. Note that projection onto either axis yields overlap in the two classes indicating that neither wavelength band alone is a sufficient discriminant in all cases.

In order to realize the separation in object and background classes shown in Figure 2,

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† Usually $0.1\ \mu$ bandwidths are the narrowest utilized.

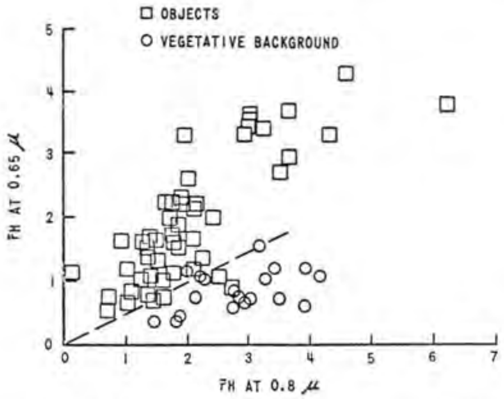

FIG. 2. Bi-band separation plot. The coordinates are quantities proportional to the expected film exposure at the indicated wavelengths.

the photographic negative at 0.65 µ was contact printed to form a positive and this positive was registered with the negative taken in the 0.8 µ spectral band. The transmittance of the registered pair is thus proportional to the point-by-point quotient of the spectral radiance of the scene in the two wavelengths. The quotient for vegetative background will be a small number (low transmittance) whereas for objects it will be generally larger. Contact printing the registered pair onto high-contrast film will yield what I call a *bi-band mask* which is clear in the background areas and opaque in areas where the objects of interest are located. The clipping level employed in making the mask will determine the sensitivity of the technique to spectral differences and the associated false alarm rate.

ABSTRACT: *The spectral reflectances of objects and backgrounds are used to generate a processing technique which increases the rate of detection and the sensitivity to detection of objects against their backgrounds. Several examples illustrating the separation of non-vegetative objects from vegetative backgrounds and the discrimination of vegetation vigor utilizing spectral filters centered at 0.65 µ and 0.8 µ are presented in false color.*

The bi-band mask was used to create color imagery of a scene. Plate 1 presents a comparison of the bi-band imagery to conventional imagery. The mask in each case was made in the manner described, and false color presentation employed to emphasize the results.

In parts *A* and *B* of Plate 1, samples from simultaneously obtained photographic frames* utilizing Plus-X, MS color, Ektachrome infrared aero, and the bi-band technique in false color are presented (the areas selected by the mask are yellow). In part *C*, the comparison is between *MS* color and *MS* color with bi-band mask superimposed in false color (in this case the areas selected by the mask are magenta).

The color exaggeration of earthen areas is an obvious feature in part (*a*). A less obvious feature is the detection of vegetation known to be mechanically disturbed in the clearing of part (*a*). This vegetation is shown as normal vegetation in all but the bi-band color photograph. In the bi-band segment the disturbed vegetation (refer to the outlined areas in the black and white segment of part (*a*)) is printed yellow just like the surrounding earthen area rather than the green hue which is indicative of vegetation. This occurs because the reflectance characteristics of the vegetation have changed sufficiently to cause the color coordinates (refer to Figure 2) to *cross* the dashed line and hence the object has been classed as non-vegetative in this binary classification system. The separation threshold (i.e. slope of the dashed line in Figure 2) can be varied in the bi-band process in order to control the sensitivity to changes in the vegetative surround.

Part (*b*) illustrates the detection of non-vegetation, namely green cloth panels. Again, the earthen areas are generally easier to locate on the bi-band segment. The effects of threshholding are evident. Note particularly the difference in sizes of the traffic routes and cleared areas on the bi-band segment and on the other color segments. The image of the vegetation overhanging these areas is a composite of the vegetation and the earth as seen through holes in the vegetation. The threshholding used in the bi-band procedure causes these composite regions to be identified as non-vegetative and hence the size of these trafficked regions appear enlarged.

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* The infrared frame was actually obtained on the day before the remaining frames.

(a)

(b)

(c)

OBJECT DETECTION ENHANCEMENT

THE INHERENT SPECTRAL PROPERTIES OF A SCENE ARE
UTILIZED THROUGH THE APPLICATION OF A BI-BAND MASK

In part *c*, the upper photograph is a print from an internegative of the scene whereas the lower one was made with two exposures, one using the internegative and one using the mask. The mask selects the clearings seen through the canopy and trees known to be less vigorous than the surrounding healthy vegetation. The explanations for these effects is essentially those already presented with regard to parts (*a*) and (*b*) of Plate 1.

THEORETICAL CONSIDERATIONS

In terms of the scene radiance, the process used to create the bi-band masks is roughly equivalent to the division of scene radiance at 8000 Å. To be more exact, the test statistic T obeys the following proportionality relationship:

$$T \propto \frac{[(\bar{r}H)_{0.8\mu}]^{\gamma_{0.8\ \mu}}}{[(\bar{r}H)_{0.65\mu}]^{\gamma_{0.65\ \mu}}}$$

where $\bar{r}$ is the spectral reflectance, H is the solar irradiance at the indicated wavelengths, and γ_λ refers to the product of film gammas of the processing of photographs at each wavelength. By reference to Figures 1 and 2, we see that T will generally be much larger for the background than for objects. Figure 3 presents the distributions of the quotient for the data of Figure 2. Note the overlap between objects and background near 0.5. In terms of T, the decision function applied when the mask was created is

$T \leq \tau$ implies an object

$T > \tau$ implies background.

The value of τ (threshold) selected will determine the detection probability and false alarm probability of the process. The slope of the dashed line in Figure 2 (or the corresponding value on the abscissa of Figure 3) is the threshold value imposed on T to determine the separation of object and background. By continuously varying the threshold value, we determine the proabilities of detection and false alarm as a function of threshold value. In this manner the Operating Characteristic curve in Figure 4 was obtained from the data of Figure 3.

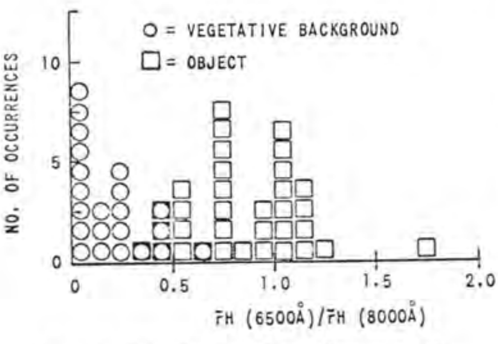

FIG. 3. Distribution of quotient statistic.

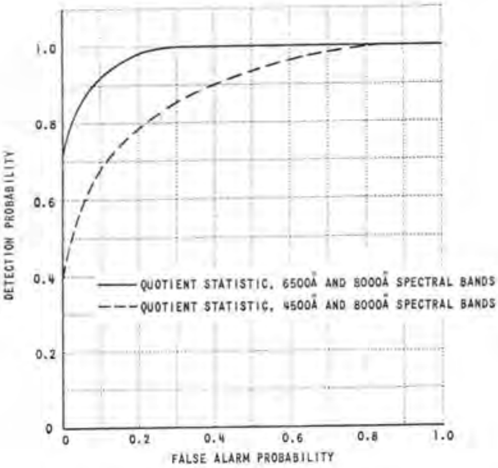

FIG. 4. Operating characteristic curves.

Similarly, the data in the 0.45 μ and 0.8 μ spectral bands were processed to yield the operating characteristic curve for the quotient statistic in these bands. Because a perfect detection system would have a detection probability of one regardless of the false alarm probability, the Operating Characteristic curve more closely approximating the perfect system represents the better system. In this case, the quotient statistic utilizing the spectral bands centered at 0.65 μ and 0.8 μ is the better system for the detection of objects in vegetative background.

The particular form of the statistic may or may not be the *best* function of the observables. A sequence of operations based upon the difference in spectral radiance in the two bands can be used as a decision function, although at this time it appears that the quotient statistic is the better of the two. The area of choosing the test statistic warrants further investigation.

ACKNOWLEDGEMENT

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