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GRADIENT MAGNITUDE AS AN AID IN COLOR PIXEL CLASSIFICATION

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ABSTRACT

When pixels in a black-and-white image are classified by thresholding their gray levels, gradient magnitude information can be used in various ways as an aid in threshold selection. This note deals with the use of color gradient magnitude as an aid in classifying pixels based on their colors or spectral signatures.

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If a black-and-white image is composed of dark objects on a light background (or vice versa), its population of gray levels is a mixture of two subpopulations, which should give rise to two peaks on its gray level histogram. Thus if we choose a threshold gray level t at the bottom of the valley between two peaks, thresholding the image at t should effectively segment it into objects and background with relatively few errors. The choice of t is easy when the peaks are comparable in size and well separated; but if they are too close together, or if one is much bigger than the other (i.e., the objects are small and few), it becomes hard to choose a good t.

Several methods have been proposed (see [1] for a review) which use the magnitude of the gray level gradient (or some other difference operator) as an aid in obtaining an improved histogram or in selecting a good threshold. These methods are based on the assumption that the gradient magnitudes tend to be higher on object/background borders than in the interiors, so that high magnitudes are associated with gray levels that are often intermediate between the characteristic object and background levels. Hence if we histogram the gray levels of only those image points at which the gradient magnitude is low, we should obtain peaks that are more clearly separated, since many of the points having intermediate gray levels have been suppressed. Conversely, if we histogram the gray levels of only the high-magnitude points, we should obtain a single peak located between the object and background peaks, and the mean of this peak is likely to be a good threshold.

In the more general case where the image is composed of more than two types of regions, having distinctive gray level ranges, its histogram will have several peaks, and we can segment it into the different region types by putting a threshold between each pair of these peaks. Here again, cleaner separation of the peaks can be achieved by suppressing points that have high gradient magnitudes, since these points will tend to lie on borders between regions of different types. The histogram of just the high-gradient points will no longer be as useful as in the two-class case, since there are now several types of intermediate gray levels; but if we could identify peaks on this histogram that fall between adjacent pairs of peaks on the original histogram, the means of these peaks should be useful as thresholds.

Analogous ideas can be formulated for color or multispectral images. Suppose first that the image consists of objects of one color on a background of another color. Then in a scatter plot of frequencies of occurrence of colors in the image, there should be two clusters, corresponding to the object and background colors. If we construct a decision surface (e.g., a [hyper]plane) that separates these clusters, we should be able to segment the image into objects and background, by classifying the pixels in accordance with which side of the decision surface they lie on. If the clusters are too close together, or one is much more populous than the other, it becomes difficult to construct this decision surface. Suppose, however, that we suppress from the scatter plot those pixels whose color gradient magnitudes are high (on color gradient operators see, e.g., [2]). This should improve the separation between the clusters, since the suppressed pixels are likely to have colors intermediate between those of the object and background. Conversely, suppose we make a scatter plot of the colors of only the high-gradient points. This should produce a cluster lying between the object and background clusters, and if we fit a [hyper]plane (etc.) to this cluster, the result should be a good decision surface. More generally, when regions of several colors are present, there will be several clusters in the scatter plot, and we can improve their separation by suppressing high-gradient pixels from the plot. Conversely, if we plot the colors of the high-gradient pixels only, and fit hyperplanes to clusters in the resulting plot, some of these hyperplanes may be useful as decision surfaces for separating pairs of region types.

This note presents experimental results on scatter plot improvement by suppression of high-gradient pixels. Two examples are given, one using a color image of a house (showing sky, brick, grass, bushes, etc.), the other a portion of a LANDSAT frame in the interior of New Zealand. For ease of visualization, only two color components were used in each case--red and blue for the house; green and infrared for the LANDSAT image. Thus the scatter plots were two-dimensional, and the decision surfaces were lines. Fitting lines to clusters of high-gradient pixels was not attempted; this approach would require some method of selecting the clusters to which lines are fitted.

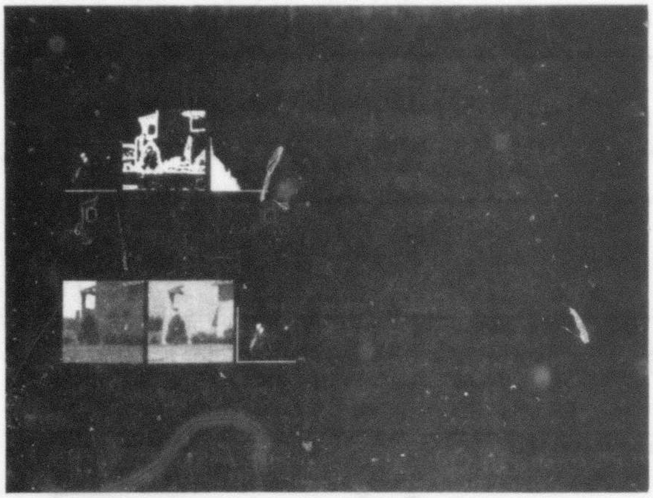
The pictures and results are shown in Figures 1 and 2. The RMS Roberts edge detector was applied to each band, and the RMS of the results was computed as the final edge magnitude. For the house image, the scatter plot after deletion of high-edge points is much cleaner, and the clusters have become much more distinct. For the LANDSAT window, there is also a significant effect on the scatter plot, but this does not seem to constitute an improvement; the smaller clusters have been greatly weakened.

It would appear from these results that suppression of high-gradient points does indeed improve the separation of clusters in some types of images. The poor results for the LANDSAT window can probably be ascribed to the fact that it does not conform well to the ideal model of homogeneous regions of different colors; the regions also differ significantly in busyness, and suppression of high-gradient points greatly weakens the clusters corresponding to the busy regions, since these regions contain many such points.

References

1. J. S. Weszka and A. Rosenfeld, Histogram modification for threshold selection, IEEETSMC-9, 1979, 38-52.

2. P. V. Sankar, Color edge detection: a comparative study, TR-866, Computer Vision Laboratory, Computer Science Center, University of Maryland, June 1978.



Key to parts

g	h	i
d	e	f
a	b	c

Figure 1. Results for house image.

a-b) Two bands.
c) Scatter plot of (a) vs. (b), log scaled.
d-e) Edge responses in the two bands (RMS Roberts operator).
f) Color edge response; RMS of (d) and (e).
g) Scatter plot after suppression of points having high edge values (>2), log scaled.
h) Mask showing suppressed points.
i) Histogram of edge values, log scaled.

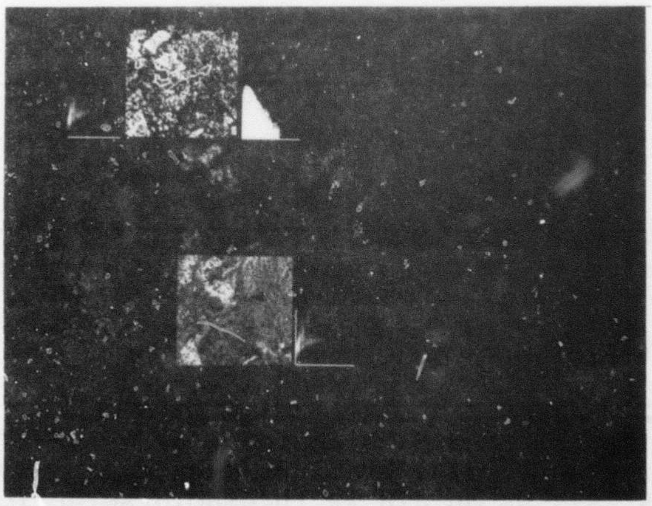


Figure 2. Analogous results for LANDSAT window.

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