SUB-PIXEL LOCALIZATION OF HIGHWAYS IN AVIRIS IMAGES

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1. INTRODUCTION

Roads and highways show up clearly in many bands of AVIRIS images. A typical lane in the U.S. is 12 feet wide, and the total width of a four lane highway, including 18 feet of paved shoulders, is 19.8 m. Such a highway will cover only a portion of any 20x20 m AVIRIS pixel that it traverses. The other portion of these pixels will be usually covered by vegetation.

An interesting problem is to precisely determine the location of a highway within the AVIRIS pixels that it traverses. This information may be used for alignment and spatial calibration of AVIRIS images. Also, since the reflection properties of highway surfaces do not change with time, and they can be determined once and for all, such information can be of help in calculating and filtering out the atmospheric noise that contaminates AVIRIS measurements. The purpose of this report is to describe a method for sub-pixel localization of highways.

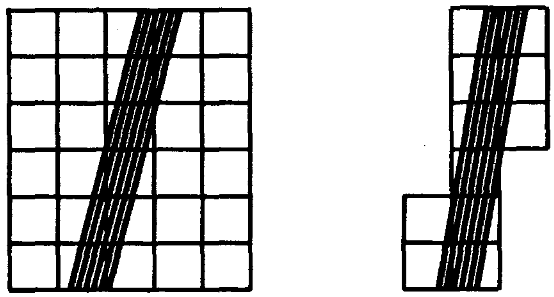
2. METHODS

2.1 General

Highways usually appear sharpest and clearest in only some of the bands. The ideal band to use for localizing a highway would have a high contrast between the highway's surface and its surrounding (vegetation). The ideal band should also be insensitive to the variations in the vegetation bordering the highway. The methodology presented here is based on first localizing the highway in each of the bands, and then making the final determination based upon the most consistent band. An extension of the basic correlator method (Hall, 1979) is presented here for localizing the highway within a one band scene.

2.2 Highway Localization

Figure 1 a. is a map in which a straight highway traverses a vegetated area. The width of the highway is known, but not its precise location. The observed intensities of the upwelling radiation from each pixel in the map are given too. To find the location of the highway, we first prepare templates of identical highways, that cross a grid at different locations and orientations. One such template is shown in Figure 1 b. Let H and V denote the intensity of the upwelling radiation from pixels completely covered by a highway, and by vegetation, respectively. The calculated intensity of the upwelling radiation from pixel i of a template is given by $H \cdot P_i + V \cdot Q_i$, where P_i is the portion of the pixel covered by the highway, and Q_i is the portion covered by the vegetation. H and V are treated as unknowns. The P_i's and the Q_i's ($P_i + Q_i = 1$) are computed from the known geometry of each template.



1.a 1.b

FIGURE 1. a. The pixels of a map of an area (vegetation), traversed by a highway. b. One of the templates that are used for finding the precise location of the highway.

To localize the highway, we shift each template over the given map, keeping the grids of the map and the template fitted. For each position r of template τ, we find H and V that minimize the Euclidean distance between the calculated intensities of the pixels of the template, and the observed intensities (Obs_i) of the corresponding map pixels that they cover:

$$D(r,\tau) = \min(\Sigma(Obs_i - (H \cdot P_i + V \cdot Q_i))^2 / \Sigma(Obs_i)^2) \quad (1)$$

The summations in equation 1 are over all the pixels of the template.

The location of the highway in the template for which $D(r,\tau)$ is a minimum as a function of r and τ is the calculated location.

To reduce the effects of the noise caused by the atmosphere, and to increase the effectiveness of the least squares fit, it might be better to match the gradients of the radiation intensity instead of the radiation intensity itself. The use of the x component of the gradient for the least squares fit will accomplish these objectives. The x component can be approximated by the difference between the intensities of a pixel and that of its left neighbor. When this approach is taken, equation 1 becomes:

$$D(r,\tau) = \min(\Sigma(Dobs_i - B \cdot DP_i)^2 / \Sigma(Dobs_i)^2) \quad (2)$$

Where $Dobs_i$ is the difference between the observed radiation of pixel i and its left neighbor, $B = H - V$, and DP_i is the difference between the portion of covered highway of pixel i and its left neighbor. The summations in equation 2 are over all the pixels of the template.

3. RESULTS

3.1 The Data

Two segments of Junipero Serra Freeway, that appear in the Jasper Ridge scene (Flight 920602A) were used in this study. Each segment was approximately 400 m long. Since the outcomes for these two segments were similar to each other, only one segment will be described here. The highway appears sharpest in the first 23 bands. In some of the other bands the highway could not be recognized at all. The analysis presented in the following was done on bands 1 through 99, excluding fuzzy bands.

3.2 Locating the Highway

Approximately two hundred templates of a highway 19.8 m wide were used. Each template was bounded within a 60x120m rectangle. The templates differed from each other by the orientation and location of the highway within the template's rectangle. The templates were shifted systematically over the portion of the map, that included the highway. Best matches, i.e. minima of $D(r,\tau)$ according to equation 2, were found and superimposed on the map. There were many local minima of $D(r,\tau)$, that did not correspond to a highway or to a road. However, most of these presumed highway segments were isolated. They were not linked with other segments in contiguous templates. Only two continuous roads were found in band 3 (figure 2.b), corresponding to the Northbound and Southbound lanes of the highway.

Band 4 gave similar results to those of band 3. The results of all the other bands were not as good; there were gaps in the two lanes, and in some cases the lanes crossed each other.

4. DISCUSSION

The results, as shown in figure 2.b, were compared with an aerial photograph of the area. The widths of the median in this portion of the road, as determined from the aerial photographs, were between one third to one quarter of the width of the road. These were also the results obtained from figure 2.b. Based on this, the accuracy of localizing the highway is estimated to be $\pm$ 2m.

It should be noted, that by looking at the raw data (figure 2.a), human observers could not detect the existence of two lanes in the scene.

References

Hall E.L., 1979, *Computer Image Processing and Recognition,* Academic Press, New York, pp. 480-484.

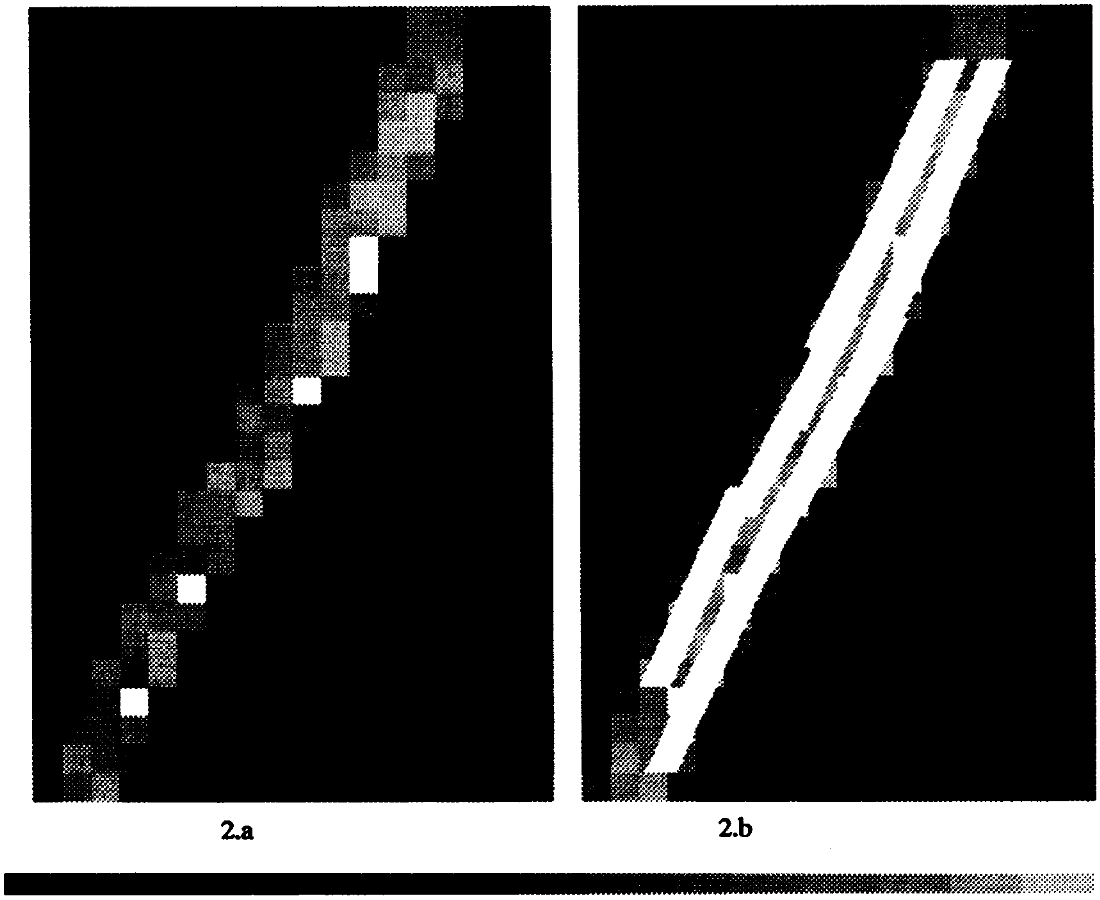


FIGURE 2. a. The highway as it appears in band 3. b. The calculated location of the highway superimposed on the original scene.