Automated Detection of Tracks in Mountainous Terrain using IRS-1C/1D Images

D. Chaudhuri*, A. Mishra#, V. Gohri and Brig. J.K.Sharma

Defence Electronics Application Laboratory
Post Bag No. 6, Raipur Road
Dehradun – 248 001 (India)
Tel. No. 91-135-787083 Fax No. 91-135-787290
Email: dealdrdo@del2.vsnl.net.in

*IAT, Girinagar, Pune
All Correspondence to be addressed to the above

ABSTRACT

Road, railway and track networks are important features of satellite imagery. Automated detection of tracks in mountainous terrain using satellite imagery is a difficult task. The track and the shadow signature of the mountainous terrain are almost same. The presence of ridges and snow also creates a lot of ambiguity. Moreover due to poor sunlight condition in the mountainous terrain the images suffer from poor contrast. So, simple low level operation like, line enhancement processes can not isolate between the track, shadows and ridge signature. The spectral and spatial properties of a satellite image provide information for extracting the line like structures from it. As the low level feature extraction is not sufficient, incorporation of higher level knowledge is necessary. The main contribution of the present track detection method consists of an effective enhancement technique and an efficient segmentation technique that removes from the image, non-track pixels by steps where parameters involved in each step are determined by the sensor characteristic. An efficient linking algorithm based on geometric calculation is proposed. We have tested the algorithm on a number of IRS-1C/1D images (both panchromatic and multispectral) and the results are satisfactory.

1. INTRODUCTION

Road, railway and track networks are important features of satellite imagery. Since track and shadow signatures of the mountainous terrain are almost same, so automated detection of tracks in mountainous terrain using satellite imagery is a difficult job. The spectral and spatial properties of a satellite image provide information for extracting the track-like structures from it. But the low level feature extraction is not always sufficient and incorporation of higher level knowledge is necessary.

Many researchers have addressed the problem of line detection with different approaches. The methods considered are low-level enhancement operators [1], detection of anti-parallel lines [2], Hough transform techniques [3,4], random field model based methods [5] and knowledge based methods [6,7]. Road profile analysis and tracking are also found in the literature [8,9]. Mukherjee et.al. [10] suggested an efficient algorithm for detection of road-like structures in satellite images on the basis that road pixels are darker than the background.

The proposed method is based on certain characteristics of the satellite sensor. The following observations are made.

a) The visible track structures are 1 to 5 pixels thick.
b) The track structures are piecewise linear.
c) The gray levels of the track pixels fall within a specified gray level range.
d) The gray levels of pixels lying on every line segment are nearly homogeneous.
e) The gray level contrast of the linear structures against the gray levels on either side of the structures is significant.
f) Each track segment has a certain minimum length.

The proposed process can be divided into three major steps: *line enhancement*, *segmentation* and *linking*. The main contribution in this paper is the techniques proposed for enhancement and segmentation. Both types of track (track is darker than the background and track is brighter than the background) are considered here. The line enhancement process is described in Section 2. Segmentation process is presented in Section 3. Linking is described in Section 4. Section 5 contains the result and discussion.

2. LINE ENHANCEMENT

Here two low-level operators are used. The first operator produces the enhanced image (G) based on observation (a), (b) and (c). The second operator outputs an image (H), which gives a heterogeneity measure of the original gray values around a pixel in a particular direction. A third operator is used which is the combination of the first two operators. On the basis of assumption (a) and (b), a set of masks is defined to enhance linear structures in a gray level image. We have considered 16 possible five-pixel long digital straight-line segments in 2-dimension.

Here, we have considered two types of track. One is black and another is white. Black track is defined as normally darker than the surrounding pixels. The output *g* of the operator for black linear features defined for each of these 16 masks is

$$g = \begin{cases} \sqrt{(A-B)\times(A-C)} \\ \text{if } (A-B)<0 \text{ and } (A-C)<0 \\ 0 \text{ otherwise} \end{cases}$$

White track is defined as normally brighter than the surrounding pixels. The output *g* of the operator for white linear features defined for each of these 16 masks is

$$g = \begin{cases} \sqrt{(A-B)\times(A-C)} \\ \text{if } (A-B)>0 \text{ and } (A-C)>0 \\ 0 \text{ otherwise} \end{cases}$$

where

$$A = (a_1 + ... + a_5)/5,$$
$$B = (b_1 + ... + b_5)/5,$$
$$C = (c_1 + ... + c_5)/5$$

a_i are the middle pixels gray values of the mask and b_i and c_i are the gray values one line apart from the middle pixels within the mask in the same direction. The value of *g* is computed for all 16 directions. The *g* value is a multiplicative score. The score that is commonly used in line enhancement is an additive one. An advantage of using this multiplicative score is that its response is very low near an edge or on gray level slope.

The second operator is also defined for each direction producing a heterogeneity measure *h* which, for the central pixels a_3, is given by

$$h = \sum_{i=1}^{5} |a_i - m| \text{ where } m = \frac{\sum_{i=1}^{5} a_i}{5}.$$

The value of *h* is used in the enhanced image to modify the pixel gray levels (*g*). More the value of *h*, less should be the gray value of the output pixels since a pixel with a higher value of *h* is more unlikely to be a track pixel. In the enhanced image (*g'*), each pixel gray value is divided by the corresponding value of *f* where $f = 2^{\gamma h}$. The constant γ is found experimentally. The output of this process is called contrast image. Fig.1 shows a 5×5 horizontal mask.

b_1	b_2	b_3	b_4	b_5
0	0	0	0	0
a_1	a_2	a_3	a_4	a_5
0	0	0	0	0
c_1	c_2	c_3	c_4	c_5

Fig.1: 5×5 horizontal mask

3. SEGMENTATION

The segmentation process basically consists of 3 elimination process.

3.1 FIRST ELIMINATION PROCESS

While considering each pixel in the original image, we check whether the gray value of the pixel is less than v_h and greater than v_l or not. Here v_h and v_l are the highest and lowest possible gray values. If the pixel gray value lies between v_h and v_l then consider the pixel as a possible track pixel.

3.2 SECOND ELIMINATION PROCESS

Here, we want to delete very low contrast pixels. So, in the contrast image, we make all pixels having *g'* less than a threshold value zero. Otherwise, some non-track pixels may produce false segments. Let the output of this process be called G_1 for each direction.

3.3 THIRD ELIMINATION PROCESS

The segmentation of G_1 is based on both contrast and length of a linear structure. In the G_1 image, in a particular direction the non-zero pixel from blurred track segment with low to high contrast and varying lengths as well as short segments with low contrasts are more likely to be non-track features. To compute the length (*l*) of each segment of G_1, we thin it and consider the number of pixels on the thinned output. Thus, for each direction, we call the thinned image of G_1, G_2. For every pixel in G_1, we consider its gray value *g'* and the length *l* of the corresponding connected component in G_2. A pixel-based segmentation is done on the basis of these two quantities. The technique is based on four threshold values g_1, g_2, l_1 and l_2 ($g_2 > g_1$ and $l_2 > l_1$) in the following way. A pixel is selected as a track pixel if $g' \geq g_1$, $l \geq l_1$ and $g'+l \geq g_2+l_2$. Thus the image G_1 and G_2 produce the binary image D.

4. LINKING

At this stage there may exist some discontinuity between the track segments extracted so far. The individual segments need to be linked depending on their relative orientation and distances between them. First the binary image D in different directions are thinned separately. For linking we consider the end pixels of the skeletons of each component and the direction near the end pixels. Let two end pixels be *a* and *b*, and the corresponding directions near the end be $\bar{a}$ and $\bar{b}$. Also, let the direction from *a* to *b* be $\bar{c}$. We join *a* and *b* by a straight line if and only if,

i) angle between $\bar{a}$ and $-\bar{b}$ is small,

ii) angle between $\bar{a}$ and $\bar{c}$ is small,

iii) angle between $\bar{c}$ and $-\bar{b}$ is small

iv) the distance between *a* and *b* is small.

5. RESULTS AND DISCUSSION

We have tested the proposed algorithm on a number of PAN and LISS images from IRS-1C/1D satellite. For IRS-1C/1D LISS, there are four spectral bands – two in the visible range and one in the near infrared range. We are considering only the near infrared band because the road like structures is not significant in the first three bands. The spatial resolutions for IRS-1C/1D LISS and PAN images are 23.5 m and 5.8 m respectively.

Fig. 2(a) shows an original image of IRS-1C near IR band LISS image and the final track output is shown in Fig. 2(b). Lower values of γ gives more detail in the detected track features. Our experience shows that γ for hilly areas lies in the range 0.1 to 0.2. Here we have chosen the values of $v_h = 100$, $v_l = 70$ and $\gamma = 0.1$. The Values of g_1, g_2, l_1 and l_2 are 5, 25, 5 and 25 respectively for both experiments.

Fig. 3(a) shows an original image of IRS-1C PAN image and the final track output is shown in Fig. 3(b). Here we have chosen the values of v_h = 180, v_l = 130 and γ = 0.1.

In Section 2, we introduced line enhancement method for enhancing the track like structures in the image. Two low-level operators are used. The first operator produces the enhanced image. The second operator outputs an image that gives a heterogeneity measure of the original gray values around a pixel in a particular direction. A third operator is used which is the combination of the first two operators. Here, we considered two types of track. One is black and another is white. We introduced a segmentation procedure based on the upper and lower bound gray values of possible track pixels, segment length and contrast in Section 3. A geometrical concept based linking procedure has been discussed in separately in Section 4. The results show the efficiency of the proposed algorithm. We have seen that the total time taken for 4k x 4k scene is approximately 35 minutes on SGI Octane (R-10000).

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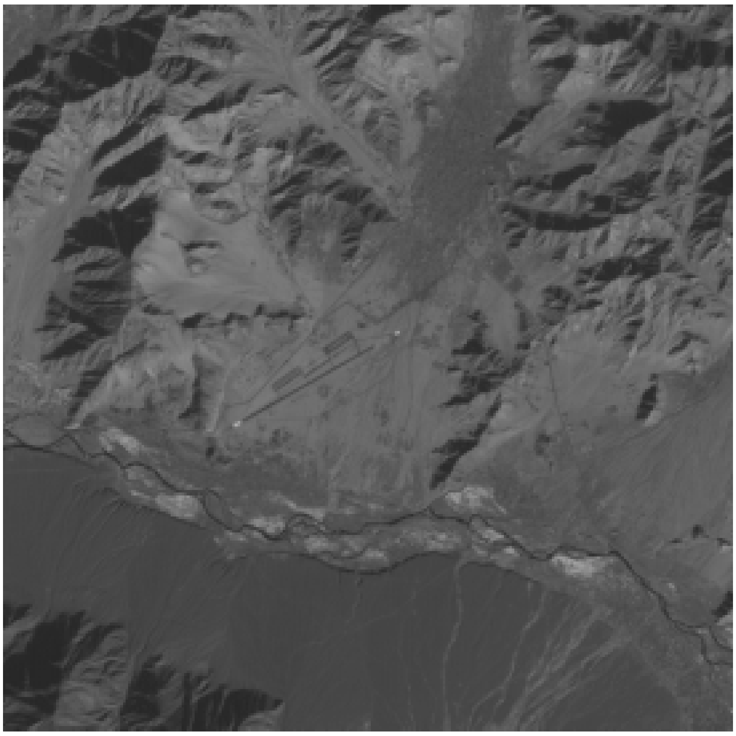

Fig. 2(a): IRS-1C near IR band LISS image

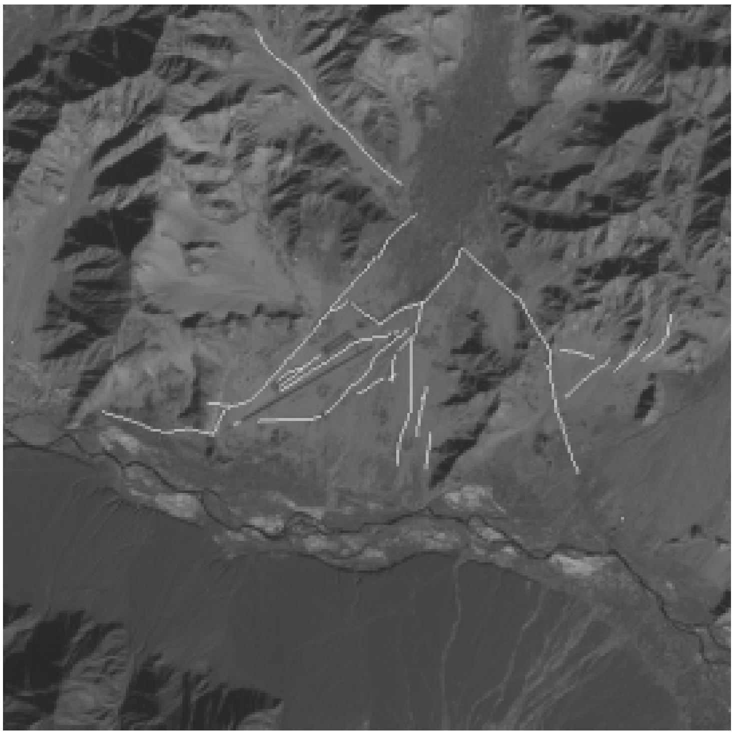

Fig. 2(b): Track output image

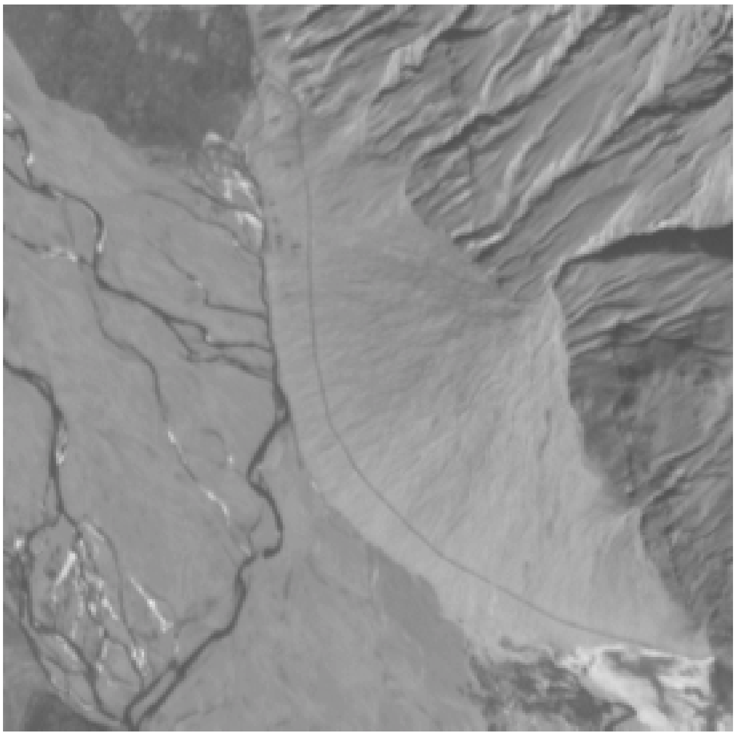

Fig. 3(a): IRS-1C Pan image

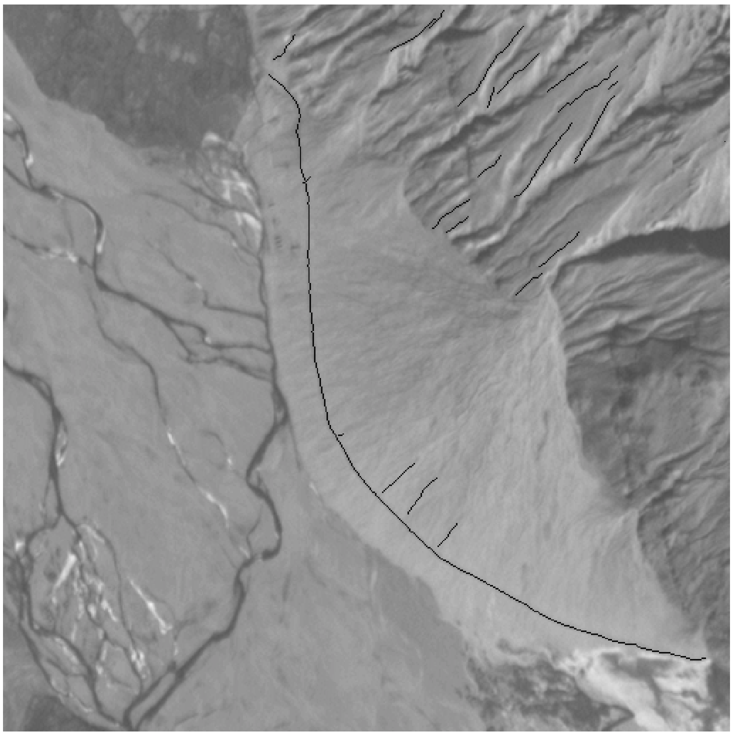

Fig. 3(b): Track output image