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Feature Extraction of Linear Objects from Remote Sensing Image (RSI) Using Gradient Filters

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ABSTRACT

Extraction of linear features from Remote Sensing Image (RSI) has found many applications as in urban planning, disaster mitigation and environmental monitoring. There were many previous studies in this field appreciating the significance of statistical operators to extract linear features. But in RSI domain, it has a different significance as it involve handling a large data set of multiband data involving complexities in terms of spectral, spatial and temporal domain. Most of the objects in nature were not easily discernable and extracted as they were often contaminated or mixed with other objects and might influence the spectral character of the object. This may be less in urban environment as they exhibit more or less uniform spectral behavior where as in natural setting it may exhibit complex spectral behavior. Present study demonstrates such complexities in extracting linear features in different setting – urban and coastal area – using first order derivative gradient filters.

Keywords: RSI, spectral, spatial, temporal, linear future.

1. INTRODUCTION

Detection and extraction of linear features from Remote Sensing Image (RSI) has caught the attention of many researchers worldwide since it has many applications (Czerwinski, *et.al.,* 1997). The edge detection algorithms are very important feature extraction methods, especially linear features that have been widely used in many computer vision and image processing applications using linear and non-linear filters (Salem Saleh Al-amri, 2010). Extraction of linear features is very vital in boundary detection (Palmer, et.al., 1996; Wang *et.al.*, 2006; Alshennawy and Aly, 2009), change detection studies (Canty and Nielsen, 2006), where a crop filed might have changed into some other objects, monitoring development of infrastructures such as roads and railways, erecting new jetties along harbors and so on. Besides, in terms of natural disaster, it is very useful in detecting vulnerable zones on earth where certain linearity of objects reveal the weakness of the earth landform features.

There were many edge-detection evaluation methods have been developed and use and significance of them still pose a challenging task for applications (Heath, et.al., 1997; Baker and Nayar, 1999). Moreover, in many studies, edge detection have been used as a pre-processing step to remove speckles and enhance images but in other it is the major image processing method to identify and extract linear features of valuable information (Yitzhaky and Peli, 2003) for further spatial analysis (Forghani, 2000). Linear features from RSI were identified by exploiting detection of edges among features or boundaries. In other words, it is an identification of sharp discontinuities in an image and while doing so some features or objects grow linearly and stand out from other objects in the image. These objects by their linearity and continuity may be identified and extracted as linear features for specific applications in RSI domain.

2. BACKGROUND OF THE STUDY

Linear features could be extracted from RSI through spatial transformation of digital values of pixels (DN values) by convolution, assessing relatively small neighborhoods of a given pixel, selecting local from a global image. For example, an image of remote sensing satellite could be processed in such a way that value of each output pixel represents small neighborhood of the input pixel, say 3x3 and when subtracted from the original image output image will represent original value of the image and the computed average of its neighborhood pixels. As the neighborhood size increases successively larger and larger structures could be isolated including the smaller ones. This way boundary of each object could be isolated and brought out. In similar fashion¸ when an array of 3x3 matrices occur in gradient direction ϴ, edges along linear directions grow in any of the 360º direction, of the RSI indicating a physical boundary as in the case of a road, or coastline. Such extraction involves high pass spatial filtering and DN thresholding estimating the difference between neighboring pixels (DN values) in a given direction, calculating directional gradient. To elaborate further, an isotropic gradient may be estimated by applying gradient filters in two orthogonal directions, vertical and horizontal, and later combining them in a vector calculation at every pixel. The magnitude of the gradient may be calculated as

$M = |M_g| =$ Sq.rt $d_x^2 + d_y^2$, and the direction of the gradient may be calculated by the angle between composite vector and co-ordinate axis, which may be written as $\Phi = \text{atan}(d_x / d_y)$ as shown in figure 1.

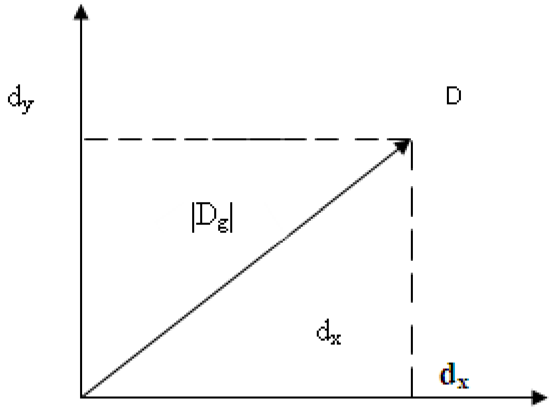

Figure 1. Image gradients using vector geometry

In these gradient filters, the detection of edges may be addressed with a DN threshold applied to the magnitude of the gradient. A too high threshold value may result in isolated pixels classified as edge pixels growing a thick and poorly defined boundary and a low threshold results in thin and broken segments. The limitation of such technique may be due to its functionalities as they use only local information of the selected image (global) in the gradient estimation.

3. METHODS AND TYPES OF ESTIMATING RS IMAGE GRADIENTS

Many local gradients are used in image processing of RSI to detect edge and linear features and they show only small variations in their performance when analyzed visually. Some of the prominent gradient filters include Robert's Sobel, Prewitt and Laplacian. Among these Sobel and Prewitt filters are more common and observed more effective in extracting linear objects and edge detection including boundary detection.

Sobel or Prewitt edge detection gradient filters accept both gray scale image and color image and applied with Sobel or Prewitt x and y gradient convolution masks dx and dy. From the outputs of these convolution blocks resultant absolute magnitude is computed and given as Sobel or Prewitt edge detection output.

4.ALGORITHM AND IMPLEMENTATION

To detect the linear features, gradient algorithms are used and as discussed in the above section Sobel and Prewitt operators were selected and to be applied on the RSI. The algorithm of these operators is given below.

Step 1: Select RSI and display as input image
Step 2: Design a vertical mask and implement it on the selected image
Step 3: Specify threshold value or automatic substitution of threshold value
Step 4: Design a horizontal kernel complementing the vertical kernel after a 90 degree rotation
The Sobel mask operator may be as given below.
-1 0 1
-2 0 2
-1 0 1, in vertical directional kernel

1 2 1
0 0 0
-1 -2 -1, in horizontal directional kernel

Step 5: Display the resultant output image

For Prewitt operator to detect edges and extract linear features, similar steps of Sobel operator were applied except the kernel window, which is given below.
The Prewitt mask operator may be as given below.
-1 1 1
-1 -2 1
-1 1 1, in vertical directional convolution mask

1 1 1
1 -2 1
-1 -1 -1, in horizontal directional convolution mask

In the present paper, the result of implementation of these two operators – Sobel and Prewitt – were discussed. For this purpose, two RS images depicting two different environments such as urban and coastal area were selected. The selection of such a different setting was to demonstrate the significance of gradient operators in delineating linear feature, roads and building in the case of an urban environment and shoreline and beach in the case of coastal area. Besides, buildings and field boundaries in the urban environment and canals, beach and shoreline were detected in the coastal environment. A discussion on the output resultant image and their interpretation were discussed in the following section.

5. RESULTS AND DISCUSSION

The gradient filters – Sobel and Prewitt - applied on the image resulted in delineation of various features both in urban and coastal areas. The isotropic gradient obtained from applying 3 x 3 kernels resulted in extraction of significant linear features and boundary detection. In the

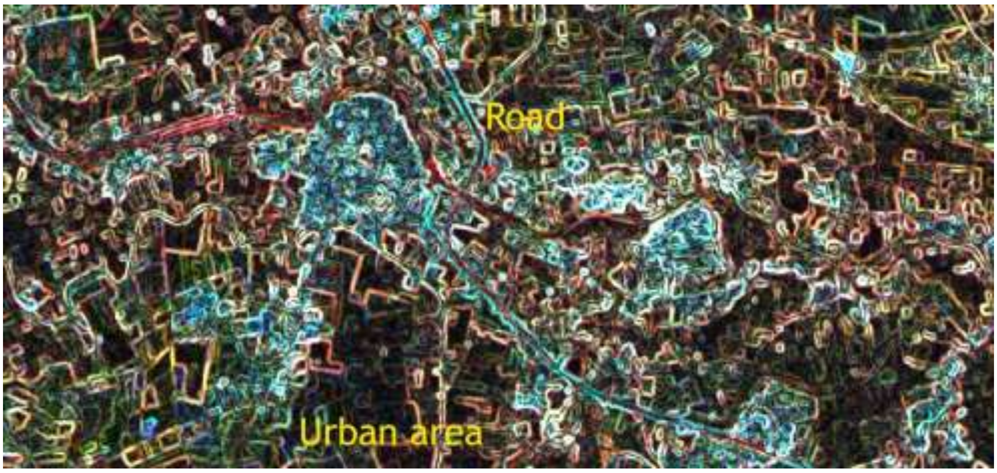

Figure 2. Linear feature and boundary detection in an urban area using Sobel filter

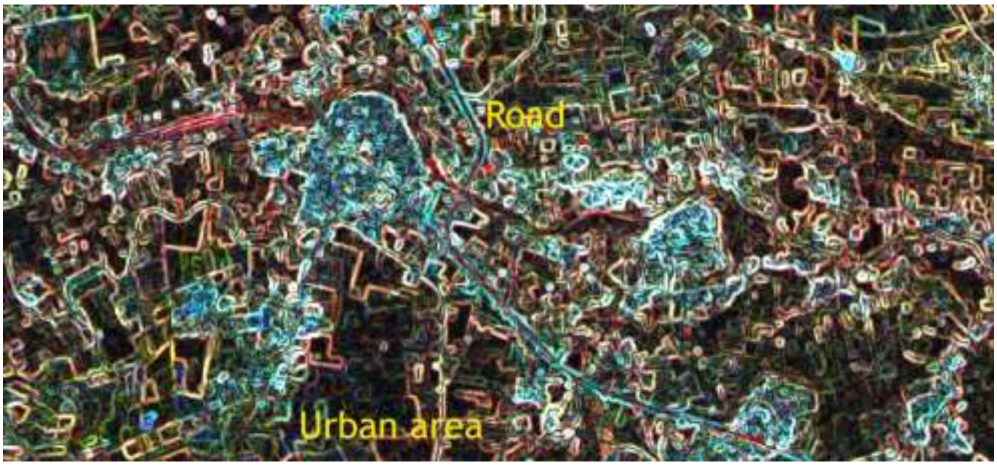

Figure 3. Linear feature and boundary detection in an urban area using Prewitt filter

kernel using Sobel operator on the urban RSI, boundaries of prominent man-made structures such as buildings, roads and urban sprawls were clearly delineated (Figure 2). The general appreciation of the figure revealed presence of urban area at the center with roads, canal, industries and field boundaries. It was also noted that other features such as crop, water bodies etc were not evidently seen and extracted using the gradient vector. A curvilinear feature at the left side of the urban center could be interpreted as a canal. The man-made objects were identified by their bluish green color including the roads and other agricultural features including many other minor features were not seen in the resulting image. Another gradient filter, Prewitt filter revealed similar outcome as that of the Sobel filter except the edges of boundaries of linear features and curvilinear were slightly blurred (Figure 3). This may be due to the estimation of neighborhood average of low pixel values both in horizontal and vertical direction at local level in the selected global image.

To further understand and demonstrate the effect of linear features detecting operators, the same were applied on an image showing coastal area. The RSI was selected because coastal area have many linear features such as coastline demarcating sea and land, beach, canals if any, besides road network. When Sobel operator was applied on such an image, the result reiterated the effectiveness of such a gradient filter. The resultant image (Figure 4) showed many linear features. It clearly segregated the land from sea exhibiting coastline as a linear feature. Similarly, another linearly grown road feature along the coast could be extracted using the Sobel operator. Also, boundary lines of a large waterbody at the center of the image were interpreted as an extension of backwaters from sea. Within the waterbody, a linear feature in blue color was later identified as a canal. Besides such features, boundaries of major land use features showing agricultural land were also identified.

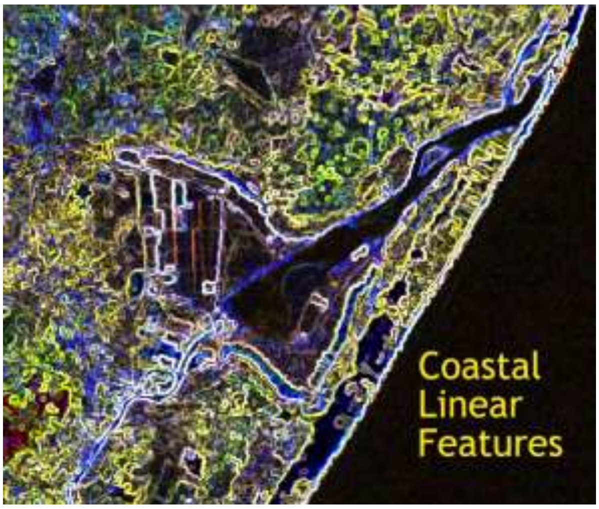

Figure 4. Linear feature and boundary detection in coastal area using Sobel filter

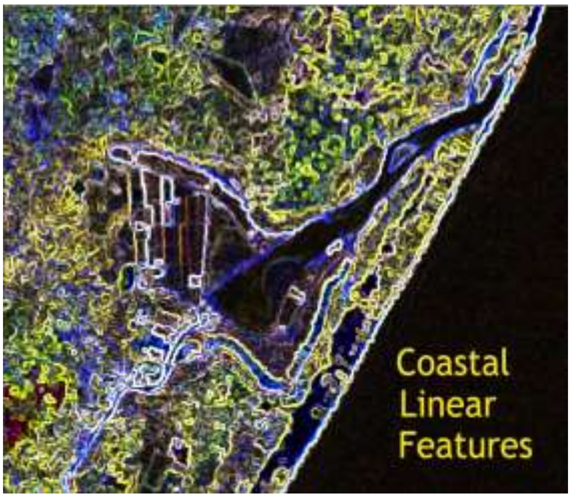

Figure 5. Linear feature and boundary detection in coastal area using Prewitt filter

The same image when applied with Prewitt operator enabled to extract similar linear features and boundary detection (Figure 5). While comparing the results visually, there was not much difference except the extracted linear futures were not as sharp as the previous operator. At the same time, the statistical details of both the operators showed certain differences in frequency and occurrence of pixels (DN values) of the resultant images as shown in Table 1.

The table showed above illustrated that there existed a small difference between two operators in terms of DN range and related mean and standard deviation (SD). This was evidently more pronounced in the second band since it was the water absorbing band. This again emphasized the spectral significance in extracting linear features using gradient operators.

Operator	Spectral Bands	DN range	Mean	SD
Sobel	B1	0 – 196	15.855	20.545
	B2	0 – 214	26.870	30.224
	B3	0 – 197	24.364	26.691
Prewitt	B1	0 – 189	20.609	18.480
	B2	0 – 202	27.540	23.950
	B3	0 – 196	25.746	22.439

Table 1

6. CONCLUSION

The paper attempted to appreciate the utility of gradient operators in extracting linear features using first order derivatives and explained the background of such operators. Two such operators were applied on RSI depicting two diametrically opposite land environment - with the first RSI showing predominantly man-made features, urban environment and the latter showing a dominant natural feature coastal environment. With this background, the study demonstrated the significance of extracting linear features and boundary detection in various land environments such as urban and coastal environment and its usefulness in image mining and the derived information could be used further for related planning and development applications.

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