Linear Feature Extraction from Satellite Imagery using Discontinuity-Based Segmentation Algorithm

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ABSTRACT:

This paper addresses the approach to extract linear features from satellite imagery using an efficient segmentation method. The extraction of linear features from satellite images has been the main concern of many scientists. There is a need to develop a more capable and cost effective method for the Iranian map revision tasks. The conventional approaches for producing, maintaining, and updating GIS map are time consuming and costly process. Hence, this research is intended to investigate how to obtain linear features from SPOT satellite imagery. This was accomplished using a discontinuity-based segmentation technique that encompasses four stages: low level bottom-up, middle level bottom-up, edge thinning and accuracy assessment. The first step is geometric correction and noise removal using suitable operator. The second step includes choosing the appropriate edge detection method, finding its proper threshold and designing the built-up image. The next step is implementing edge thinning method using mathematical morphology technique. Lastly, the geometric accuracy assessment task for feature extraction as well as an assessment for the built-up result has been carried out. Overall, this approach has been applied successfully for linear feature extraction from SPOT image.

1. Introduction

Complexity, boringness, being costly in terms of generation, maintenance and updating of linear features maps including roads, coastlines, borders of cultivated lands, rivers, and so on particularly in broad expanse of lands are among major problems facing geomatics community. The ability of using new and fast methods for updating of maps especially linear features maps plays a major role in Geographic Information System (GIS). Linear features extraction is broadly used for developing linear maps in geomatics engineering (Wheate, 1983). Linear maps can be used for producing (Domenikiotis, 1994) and updating maps (Wang, 1867). Linear extraction and line linking can be included in automatic methods (Shojaei, 2000). The majority of linear features extraction algorithms use single band images (Wang, 1994). Many researches have been accomplished in this regard. For example, VanderBrug (1978) used background information for locating and defining the composition of linear features, Gummey presented a nonlinear algorithm (Gurney, 1980), Simons developed a new method based on the numerical image processing technique (Sijmons, 1984), Theissen (1994) provided a circular operator, and Forghani (1995) developed an approximately automatic method. The main objective of this paper is to investigate continuity based segmentation method in extracting linear features information from satellite imagery. To this aim, this research has been implemented in several steps. The results of this study were satisfactory and with a great level of success and accuracy, the linear features map was calculated.

2. Materials and Methodology

This study is to consider the process of extracting linear features from satellite imagery through discontinuity-based segmentation algorithm. In this study, this technique is based on the gray scale of image pixels and looks for those neighboring pixels with different spectrum characteristics. Various steps of this research after explaining about study area are as follows: first of all through low level bottom-up methods including geometric correction and noise removing were carried out and then through medium level bottom-up methods, the optimum operator for edge extraction was explored and determined through a built-up image by investigating the geometric accuracy of results, then the thinning of edges was considered as the next step and finally, the accuracy of final linear features map was determined.

2.1 Study Area

The considered area for this study was Varzaneh region, an area near to Isfahan city in center of Iran. For example, the linear features in this area are roads, railways, and rivers. The satellite imagery used for extraction of linear features, were SPOT in two types of panchromatic (P) and multispectral (XS), dated 1993. In order to evaluate the accuracy of the final linear features map, the 1:25000 scale topographic map of the area under 1992 WGS84-UTM projection system was applied. Since the only one band from a multi band image is necessary for this process, the first blue band due to clarity of linear features like roads was selected in this study.

2.2 Low level bottom-up processing

This step refers to all processing activities which lead to preparing the satellite imagery which is used for extracting the linear features. This step includes geometric correction and noise removing. In this step the images are corrected in order to be appropriate for creating a dataset and are visualized geometrically on the land surface. In order to carry out this process, some control points which had been extracted from topographic map previously were applied. Furthermore, the satellite images typically are affected by noise. In this study among all low pass filters including median, mean and wiener, the median filter was selected. Because although both mean and median filters are able to remove fluctuations, the median filter is more successful in removing single and outlying pixels and is more capable to maintain margins namely those pixels which have faced more variations in terms of value, however the costs of calculating median filter is higher than other relevant filters. Meanwhile, several research studies have been investigated in this regards like Shojaei (2000) believes that the median filter is faster than wiener filter.

2.3 Medium level bottom-up processing

In this step, extracting and processing linear features are carried out by using image segmentation technique. In order to achieve the objectives of this step, the most optimum linear extracting operators like Sobel, Canny were determined by evaluating the geometric accuracy of applying those operators in designed built-up image which includes the characteristics of the linear features in the satellite imagery.

2.3.1 Finding the best edge extracting operator

In order to find the best edge extracting operator from several existing operators of this type, in this paper a single band built-up image was designed to evaluate various existing edge extracting operators, and then the results of evaluation were applied to satellite imagery. The main reason of using built-up image is the complexity of satellite image analyses such as atmosphere complexity, noises produced by sensor, which complicate the direct investigation of the operators on satellite imagery. So the main function of built-up image is to test the accuracy of edge extracting operators, in order to make it possible to find the best and optimum operator for the main processing task. The built-up image should have some necessary features: firstly, it should include different linear features in different directions so that it could have a better approach toward the real situation, secondly, if this image wants to be a better representative of the satellite imagery, some levels of noise shall be added randomly to this image. For this reason some natural noise were added to the image through Gaussian filter (Figure 1).

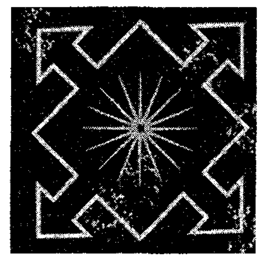

Figure 1. Built-up image including Gaussian noise.

Basically, there are several operators for edge extraction. Many researchers believe that Sobel, Canny, and Deriche are the most popular operators for edge extraction (Shojaei, 2000). So, in this paper those operators were investigated. In this step, the various operators with different levels of threshold to the built-up image were applied. In order to find the best and optimum filter and suitable its threshold in terms of accuracy, the following method was applied. By digitizing the built-up image, a basic image including linear features was made. This digitized image is as the representative of the real situation of the features. For accuracy calculating, the results achieved from each operator applied to the built-up image with a specific threshold were compared with this digitized file. Richard (1993) suggested using following formula in this regards.

In order to calculate the accuracy of edges for every operator with a specific level of threshold, considering that class B is related to black pixels which are the representatives of the non-edge pixels and class W is related to white pixels which are the representatives of the edge pixels in the image, then this accuracy can be calculated via Formula 1 as stated bellow:

$$A_{BI} = \frac{N_C}{N_C + N_I} \times 100 = \frac{C_1 + C_2}{C_1 + C_2 + I_1 + I_2} \times 100 \qquad (1)$$

Where: A_{BI} is the overall accuracy of the built-up image.

N_C is the total number of rightly classified pixels in class W and B.

N_I is the total number of wrongly classified pixels in class W and B.

C_1 is the number of rightly classified pixels in class W.

C_2 is the number of rightly classified pixels in class B.
I_1 is the number of wrongly classified pixels in class W.
I_2 is the number of wrongly classified pixels in class B.

2.4 Edge Thinning

Considering this fact that many of the methods edge extraction use threshold of brightness values, edge pixels could be extracted with other nearby pixels and since one edge is defined as the boundary between two neighboring areas in an image, so the extracted edges shall at most include one pixel. The stage of recognizing the selected pixels as edge pixels is called edge thinning. One of the prevalent methods of edge thinning is the application of morphologic transformations. Morphologic functions are used for extracting the boundaries and connected elements and thinning thick edges. The skeletonization function which is an example of morphologic function is used in this research. It creates a line with a minimum level of connection which has similar distances from the boundaries of the image.

2.5 Extracting linear features and geometric accuracy assessment

At the next step the selected optimum operators were applied to P & XS satellite SPOT images. Then the considered linear features were extracted. In order to find the geometric accuracy, evaluation of the horizontal accuracy of the extracted linear features would be necessary which is dependent on two parameters, namely georeferenced image horizontal accuracy and linear detected features horizontal accuracy. Georeferenced image horizontal accuracy has been done by several control points and checkpoints for panchromatic and xs. Then, in order to calculate the geometric accuracy of the extracted linear features map several points in both extracted map and topographic map have been derived.

3. Results and Discussions

The results of this study show that various steps of extracting linear features through discontinuity-based segmentation technique had been accomplished properly and the geometric accuracies of extracted linear features prove this fact clearly. Basically the reason of applying image segmentation techniques based on discontinuity property of satellite imagery pixels values, is their great and significant level of positioning accuracy in extracting the boundaries and since the main objective of this study was to find a better way to facilitate the updating of linear features maps in which the positioning accuracy is of great importance. Therefore application of discontinuity based segmentation technique became necessary.
After applying median filter for noise removing in low level step, then in medium level process several edge detection filters such as Sobel and Canny operators were performed in built-up image. In order to define the appropriate threshold for those operators, many values were tested. Table 1 illustrates the accuracy of these thresholds which are calculated by mentioned formula 1. As these table shows the best level of accuracies in linear extraction is 125 and 180 for Canny and Sobel operators respectively.

Table1.The results of accuracy assessment for Canny and Sobel operators.

Thre.	Accuracy (Canny)	Thre.	Accuracy (Sobel)
0	18.618	0	14.401
10	30.467	1	14.638
30	53.891	10	20.894
50	54.351	20	30.911
80	57.690	30	39.674
100	58.058	80	53.340
120	58.147	120	53.832
125	**58.157**	140	53.894
130	58.155	150	53.898
140	58.128	170	53.878
180	57.934	**180**	**53.877**
200	57.672	190	53.859
240	56.215	200	53.841

After finding the appropriate operators and their threshold, these filters have been applied to the both Pan and XS satellite SPOT imagery. Then the considered linear features have been extracted (Figure 2, 3). Then the geometric accuracy of linear features shows the successfully implementation of this method.

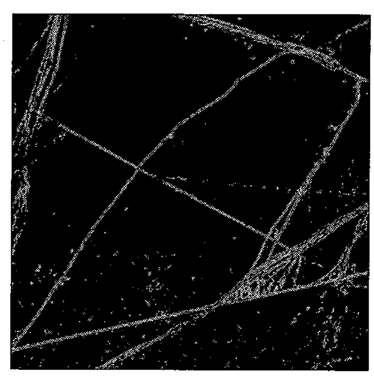

Figure 2. Linear features extracted from SPOT (P).

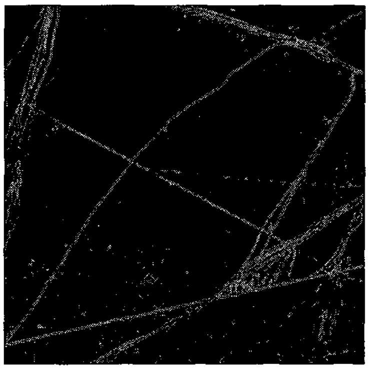

Figure 3. Linear features extracted from SPOT (XS).

Sometimes, in some operators it is seen that in a specific level of threshold the geometric accuracy is much better than other levels of threshold, however, at the same time the visual and environmental accuracies are quite low and more noises are in effect. Since in this case the noises are playing the role of edge pixels, these noise would assumed as parts of the real linear feature and create an unreal continuity in the feature. In order to resolve these problems, edge linking, domain knowledge, knowledge based, or mode based algorithms can be used.

4. Conclusions and Future Research

The main objective this study is to resolve many problems of traditional techniques of generation, extraction and updating of linear features from satellite imagery through discontinuity-based segmentation algorithm. The results show that this technique due to its significant level of positioning accuracy is very suitable for generating and updating linear features. Simplicity and appropriate speed are among major advantages of this technique. An interesting result achieved in this study is that applying one single threshold to the overall image might not be appropriate. Since fixed specific threshold has the useful behavior of the areas with appropriate level of contrast which is different from the areas with inappropriate level of contrast. Therefore it is proposed for future studies that the thresholds would be applied locally and not globally and based on the image contrast and other effective factors, an appropriate level of threshold would be applied to each area. At last, in order to improve the level of geometric accuracy, in addition to the discontinuity based segmentation technique, applying similarity based segmentation technique which actually includes edge connection process could be much more useful.

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