HYBRID TECHNIQUE FOR AUTOMATIC MAIN ROAD EXTRACTION

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Abstract

As manual extraction of road is time consuming and it relies on operator's efficiency, automatic extraction of road from remotely sensed data has become the subject of extensive research for the past decade. In this paper the task of automatically extracting road remotely sensed image is explained. Road can be extracted from colour image by determining its spectral signature. As there are more than 16 million colours available in any given colour image analysing the image based on its colour components is a complex task. Even if the road spectral signature is extracted, it is difficult detect road alone since soils and roads have the same spectral signature. A hybrid technique has been developed to extract road. First the image is preprocessed to remove the noise. Then the road spectral signature is extracted using Artificial Neural network (ANN). Contour tracing algorithm and mathematical morphology are used to remove the non road segments.

Keywords: Road extraction, ANN, LoG Filter, Contour tracing, Granulometry, Mathematical Morphology

I. INTRODUCTION

Roads are important objects for various topographic applications. The manual extraction of road takes significant effort. Hence, automation is highly desirable.

For identifying road segments from satellite or aerial images, human beings search for a set of linear features and then they apply knowledge or use experience to decide whether these linear features are roads are not. Road extraction by template matching [1] has been proposed by Park and Kim. A semi automatic method [2] which takes road segment as seeds, was suggested by Jin,Davis. A context based road center line extraction [3] has been introduced by Wessel, Wiedemann and Hebner. A line detection algorithm based on Hough transform [4] has been used by Rianto for automatic road detection. Mokhtarzade and Valadan have used neural network classifier for road extraction [5]. There have been intensive efforts to develop algorithms for automatic extraction of roads for the past two decades[6 -20]. Despite these efforts no practical system has been developed so far.

In this paper we present a novel approach based on ANN, mathematical morphology and filtering for extraction of main roads.

The rest of the paper is organized as follows. The methodological frame work for road extraction is given in section II. The proposed method has been used to extract road from aerial and satellite image. The accuracy assessments of the results are discussed in section III. In section IV concluding remarks are given.

II. METHODOLOGICAL FRAME WORK

Though roads and soils have same spectral signature, roads have some specific characteristics. Their characteristics can be classified into radiometric, geometric, topological, functional and contextual categories. The geometric characteristics of roads are that they are elongated and have maximum radius of curvature. Their radiometric characteristics intimate that their surface is homogeneous and they have good contrast with the adjacent areas. Their topological characteristics are that they intersect and build a network and they do not stop without a reason. Roads connect cities. It is a functional characteristic of road. Their contextual characteristics suggest that fly-overs and trees cast a shadow on the road surface. All characteristics of road except the functional characteristics are used in our work. The extraction technique can be divided into four parts: Image preprocessing, Spectral signature extraction, Closed contour removal and Morphological operations.

The goal of image preprocessing is to increase both the accuracy and the interpretability of the image data during the image processing phase by eliminating the noises. High spatial resolution satellite imagery is affected by three primary noises. The white noise is formed during the imaging stage. The second is produced during re-sampling and compressing process. The last refers to noises that are caused by the difference of extracted features to non-extracted features. Image smoothening reduces the first two kind of noises. In our work, we have utilized averaging filter to for smoothening the image. Through repetitive tests it has been found that 3×3 template proves to be effective in eliminating speckles and small vehicles on roads in the imagery. This preprocessing step is simple, quick and automatic, hence can be appliedto high spatial resolution images of huge volumes.

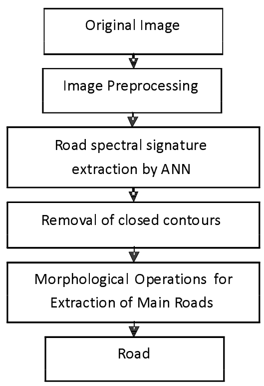

Fig.

Artifical Neural Networks

Artifical Neural Networks have already been used in many instances in feature extraction and image classification problems. In our method they are applied as sophisticated pattern classifiers used for road spectral signature extraction. A set of sample data are taken from the satellite image. The RGB values of each pixel are found. Depending on the spectral value, the pixels are classified as Road and non-road pixels. The sample data and target are used to train the ANN. When new images similar to the sample data are fed to the ANN, it classified the land cover successfully. A feed-forward neural network, which is one of the most frequently implemented network types as the pattern classifier. The network construction comprises an iterative back propagation training method. The network has a neuron layer with equally tangent sigmoid processing elements. This neural transfer function has a simple derivative, which is very valuable, since it is allows very fast training. The training of neural networks is a time-consuming task. The Levenberg-Marquard algorithm has been selected for training due to its efficiency. This algorithm makes use of a learning rule of second order gradient descent with momentum. The momentum helps to avoid the local minima on the error hypersurface. The mean square error measure has been used, because it adjusts the network weights and it has moderate performance requirement. The implemented weight update was almost constant, which is achieved by adaptively modifying the optimization step length.

Closed Contour removal

Soils , building roofs and parking areas have same spectal signature as roads, the geometrical and topological characteristics of road are to be used for extracting them. As roads do not stop without a reason, the road edges do not form closed contours. Initially, all non zero connected objects are labeled. Then an edge filter is applied to the extract the edges. The edge filter used in our work is Laplacian of Gaussian i.e. LoG filter.

The Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection The Laplacian is often applied to an image that has first been smoothed with a Gaussian smoothing filter in order to reduce its sensitivity to noise, and hence the two variants will be described together here. The operator normally takes a single gray level image as input and produces another gray level image as output.

The Gaussian function is given by

$$G_{\sigma}(x, y) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{x^2 + y^2}{2\sigma^2}\right]$$

The Laplacian function is given by

$$L(x, y) = \nabla^2 f(x, y) = \frac{\partial^2 f(x, y)}{\partial x^2} + \frac{\partial^2 f(x, y)}{\partial y^2}$$

By combining the Laplacian and Gaussian equations the Laplacian of Gaussian is given by

$$Log(x, y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{X^2 - Y^{2-}}{2\sigma^2} e^{-x^2+y^2} 2\sigma^2\right.$$

The LoG operator takes the second derivative of the image. Where the image is basically uniform, the LoG will give zero. Wherever a change occurs, the LoG will give a positive response on the darker side and a negative response on the lighter side.A contour tracing algorithm has been developed for finding the closed contours. The no. of pixels in each label is counted. The first pixel coordinate of each label is stored.

The next pixel coordinate is traced in all 8 directions and count is increased. If a pixel has been already traced, it is not considered again. The contour tracing is continued till the count equals the no. of pixels in the respective label. The last pixel coordinate of each label is compared with the respective first coordinates. If they are neighbors then the contour is closed. By comparing the labels of closed contours they are removed from the image, to obtain the road.

Mathematical morphology

Mathematical morphology is an image processing tool used for extracting features of interest. Mathematical morphology is a set theory approach, which is based on geometrical shape. It uses set operations such as union, intersection and complementation. Mathematical morphology operations include dilation, erosion, openings, closings and the derived operations such as Hit or Miss, thinning, their properties and their use. The objective of the work undertaken is to develop an algorithm for automated road network detection from high resolution images using mathematical morphology. Firstly a road is segmented from background. The mathematical morphology tools used are granulometry and trivial opening. A granulometry analysis of objects in image is performed and the size information of road network is obtained. The road is extracted preprocessed images and differentiated other features with similar properties as roads using Trivial Opening and closing. It is done based on the size information provided by the granulometry.

Granulometry

Granulometry is one of the most useful and versatile tools of morphological image analysis. Granulometry techniques find wide range of applications in feature extraction, texture characterization, size estimation image segmentation etc. The concept behind granulometry is to determine the size and shape distribution of objects present within image. Granulometry is a field that deals principally with determining the size distribution of particles in an image. Opening operations with structuring elements of increasing size are performed on the original image. The difference between the original image and its opening is computed after each pass when a different structuring element is completed. At the end of the process, these differences are normalized and then used to construct a histogram of particle- size distribution. This approach is based on the idea that opening operations of a particular size have the most effect on regions of the input image that contain particles of similar size. Thus, a measure of the relative number of such particles is obtained by computing the difference between the input and output images. These measures can be used as shape and size signature of the original image and can be plotted as a pattern spectrum.

Morphological Trivial Opening is defined as one, which provides a practical mean of object detection and identification. It does not affect the shape and size of the objects of interest. Let X be an image, $\{ X(n) \mid n = 1, 2, 3, \ldots, N \}$ is a series of connected components in the image, $x(i)$ is a point in $X(i)$. We define the trivial opening with a criterion T, as follows.

$$\{T = \{ \begin{cases} X(i), & \text{if } X(i) \text{ satisfies the criterion } T \\ \phi & \text{otherwise} \end{cases}$$

where TO is the trivial opening associated with criterion T. It is a morphological opening, because it is idempotent, anti- extensive and increasing. In image processing, this operation uses the criterion T to filter the connected components that satisfy the criterion T. Trivial opening based on criterion T provides a practical means of object detection and derived area opening from connected and trivial opening to find the connected regions in an image with a certain area. Trivial opening does not affect the shape and size of the connected regions that are preserved because it preserves the entire connected regions.

Since the width of street is less than that of the main road, opening operation with the structure element whose size is smaller than main road but slightly larger than that of street can remove small paths. Further it removes the paths connecting road network to the houses. It is necessary to develop tools to reconstruct these road parts. Mathematical morphology based window operation is designed for this purpose.

III. EVALUATION OF EXTRACTION

The quality measures for road extraction are used for comparing the results of different algorithms, rather than to evaluate the extraction and the matching results in an absolute way. Because these results of the extraction are quite different and still relatively far away from a perfect solution, a simplified set of measures is justified. In our work, the automatically extracted road data are evaluated using three quality measures.

These measures aim at evaluating exhaustivity as well as assessing geometrical accuracy. The measures used are completeness, correctness and quality. These quality measures are used with road center line in many literatures. The measures have been extended for the entire road by considering a reference road.

Completeness:

The completeness is the percentage of the reference data which is explained by the extracted data, i.e., the percentage of the reference network which lie within the buffer around the extracted data. Completeness varies from 0 to 1. The optimum value of completeness is 1.

Completeness = MRP/ RP

where,

MRP- No. of reference road pixels matched with extracted road pixels

RP – No. of reference road pixels

Correctness

The correctness represents the percentage of correctly extracted road data, i.e., the percentage of the extracted data which lie within the buffer around the reference network. Correctness varies from 0 to 1. The optimum value of completeness is 1.

Correctness = MRP/ EP

EP – No. of extracted road pixels

Quality

The quality is a more general measure of the final result combining completeness and correctness into a single measure. Quality varies from 0 to 1. The optimum value of quality is 1.

Quality= MRP/ (EP+UMRP)

UMRP - No. of reference road pixels not matched with extracted road pixels

Quality can also be defined as

$$\text{Quality} = \frac{\text{CC}}{\text{Completeness} + \text{Correctness} - \text{CC}}$$

here, CC=Completeness* Correctness

RMS Error

The Root Mean Square (RMS) error represents the difference between the reference road pixels and the extracted road pixels. The optimum value of quality is 0. It is given by

$$RMSE = \sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} (F(i,j) - f(i,j))^2}$$

IV RESULTS

Three test images of different size are used for evaluating the results of the hybrid technique framed. The first two are the high resolution satellite images of part of Denver. The resolution of these images is 1m. The third one is a multi spectral satellite image of 30m resolution. Due to the high resolution the vehicles on the roads are visibly seen in the first two images. The test images are shown in fig. 2a to fig. 2c.

Figure 2a

Figure 2b

Figure 2c

The extracted main roads are superimposed as while pixels on the original image and are shown on fig. 3a to fig. 3c.

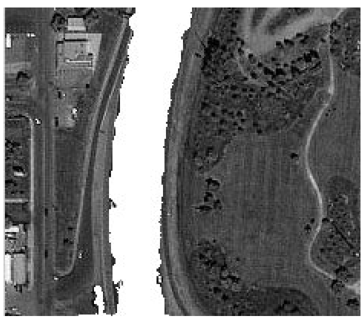

Fig. Figure 3a

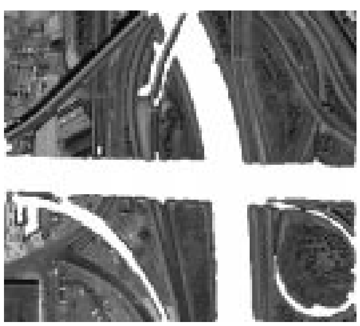

Fig. Figure 3b

Fig. Figure 3c

The evaluation of road extracted by the proposed method and by unsupervised clustering and region growing for the three test images are given in table I.

Table I Evaluation of Extracted Road

Image	Quality Measure	Clustering & Region growing	Proposed Method
Test Image I	Completeness	0.9745	0.9794
	Correctness	0.9658	0.9866
	Quality	0.9419	0.9666
	RMSE	0.0495	0.0284
Test Image II	Completeness	0.9659	0.9706
	Correctness	0.8669	0.8935
	Quality	0.8412	0.8699
	RMSE	0.1241	0.1013
Test Image III	Completeness	0.8493	0.9545
	Correctness	0.9873	0.9927
	Quality	0.8401	0.9478
	RMSE	0.1363	0.0474

V. CONCLUSION

A hybrid technique has been proposed for extracting road from satellite imagery. First the image preprocessing has been done to remove noises. Next the road spectral signature has been extracted by ANN. A contour tracing algorithm has been developed to remove the soils that resemble road spectral signature. Mathematical morphology has been used to remove small objects and reconstruct some portion of missing roads. The results show that the proposed method is useful for extracting roads from high resolution satellite imagery. The occlusions due to vehicles are also extracted by this method. From the quality measures it can be seen that the proposed technique is better than the semi automatic technique based on unsupervised clustering and region growing. Though only testing with three images are given in the paper, the technique has been tested with several high resolution satellite images and the results are consistent.

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