Semi-Automatic Road Extraction from Satellite Images

Kumaru Sai Prasanna Kumar
Department of CSE ,
Indian Institute of Information Technology,Sri City, India,
Saiprasannakumar.k16@iiits.in

***Abstract*— In this report we propose an approach for automatic road extraction from high resolution satellite images. Extracting images from aerial images is a difficult problem with many practical applications. The major steps in the model are the enhancement of the image, the segmentation of the enhanced image, the application of the morphological operators, and finally the extraction of the road network.**

Keywords*— *High Resolution Remote Sensing Imagery ; Road Extraction, Spatial Resolution

I. INTRODUCTION

In recent years, the road network changes at a rapid rate because of urban development. Thus, it is hard to maintain the accuracy and precision of the road network. In order to execute massive applications such as city planning and management system, automatic extraction of roads for updating city map has recently come to a popular research topic . It is also used for the urban mapping, urban planning and updating of geographic information system (GIS) etc[3]. Roads are one of the most important man-made components in every country. Therefore road network must be correctly and accurately updated to maintain the precision of road network for traffic management, military decision making, emergency management, and vehicle navigation and so on. Manual extraction methods from satellite and aerial images are very time consuming and accuracy as that of automatic methods are not obtained.

Roads are the base for implementing innovative technologies and methods for production, transport, management and so on. Satellite imaging system became an inevitable source in providing geographical information irrespective of the field and spheres of human life. In short, it made human life so easy by catering to every walk of life. Satellite and remote sensing images provide quantitative and qualitative information that considerably lessen intricacy of field work and study time. At present, road maps are constructed and updated by hand based on high-resolution aerial imagery. There are many researchers interested in road detection. Some of them propose the use of Hough Transform to detect road lines and implementing “snake” method to reconnect the broken road lines[1].

In this paper we follow a different approach, where we use morphological image to detect roads. This is very useful because we detect a wide range of roads using this method. To overcome problems and to create a robust toward an unsupervised road features extraction model, several methods are combined. The new model consists of several processing steps such that each step is a prerequisite for the success of the next one. The initial step is to improve the extraction of information by applying many different image enhancement techniques. The next step in the model requires the use of an unsupervised classification technique to separate the road features from other features. Then morphological operators are used to improve the feature extraction. Mura et al. [7], Bellens et al. [8], and Akcay and Aksoy [9] used mathematical morphological operators for automated extraction of multiscale urban features, such as buildings, shadows, roads, and other man-made objects.

II. EXISTING WORKS

Many researchers have proposed different methods to extract roads object such as multi-scale grouping, model-based approach, fuzzy-based, fusion-based and dynamic programming (Mohammad Zadeh et al., 2009; Mohammad Zadeh et al., 2007). A fuzzy-based mean calculation method is proposed (Mohammad Zadeh et al., 2009), which is optimized by a Particle swarm optimization (PSO). It also evaluates the best mean values for road detection in particular spectral band, which also improves the fuzzy cost function.

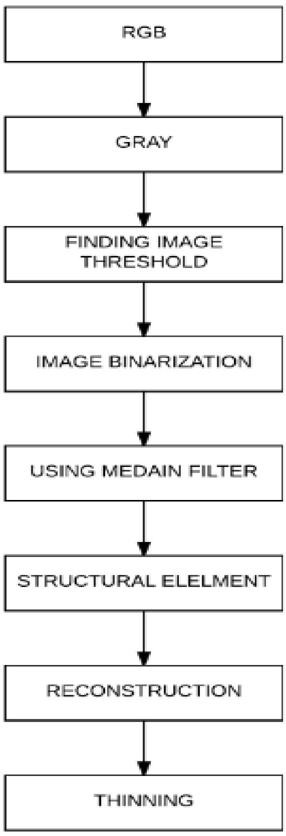
To update the Geographic Information System (GIS) database, (Zelang et al. 2013) a road extraction approach is proposed, which is based on shape features and multivariate adaptive regression splines (MARS). The measurement of optimally oriented flux (OOF) helps to eliminate the undesired spurs for the selection of end points from a classified image and further these end points are connected accurately to formulate the road network using a geodesic method (Zelang and Wenzhong 2014).

The spectral reflectance of asphalt surface helps to distinguish road surface from other impervious surfaces (Singh and Garg, 2013). The controlling parameters have utilized in the fuzziness of the FCM approach, which help to estimate the segmented road results and thereafter Stentiford thinning algorithm (STA) is used to estimate the road network from classified results. Such improvements facilitate FCM method manipulation and lead to segmentation that is more robust (Singh and Garg, 2014a).

The process of road extraction may be achieved in a single or multiple operations such as image segmentation (classification techniques), linear segments with constant width (Hough transform and edge detector), snakes (contour based object outlines), removing small blobs and merging relevant road segments (morphological operations), similarity with road templates, etc.

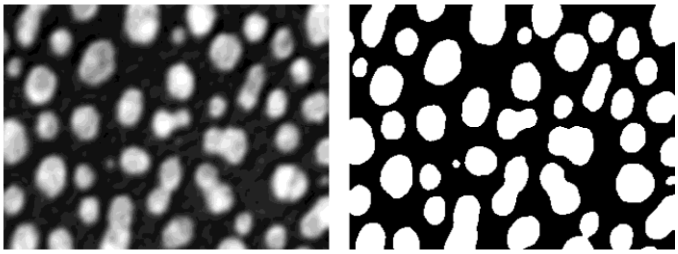
III. METHODOLOGY

This paper presents an automated approach for extracting roads using Morphological image processing [2]. The road network objects are selected, and they are subjected to a repetitive and equal number of morphological operators of *opening* and *closing*. These operators depend on other operators which are the *erosion* and *dilation* operators. The last two operations are fundamental to the morphological image processing. Dilation is an operation that “grows” or “thickens” objects in a binary image. The specific manner and extent of this thickening is controlled by a shape referred to as a *structuring element*. Mathematically, dilation is defined in terms of set operations.



A. *Image Binarizaion*

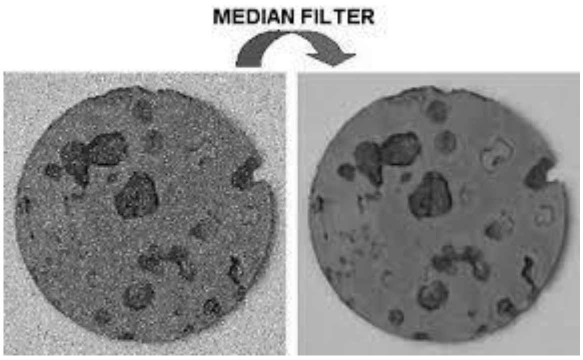
The given image is converted into binary image that only have two possible values for each pixel. Typically, the two colors used for a binary image are black and white. The color used for the object(s) in the image is the foreground color while the rest of the image is the background color.[4] In the document-scanning industry, this is often referred to as "bi-tonal". Each pixel is stored as a single bit i.e., a 0 or 1 same as black and white.



B. *Median Filter*

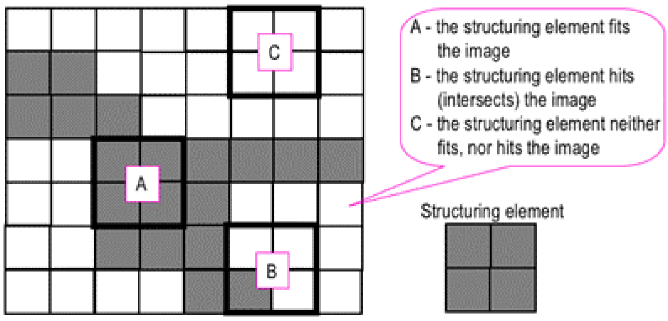
The median filter is a nonlinear digital filtering technique, often used to remove noise from an image or signal. Such noise deduction is a typical pre-processing step to improve the results of later processing. Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise also having applications in signal processing.

Algorithm def : - The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal.



C. *Structural element*

Structural elements are used in structural analysis to split a complex structure into simple elements. Within a structure, an element cannot be broken down (decomposed) into parts of different kinds (e.g., beam or column). Structural elements can be linear, surfaces or volumes[6]. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighbourhood of pixels. Some operations test whether the element "fits" within the neighbourhood, while others test whether it "hits" or intersects the neighbourhood:



D. *Erosion*

Erosion (usually represented by ⊖) is one of two fundamental operations (the other being dilation) in morphological image processing from which all other morphological operations are based. It was originally defined for binary images, later being extended to grayscale images, and subsequently to complete lattices.

In Binary Morphology, Let *E* be a Euclidean space or an integer grid, and '*A'* a binary image in *E*. The **erosion** of the binary image *A* by the structuring element *B* is defined by:

Equation : -

$$A \ominus B = \{z \mid (B)_z \cap A^c = \phi\}.$$

where B_z is the translation of *B* by the vector z, i.e., Bz = {b+z | b Є B}, for all z Є E

E. *Dilation*

Dilation (usually represented by ⊕) is one of the basic operations in mathematical morphology. Originally developed for binary images, it has been expanded first to greyscale images, and then to complete lattices. The dilation operation usually uses a structuring element for probing and expanding the shapes contained in the input image.

Equation:-

$$A \oplus B = \{z \mid (B)_z \cap A \neq \phi\}.$$

where B_z is the translation of *B* by the vector z, i.e., Bz = {b+z | b Є B}, for all z Є E

The opening operator ○ is the combination of erosion followed by dilation such that

$$A \circ B = \{A \ominus B\} \oplus B.$$

On the other hand, closing ● is the combination of dilation followed by erosion such that Reconstruction

$$A \bullet B = \{A \oplus B\} \ominus B.$$

a. *Reconstruction by Dilation*

Reconstruction by dilation reconstructs bright regions in grayscale images and reconstructs particles in binary images. Starting at the marker points, neighboring pixels are reconstructed by spreading the brightness value. Reconstruction by dilation starts with the maximal grey valued pixels of the marker and reconstructs the neighboring pixels ranging from 0 to the maximal valued pixel. Refer to Primary Morphology Operations for more information about dilation.

b. *Reconstruction by Erosion*

Reconstruction by erosion reconstructs dark regions in a grayscale image and holes in a binary image. Starting at the marker points, neighbouring pixels are reconstructed by spreading the darkness value. Reconstruction by erosion starts with the minimal valued pixels of the marker and reconstructs the neighbouring pixels ranging from the minimal valued pixel to the image maximum value (for example, the image maximum value is 255 for U8 images). Refer to Primary Morphology Operations for more information about erosion.

F. *Morphological Thinning*

Thinning is a morphological operation that is used to remove selected foreground pixels from binary images, somewhat like erosion or opening. It can be used for several applications, but is particularly useful for skeletonization. In this mode it is commonly used to tidy up the output of edge detectors by reducing all lines to single pixel thickness. Thinning is normally only applied to binary images, and produces another binary image as output. The binary structuring elements used for thinning are of the extended type described under the hit-andmiss transform[5].

The thinning operation is related to the hit and miss transform, and so it is helpful to have an understanding of that operator before reading on.

IV .Experimental Results

A Prototype algorithm was created using the morphological operation. Following results are obtained,

The image in Fig1 is the original image.

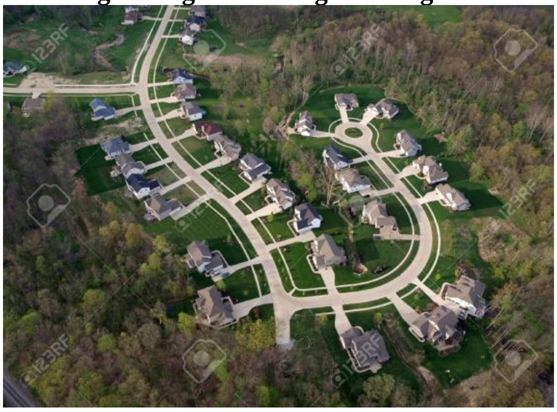


Image is read and threshold is applied in order to obtain the foreground pixels.

Linear transformation threshold segmentation binary image

Median filter 5*5 is applied to image obtained after linear transformation the following result is obtained.

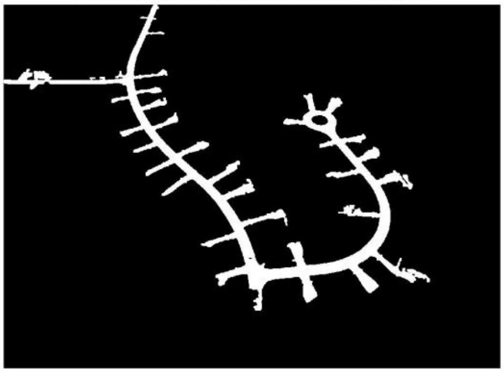
5 * 5 template median filter

Further a 5*5 structuring element is used on the image and following image is obtained

5 5The structural elements of the form of open operation processing diagram

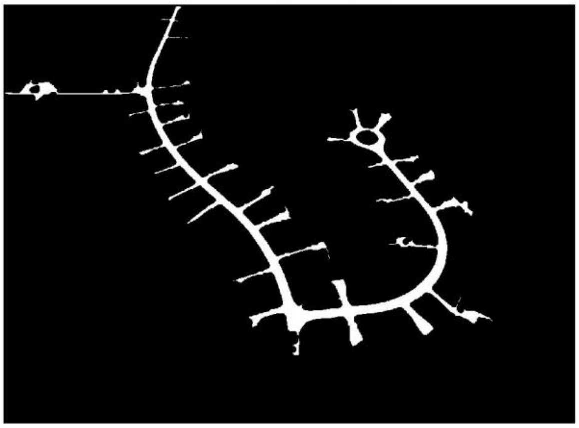
Reconstruction is done on this image giving the following result.

Morphological reconstruction operation processing diagram



After applying thinning the final output of the algorithm is shown in the below figure

Shape refinement processing diagram



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V. CONCLUSION

The road extraction process can be divided into two groups, namely automatic and semi-automatic (or manual). The automatic way is getting popular attentions due to its short processing time, but the algorithm proposed here is semi automatic but still it has very good accuracy and also takes less computation time. The purpose of this paper is to show an efficient system and method to detect roads from satellite images. The proposed algorithm for road detection using morphological operations has shown good results.

For further studies, the use of median filter and structuring element can be automated by analyzing the accuracy of the final output obtained. Based on the different variations of roads we can vary the use of morphological operators, and make the algorithm more automatic.

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