Extraction of Roads from High Resolution Satellite Images by Means of Adaptive Global Thresholding & Morphological Operations

D.Sandeep Reddy, Dr.M.Padmaja

Abstract— In the high resolution satellite images the extraction of roads is one of the important research fields. It requires the very efficient database for road network because in the urban region the road map changes due to the expansion of region. The paper deal with the one of the most important algorithm for extraction of roads is adaptive global thresholding. The proposed work consists of three stages. At first the segmented road region is separated using adaptive global thresholding. In the further stages the non-road pixels are separated using mathematical morphology operations. The algorithm is tested on various high resolution satellite images and the results are obtained. The performance or the accuracy can be calculated based on the parameters like correctness, completeness, quality.

Index Terms— Road extraction, High resolution satellite image, Morphological Operation, Correctness, Completeness, Quality.

1 Introduction

The extraction of roads from high r esolution satellite images is an important research field. It is also used for the urban mapping, urban planning and updating of geographic information system (GIS) etc [3]. In urban region the map changes due to the expansion of region. In the present paper the auotomatic extraction of roads have been proposed to extract road. The satellite image contain large amount of data to analyze global information and it is difficult to collect data from the traditional methods.

The satellites at present provide images with a very high resolution of less than 1 meter pixel [1]. Geographic information system requires the updated data for its applications. In detection of roads one of the major problems obtained are image resolution and occlusion. The extraction of roads is broadly classified in to two categories such as auotamatic and fully automatic [4]. In semi automatic road detection it requires the human interaction and compared to automatic human is not required for detection.

The proposed methodologies on the road extracton depends on the geometrical properties like road appear as a linear feature in the image. The semi automatic method is not suitable for real time applications and for other applications.The most common automatic methods that many of them work on the road segments through line and edge detections. Then the road segments are reconstructed to form r oad network. And many of these methods assume that road network has a set of straight lines or linear structure only so the accuracy suffers from these assumptions.

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2 Methodology of Proposed Work

The proposed work for the extraction of roads from high resolution satellite image is based up on the connected component analysis and mathematical operations. The mathematical operation include morphological closing, opening, thinning for the road segmentation [4]. And methodology also includes adaptive global thresholding for the removal of non-road segments (figure 1).

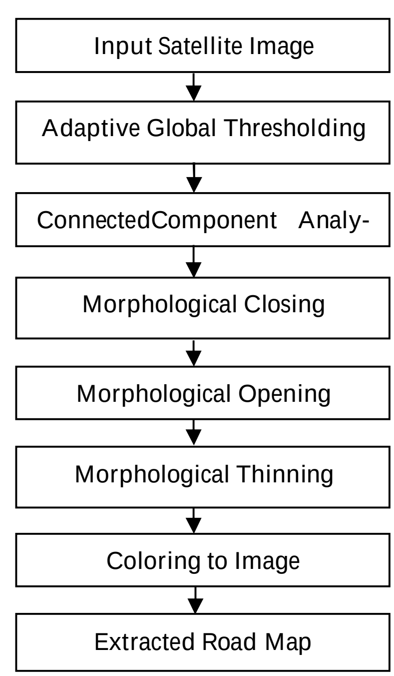


Figure 1: Methodology

2.1 ADAPTIVE GLOBAL THRESHOLDING

The term adaptive thresholding means it takes gray scale image or color image as input and it gives binary image as the output image. At first the input satellite image is converted in to gray scale image. In the gray scale image the road region is segmented from that image using histogram analysis [4].The adaptive global thresholding is applied to remove the non-road region from the satellite image. The histogram image is obtained from the gray scale image form the satellite image. The histogram image is analyzed and divided in to four regions in order to obtain the threshold value.

The histogram image is divided based on the mean value (M) of the pixel intensity value of the image. The region A includes the pixel value of having intensity values lies between the lower intensity values and to the half of the mean value. It identifies the dark vehicles, shadows, ponds etc [9]. In the region B the group of pixel value of having the intensity values between half of the M value to the m value. The region B identifies the dark gray shade objects like trees, grasslands etc. The region C includes the intensity value of pixel in between M value to half of maximum intensities. It identifies the bright gray objects like lane markers, concrete road etc (figure 2). The last region D specifies the intensity of pixel value lies between the half of maximum intensity and maximum intensity. This section identifies the bright objects like bright vehicles, concrete cement roads etc.

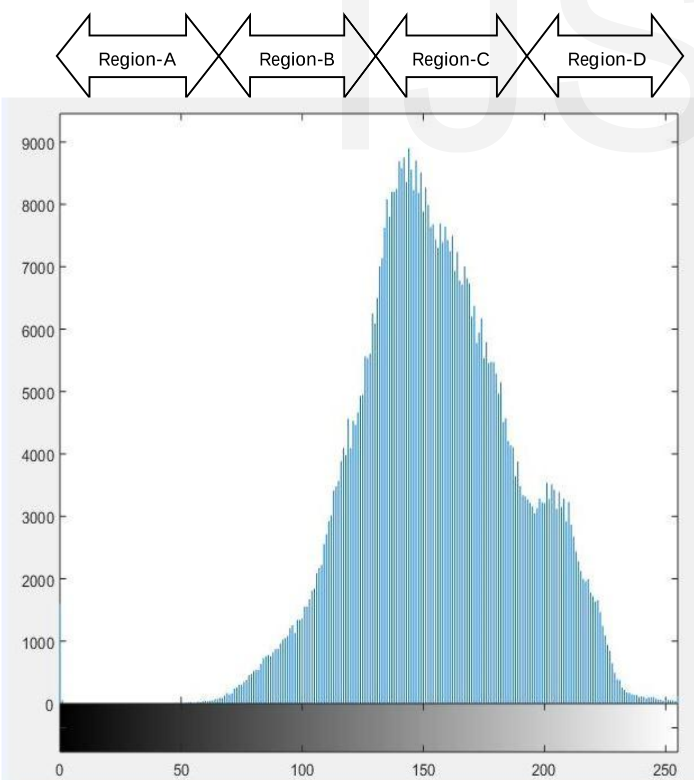


Figure 2: Histogram of test image 1

2.2 CONNECTED COMPONENT ANALYSIS

The connected component analysis states that for any pixel in an image, the set of pixels which are connected to that pixel is known as connected component of an image. In an image if any set of pixels which are not separated by a boundary is known connected pixels.The maximal region of the pixel is called a connected component. In satellite image the connected component is divided in two segments [6].The connected component is mainly used for analysis of many applications like object extraction, line detection, road region etc.The connected components can only be extracted using mathematical morphological operations. By using dilation operation the connected component of an image is extracted [1]. Let us take I be an image, and connected component in an image is denoted as A, and a known point is denoted as p which is assigned to X0. The following equation 1 gives all the elements of A.

$$X_k = \left(X_{k+1} \oplus \mathrm{B}\right) \cap \mathrm{I}, k = 1,2,3,... \quad (1)$$

Where the symbol $\oplus$ represents morphological dilation operation, $\cap$ represents intersection, and B is a suitable structuring element. If $X_k = X_{k+1}$, then the algorithm has converged and let A $= X_k$. Let I be an image, {I (n) | n=1, 2, 3… N} is a sequence of connected components in the image I, and i (i) is a point in I (i). The path opening can be defined with a condition T, as follows in equation 2.

$$\tau_o(i) = \begin{cases} \text{I (i), if I (i) satisfy the condition T} \\ \varnothing\text{, otherwise} \end{cases} \quad (2)$$

Therefore, $\tau_o(i)$ is the path opening associated with the condition T. The connected component from the image is extracted by using path opening based on the condition T. The path opening satisfies with the condition T then the components are stored in it. If the condition T is not satisfied then the components are removed. The size and shape are not disturbed by using path opening [8]. It is only mainly used for only to detect object and its identification. The road width and the region are easily found out by using path opening. The high resolution satellite image is selected because it consists of identical region and long features. The path opening for the road detection is obtained using the following equation (3)

$$R_O = \left\{ \text{P} \mid \text{Long axis of minimum ellipse enclosing P (i)} \geq \text{T} \right\} (3)$$

Where P is an image and P (i) is a connected component of an image. By using the equation (1), all the connected components of a satellite image are extracted. The connected components and road components are segmented by using the equation (3). The resultant image R_o has the connected road component which is greater than T.

3. MORPHOLOGICAL OPERATIONS

Mathematical morphology is specified up on the morphological operations for removing particular region in the image. To extract the image components like boundaries, skeleton or thinning of the road we use morphology technique [1]. The digital satellite images can be performed based on the characterized shape and the resolution of the image. In morphological operations dilation and erosion are the fundamental basic steps for the image processing.

3.1 MORPHOLOGICAL CLOSING

The morphological closing or path closing can be defined as dilation followed by erosion. The dilation means grow or thicken an object in the binary image. It combines two sets using the vector addition of elements of sets. The closing of set A by B is the dilation of A by B, followed by the erosion of the result by B (the same structuring element) in the equation 4.

$$A \bullet B = (A \oplus B)\Theta B \tag{4}$$

The dilation can also be understood as the union of translations of A by element of B. The dilation of a set A by B denoted by $A \oplus B$, is given by equation 5.

$$A \oplus B = \left(x \middle| (B)x \cap A \neq \phi\right) \tag{5}$$

3.2 MORPHOLOGICAL OPENING

The path opening means erosion followed by dilation. The term erosion means it reduces the object present in the image against the background image [1]. The morphological opening of A by B is defined as erosion of A by B, followed by the dilation of the result by B (the same structuring element) is defined as in the equation 6.

$$A \circ B = (A \Theta B) \oplus B \tag{6}$$

The morphological operation in the path opening combines the two sets of vector using vector subtraction of the element [8]. The erosion of A by the structuring element B is denoted by $A\Theta B$, is given by equation 7.

$$A \Theta B = \left(x \middle| (B)x \subseteq A\right) \tag{7}$$

The erosion of A by B is the set of all points x such that B, when translated by x, be contained in A.

3.3 MORPHOLOGICAL THINNING

The morphological thinning operation is performed based on the hit-and-miss transform [6]. The thinning of a set A and the structuring element B can be denoted by the equation 8.

$$\begin{aligned} A \otimes B &= A - (A \circledast B) \\ &= A \cap (A \circledast B)^c \end{aligned} \tag{8}$$

Where $(A \circledast B)$ represent the hit or miss transform of A and B. It is a fundamental tool for shape extraction and also identifies the specified configuration of pixels.

4 PERFORMANCE EVALUATION OF ROAD NETWORK

The performance of extracted road from satellite image is observed by using some parameters like completeness, correctness, and quality. These are the basic parameters to be obtained from the extracted road. In order to calculate these parameters at first the extracted road is compared with manually drawn ground truth image. The matched extracted road data is obtained from the portion which is laying inside the buffer area it is shown in figure 3(a). There is a specific term like true positive (TP) known as matched extracted road data. The unmatched extracted data is known as false positive (FP) is to be calculated. The buffer width is formed in between extracted road data and to the portion of the reference data. The unmatched reference data is known as false negative (FN) and to be calculated and it is shown in the figure 3(b).

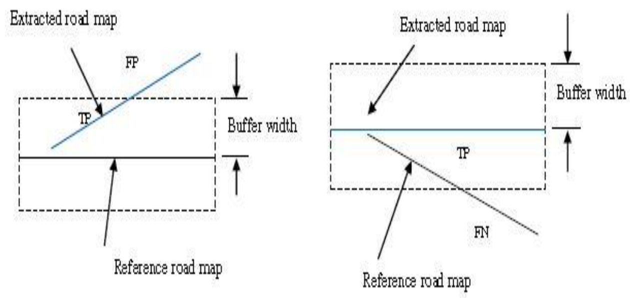


Figure 3: (a.) Matched Extraction, (b.) Matched Reference

4.1 COMPLETENESS

The completeness is the ratio between the matched reference road data with total length of reference road map. The completeness is calculated by using the following equation 9.

Completeness =length of matched reference / length of reference

= TP / TP + FN * 100 (9)

4.2 CORRECTNESS

The correctness represents the percentage of correctly extracted data from the extracted road map. It is the ratio between matched parts of extracted road network with the total length of extracted road network. And it is represented by the equation 10.

Correctness =length of matched extraction/length of extraction

= TP / TP + FP * 100 (10)

4.3 QUALITY

The quality measures both completeness and correctness of the extracted data. The goodness or the quality is measured from the extracted road. The value is calculated by using the equation 11.

Quality = length of matched extraction / length of extracted data + length of unmatched reference

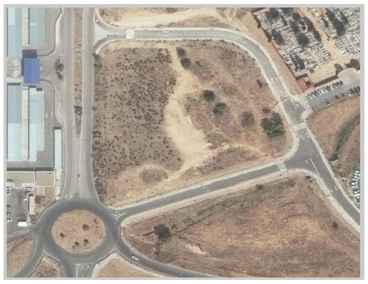
= TP / TP + FP + FN * 100 (11)

5 EXPERIMENTAL RESULTS

The proposed algorithm is applied on the Madrid image located in Spain with a resolution of 0.3m.The test image 1 is taken from the original image with a small area of 802x802 pixels. The results are obtained by using adaptive thresholding and morphology techniques [8].The algorithm is also implemented on the test image 2 which consists of 810x880 pixels. The unwanted segmented region is separated by using morphology operations in the figure 4(g).The modified resultant road image is observed in the figure 4(h). In the test image 2 the extracted road map is shown in the figure 4(h).

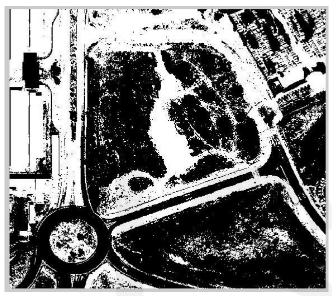
TP – True positive, an element present in ground truth image and extracted road network
FP – False positive, an element present in extracted road network but not in ground truth image.
FN– False negative, an element present in ground truth but not in extracted road network.

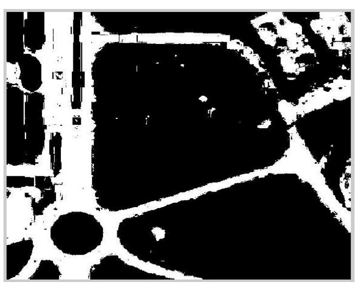
5.1 RESULTS OF TEST IMAGE 1

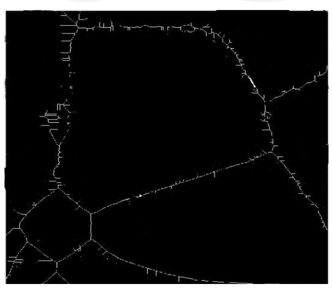

(a.) Input Image

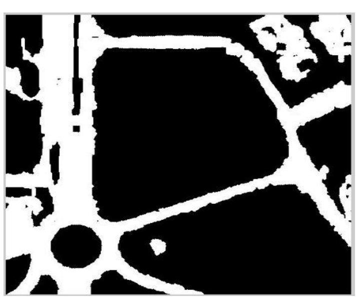

(b.) Gray Scale Image


(c.) Segmented Image


(d.) Path Opening


(e.) Path Closing

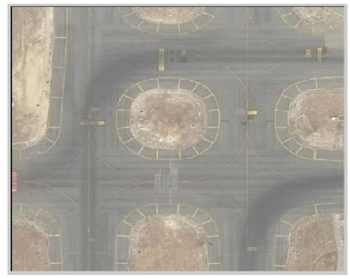

(f.) Thinned Image

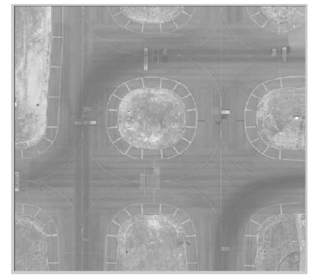

(g.) Threshold Image


(h.) Extracted Road

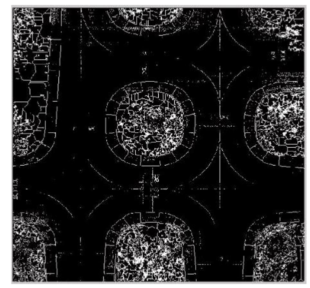
Figure 4: Experiment Results Of Test Image 1 (a.) Input Image, (b.) Gray Scale Image, (c.) Segmented Image, (d.) Path Opening, (e.) Path Closing, (f.) Thinned Image, (g.) Threshold Image, (h.) Extracted Road

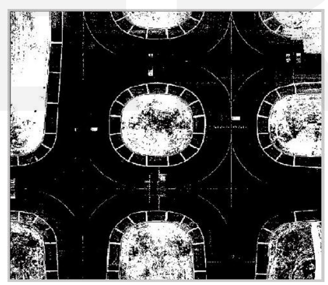
5.2 RESULTS OF TEST IMAGE 2

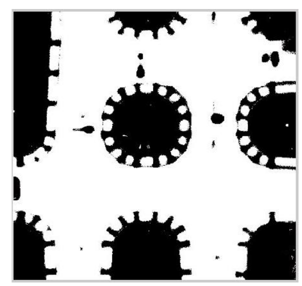

(a.) Input Image

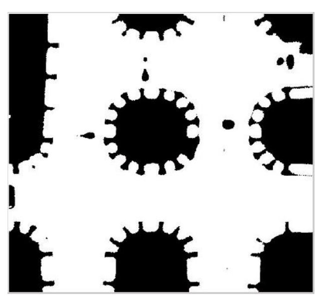

(b.) Gray Scale Image


(c.) Segmented Image


(d.) Path Opening


(e.) Path Closing


(f.) Threshold Image


(g.) Threshold Image

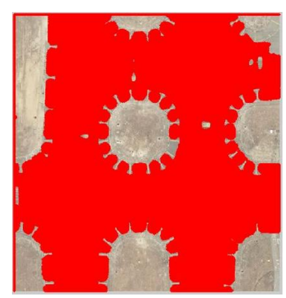

(h.) Extracted Road

Figure 5: Experiments Results Of Test Image 2 (a.) Input Image, (b.) Gray Scale Image, (c.) Segmented Image, (d.) Path Opening, (e.) Path Closing, (f.) Threshold Image, (g.) Threshold Image, (h.) Extracted Road.

The performance of the road network from the extracted road map is calculated based on the confusion matrix values and the percentage values are shown in table 1 below.

IMAG-ES	COMPLETE-NESS %	CORRECT-NESS %	QUALITY %
TEST IMAGE 1	89	90	86
TEST IMAGE2	91	89	88
TEST IMAGE 3	92	90	89
AVER-AGE	90	89.6	87.6

TABLE 1

6 CONCLUSIONS

The extraction of road is obtained from the high resolution satellite image by using adaptive thresholding and morphological techniques. The adaptive thresholding algorithm is implemented to separate the approximated road region from the satellite image. The morphological opening and closing is applied using the structure element which is equal to the width of the road. Finally extracted road region is appeared. So thinning or skeleton is performed for the extracted road region to get centerline of the road. The completeness value of both the test images lies in between 89% and 91%. The correctness value of the images lies in between 89% and 90%, quality value lies in between 86% and 89%. But in experimental results it revel that some of barren land, and parking area are also considered as the road. It is mainly depends on the pixel intensity values and it induces the detection of some unwanted objects. Still there is a requirement or changes on algorithms to resolve the problem of extraction of non-road segments.

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