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Modified Automatic Extraction of Roads from High Resolution Images

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***Abstract*—Automated road extraction is an important area of road database creation, refinement and updation. However, the differentiation of road objects for a satellite image is a critical issue. Road extraction from the satellite imagery is classified as semi-automated and fully automated process. Semi-automated extraction requires some human input whereas; the automated extraction process requires no human input. A multistep approach for automatic road extraction is proposed in this paper. Proposed algorithm is implemented for different high resolution images. Experimental results show that the algorithm extracts the main roads from satellite images with about 91% accuracy. However, it is less accurate to detect secondary roads like lanes and by-lanes.**

***Index Terms*— Road Extraction, Image Segmentation, Seed Point Detection, Image Filtering, Morphological Operations.**

I. INTRODUCTION

Extraction of roads from high resolution imagery is of prime importance in road database creation and updation. Moreover, updation of road databases is crucial for many Geographic Information System (GIS) applications like urban planning and change detection.

For the high resolution imagery, the appearance of a road tends to vary drastically at different time and locations. Therefore, it is difficult to model a road into a single processing module. Since the roads are observed as a layout of high resolution images, it is a challenging task to model the road mathematically [1].

Roads cannot be defined as object having unique shape and/or having unique contrast against background. Therefore, researchers use –i) Semiautomatic and ii) Automatic Road Extraction System to extract road. The semiautomatic approach requires the manual identification of seed points where as automatic approaches do not require any human intervention for road detection.

In this paper, an automatic approach for road detection is proposed. The proposed technique is based on basic features of roads such as observation by the user, the intensity contrast with respect to the background and linear trajectory. Main focus of the proposed method is to extract these features which is based on the selection of seed points. The detection of seed points is automated by making use of linear feature of the roads.

False detection of road like regions is one of the major difficulties of the automatic process. To overcome this limitation a multistep approach is proposed. The proposed approach uses three steps - i)Pre Processing, ii)Automatic Identification of Seed Points and Extraction of Roads, and iii) Post Processing - to enhance the road extraction system, to remove non-road objects.

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The rest of the paper is organized as follows. Section II briefs the related work done, for road extraction from high resolution imagery. Section III, describes the proposed method to extract road from high resolution images. Section IV, discusses the results of implementation followed by Section V which presents the conclusion.

II. Related Work

A road tracker, based on angular texture signature, is proposed by Shen *et al.* [2] based on the knowledge of the roads on high-resolution imagery. However the algorithm may not work on a road cast by a large shadow and occlusion in complex scenes. It can only track long ribbon roads on gray scale imagery, and needs more computing time. Results are shown using a single high-resolution satellite image.

In [3], a road tracker based on shape classification of the road footprints effectively detects road intersections. It extracts almost all inscribed lines of road networks and forms a road tree. However, the multidirectional road tracker suffers from over-extraction. Therefore it is necessary to remove the portions of the road tree that do not appear to be roads. Completeness of 84%–94% and Correctness of 82%–92% were reported for the sample size of six images.

Zhang *et al.* [4] proposed an approach for detecting road networks from high-resolution images using a combination of mathematical morphological operations. The image is segmented to separate the road network regions from their surroundings, followed by a morphological trivial opening operation. This process preserves the elongated road areas and filters almost all the houses and small clusters of noise. The result is further refined by filling holes, removing small paths and recovering shadowed areas. In high-resolution simulation images and aerial photos, the approximate road centerline network is extracted. However, road gaps may still exist.

A model and a strategy based on the multiscale detection of roads in combination with geometry-constrained edge extraction using snakes are presented in [5]. Results are shown for three sample images, and the approach is intended for rural areas.

Sahar and Alireza [6] proposed a road tracing approach using extended Kalman filter and a special particle filter module. It is based on uses of clustering algorithms, which are able to pass severe obstacles on the road and trace all road branches at a junction. All road segments in a connected road network are traced using a single seed point. However, the performance of the algorithm depends on the parameters of the module. Amo *et al.* [7] proposed a combined approach consisting of region growing and region competition to extract road centerlines and sides. The initial seeds are given manually, and hence, this is a semiautomatic process. Subsequently region-growing-based model is applied to obtain a rough road approximation. This model is refined by the region competition algorithm.

Hu *et al.* [8] presented a two-step approach detecting and pruning, for the automatic extraction of road networks from aerial images. Results are shown for four images of high resolution. A rich body of literature exists in automated road extraction [9].

Statistical inference methods model linear features as a Markov point process or a geometric-stochastic model on the road width, direction, intensity and background intensity, and use maximum a posteriori probability to estimate the road network [10] - [12].

Doucette *et al.* proposed a methodology for fully automated road extraction that exploits spectral content from high resolution multispectral images [13].

III. Proposed Method

The proposed algorithm uses an automatic approach for road detection from satellite images. Automated road extraction can save time and human efforts as compared to semi-automatic approach. Misclassification of road-like structures is a major difficulty in automated road extraction. Hence a multistep approach is adopted to extract roads from input images. Fig. 1 shows the flowchart of the proposed algorithm. The details of steps are shown below.

A. Pre-Processing

This step consists of morphological operations like opening and closing. The purpose of this step is to improve quality of image to facilitate image interpretation and to improve the contrast and background. Directional morphological operations: erosion, dilation, opening and closing are used to enhance the image quality. Four directions – horizontal, vertical, left and right diagonals are used for morphological operations [1].

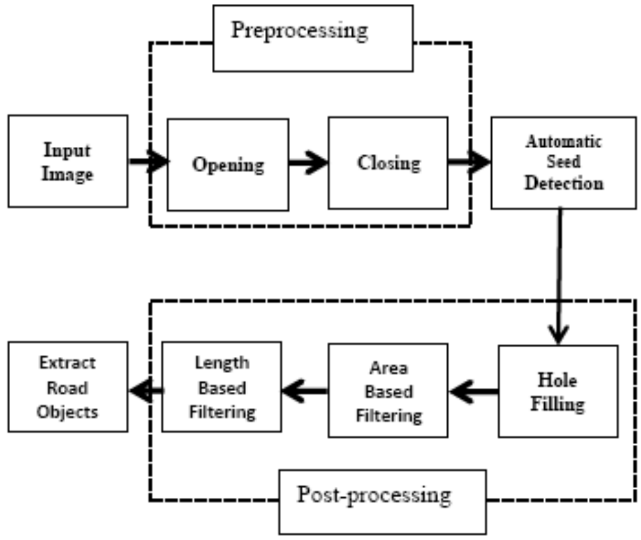


Figure 1: Flowchart of Proposed Algorithm

Since road has a direction, directional morphological filters are used for the image smoothing and noise removal. This technique makes use road template for opening and closing operations. Therefore, the image enhances in the direction of road template (structuring element).

B. Automatic Seed Detection:

Since a road has a long and elongated feature with almost uniform width and similar radiometric variance along its path. Since, humans usually recognize a road using its geometric characteristics. Such vital clues can be used to identify a foreground road object from background non-road objects.
The significant characteristics of roads are –

a) Roads are mostly elongated elements
b) Generally, the road surface is homogeneous.

These characteristics are used for extraction of roads from an image. The proposed method attempts to extract the salient features from images. The proposed algorithm automatically determines two seed points from the road objects present in the image. The algorithm for extracting two seed points is described as follows.
After pre-processing, the input image is thinned [15], and then the region having longest length is identified. From the collection of pixels available on longest path, select the one having maximum intensity in the input image. This point is the seed point1. The second seed point is based on intensity of first seed point[14].
Once the seed points are detected, they are used for segmentation to extract road object of the image. The segmentation technique depends on the homogeneity of the two road templates in different directions. The segmentation is carried out using Chaudhari's distance (d_{ch}), to compare the image section with the road templates by making use of different eight directions [1].

$$d_{ch} = |X_{i0} - Y_{i0}| + \frac{1}{n - flr\left(\left(\frac{n-2}{2}\right)\right)} \,.\, \sum |X_i - Y_i|; \quad \text{for } i \neq i_0 \text{ and } 1 \leq i \leq n. \qquad (1)$$

The segmentation algorithm operates with 8 directions as shown in Fig. 2. It uses a window of size, 5 X 5. Along a given direction five pixels a_1, a_2, a_3, a_4, a_5 from image, and five each for the two road templates x_1, x_2, x_3, x_4, x_5 and y_1, y_2, y_3, y_4, y_5 are extracted. The pixels are aligned in the given direction. The distance between the image and the two templates is calculated using (1) for all eight directions and the minimum of these is used for segmentation. The segmentation threshold (S_{th}) is calculated as the average value of the intensity of the longest region in the thinned image. Then the roads objects are detected based on this threshold value using the segmentation algorithm of [1].

C. Post-Processing

Post-Processing involves Hole filling, Area and Length based filtering. It is a refinement process. A few undesired or noisy structures are sometimes erroneously identified as road segments in the given image.

Thus, the output of step 2 has two issues – i) discontinuity - presence of holes/gaps and ii) False detection – non-road regions identified as roads.
To address the first issue, a pixel with label 0 (non-road object) is selected and marked it as visited. The procedure simultaneously looks for other pixels in its 5 X 5 neighborhoods. Follow the same process for whole image. Then the area of each non-target region is computed. If the area of non-target region is greater than S_{th}, then the region is labelled as background else the region is labelled as road object and the region is converted into road region.

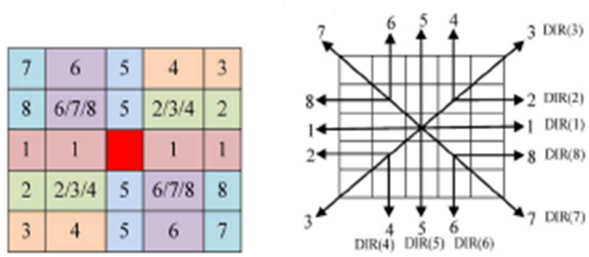


Figure 2: Template directions for segmentation [1]

The second issue is due to false detection. Small non-road objects are distributed all over the image. Non-road objects are removed by using a filtering technique based on the area. Similarly, linear regions with length less than S_{th} , are eliminated from further processing. A thinned image is used for the elimination of linear objects.

IV. Experimental Results And Discussion

The images selected for experimentation are of scenes from satellite images of 1-m/pixel resolution and are of 512 X 512 pixels.
The road segments of the test figure are manually digitized to from the reference road network. Road network covers all roads present in the image. This is used as a reference to estimate the accuracy measure for road extraction system.
The accuracy of the proposed system is shown in Table I, for Seed Point 1 and Seed Pont 2 is selected as below.

$$\text{Seed Point 2} = \text{Seed Point 1} \times x; \text{ for } 50 \leq X \leq 100 \qquad (2)$$

It is found that, the proposed system gives better accuracy when x = 80 % in (2).
Table II compares the accuracy of results for Seed Point 2 = 80% of Seed Point 1, with semi-automatic approach of manual selection of seed points.
Fig. 3, shows the graphical comparison of accuracy of proposed system with that of semi-automatic approach observations.
The results of the proposed method are as shown in Fig. 4. The input image is shown in Fig.4 (a), Fig. 4(b) gives the output after segmentation and Fig. 4(c) presents the result after post-processing. The results of Semi-Automatic Approach are as shown in Fig. 5 for the same images.
From Fig.4, it is observed that the proposed system extracts main roads whereas for the secondary roads (lanes, by-lanes, and links) the system sometimes fails. This is because, the secondary roads are more difficult than main roads to deal with because of low discrimination of gray levels with respect to background and greater effect of occlusions and noise on narrow roads. The primary concern is the false detection of non-road objects such as parking lots, roof tops.
From Fig. 3, Fig. 4 and Fig. 5, it is observed that the results, of proposed algorithm, Fig. 3, are comparable with the results of semi-automatic approach, Fig. 5.
The proposed algorithm fails to detect narrow roads, and large road structures with heterogeneous gray values against background. It also fails to detect complex road structures.

TABLE I. ACCURACY OF PROPOSED SYSTEM FOR DIFFERENT SEED2 POINTS

Sr. No.	Image	Seed2 = x % 0f Seed1				
		x = 50%	x = 60%	x = 70%	x = 80%	x = 90%
1	Image1	99	99	99	99	99
2	Image2	100	100	100	100	100
3	Image3	94	100	100	97	98
4	Image4	100	100	100	91	89
5	Image5	100	95	99	99	97
6	Image6	98	98	78	94	52
7	Image7	100	100	100	99	100
8	Image8	100	100	99	100	88

TABLE II. COMPARISON OF ACCURACY OF ROPOSED SYSTEM WITH SEMI-AUTOMATIC APPROACH

Sr. No.	Image	Semi-Automatic	Automatic (Seed2 = 80% of Seed1)
1	Image1	98	99
2	Image2	100	100
3	Image3	83	97
4	Image4	88	91
5	Image5	98	99
6	Image6	99	94
7	Image7	99	99
8	Image8	100	100

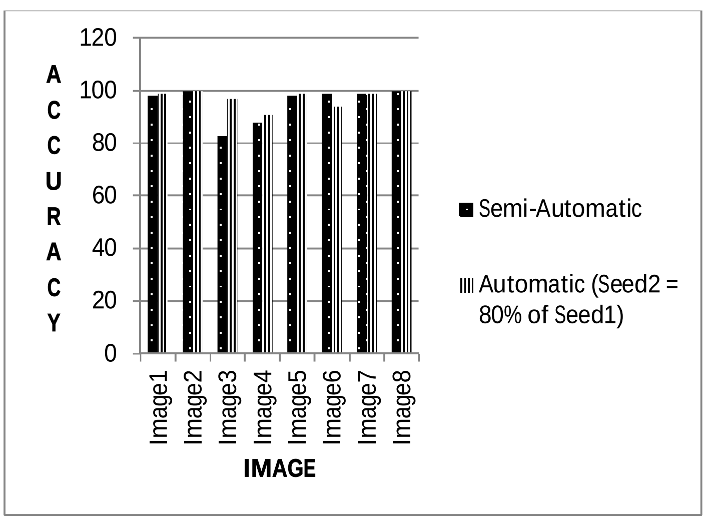
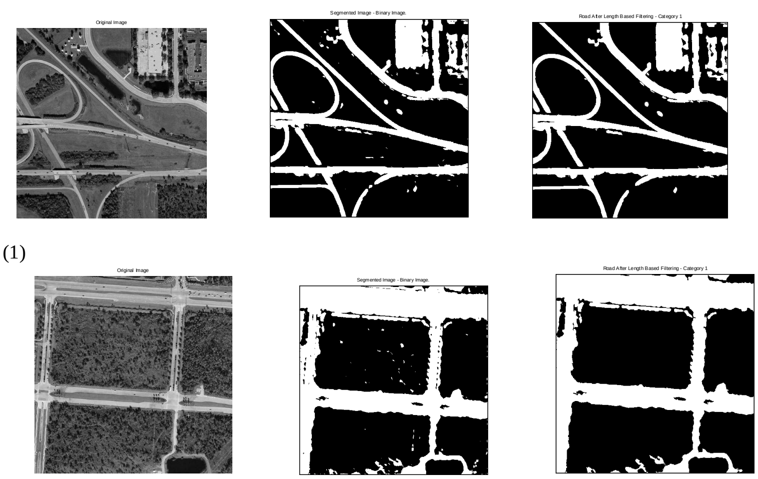


Figure 3: Comparison of Proposed System with Semi-Automatic Approach

V. CONCLUSIONS

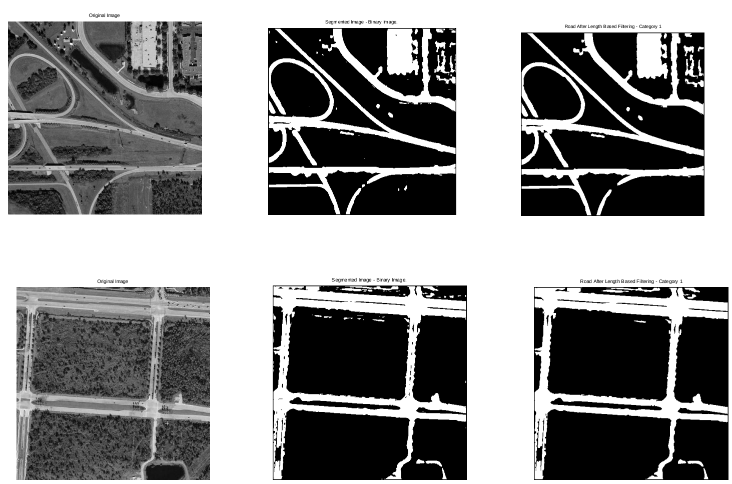
An automatic approach to extract roads from high resolution imagery has been proposed. The proposed method makes use of spectral and spatial properties of roads. It is a multistep algorithm consisting of preprocessing for image enhancement, image segmentation for Road Extraction from input image and Post-Processing consists of hole filling, area and length based filtering. The novelty of this algorithm lies in a way the seed points and threshold value are detected for automatic extraction of roads from input images. The results prove that the proposed system is able to extract major sections of road network, junctions and curved roads from high resolution images. It is also observed that the performance of proposed algorithm is comparable with that of semi-automatic approach.

The proposed road detection system fails to avoid false detection due to presence of parking lots, roof tops. The presence of buildings and other occlusions made the extraction process somewhat more difficult.



(1) (2) (a) (b) (c)

Figure 4: Results of Proposed Method. (a) Input Image of Size (512 X 512), (b) Image after Segmentation, (c) Image after Post-Processing



(1) (2) (a) (b) (c)

Figure 5: Results of Semiautomatic Method. (a) Input Image of Size (512 X 512), (b) Image after Segmentation, (c) Image after Post-Processing

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