# Automatic road extraction from satellite image by Difference of Gaussian and convolution overlap add method

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**ABSTRACT-**The road network detection is an emerging area in information extraction from high-resolution satellite images (HRSI). The proposed work in this paper consists of three steps: Pre-filtering, connected component-based operations, and removal of unwanted non-road pixels using morphological operations. The proposed algorithm is experimented on various satellite images and the performance of the system is evaluated by comparing the results with ground truth road map as reference data, and performance measures such as completeness, correctness, and quality are calculated.
Keywords – **Gaussian Filtering, Gradient operation, Convolution, Smoothening, Edge Detection, Morphological operations.**

## 1. INTRODUCTION

Automatic road detection is particularly employed in the city planning, cartography and to revise already detected roads in Geographic Information Systems environment. Manual manipulation of GIS database is costly, time-consuming process, and also there is a possibility of error. Therefore, automatic road feature extraction from high resolution satellite image is required to detect the road network in a robust manner. The process of road detection from remote sensing images is quite complex, due to the presence of various noises. These noises could be the vehicles, crossing lines and toll bridges. Few small and large false road segments interrupt the extraction of road segments that happens due to the similar spectral behavior in heterogeneous objects.Images obtained from satellite are useful in much environment application such as tracking of earth resources, geographical mapping, and production of agricultural crops, urban growth, weather, flood and fire control.

The objective of road feature extraction method is providing a binary mask in which true pixels represent road regions, and false pixels indicate non-road regions. The major problem of road extraction method is the complex structure and texture of the images, which contain many different objects, such as roads, houses, trees, vehicles etc., with differences in shape, tone.

Road extraction methods can be classified into two types such as semi-automatic and fully automatic. The road detection methods which requires human interaction are known as semi-automatic, and those that are not requires human interaction are known as automatic and semi-automatic are not suitable for real-time application.

## 2. RELATED WORK

Sujatha et al. [1] has proposed an automatic road extraction system which uses connection component-based techniques for the high resolution satellite images. The algorithm is implemented on different satellite images and the results are evaluated for correctness, completeness and quality with true road maps as reference.

**Jiuxiang[2]** as proposed an automatic road detection algorithm which will include three stages such as identify the road pixels, track the road and road segments are grown. A road tree is constructed in order to identify the network of the roads.

**Xiaoying et al. [3]** used the combination of two detectors: segmentation based and fuzzy based detectors in order to extract the centerlines. The outputs of these two detectors are then combined to extract the road network. He used path searching algorithms to integrate the outputs.

**Cem et al.** has also proposed a method based on the probability and graph theory. In this method, first the edge pixels are extracted and using them the road centerline is obtained. At the last stage, the graph theory is implemented which will represent the extracted road regions in the form of graph. This system completely depends on the edge detection of the image [4].One more road extraction algorithm proposed by **Zhujian et al. [5]** which are based on the two methods. This system cross-validates the features of the Line Segment Detector (LSD) and Statistical Region Merge (SRM) based on their spatial relationship.

**Xiangguo** in his proposal classified the road into salient and non-salient markings and then used various tracking systems to detect roads. The salient road markings are extracted using the least squares interlaces matching; match the profiles, rectangular

matching and texture signatures. All these are combined to extract the road network with non-salient markings [6].
**Senthilnath et al. [7]** proposed an automatic road detection system which can be used in urban areas. This system is based on the road characteristics like structure, geometric and spectral. The main process of this system is to reduce the non-road unwanted regions and used texture progressing analysis and cut methods to extract the road segments. The result is compared with the true road map in order to evaluate the performance measures.
Support vector machine (SVM) based road centerline extraction is proposed by Xin et al. [8]. In this algorithm, both the geometric and spectral characteristics are used. The hybrid combinations of the spectral and geometric data are analyses using the SVM analyzer. Hang et al. [9] has also proposed a hybrid method for road extraction for both urban and rural regions. Gabor filtering is used along with the threshold based histogram to mark the surface and lane segments on the rural images. SVM analyzer is used in order to extract the road surface in the urban area. For further enhancement Gabor filtering is used. The experimental results were impressive.
**Sukhendu et al. [10]** has presented an automatic method for road extraction which is based on pre-dominant features of the road. Probabilistic SVM analyzers and Dominant Singular Measures are used for the segmentation of the road areas. Numerous post processing are done in order to remove the non-road regions from the image. This actually helped to solve the problems with the discontinuity.
**Tieling et al. [11]** proposed a road detection system which used the wavelet transform from the high resolution satellite images. In this work there are two parts. In the first part, the road edges are determined using the two dimensional wavelet transform. In the next part, thinning algorithms are performed which will detect the thin centerline in the road networks.
**Sahar et al.** has proposed an algorithm on satellite images which uses both particle filtering and extended Kalman filtering[12]. These two filtering mechanisms are applied in order to trace the roads which lies beyond the obstacles and also to track the different branches of road once the junction is found. To evaluate the results, the output is compared with the manually drawn road maps.
**Thierry et al. [13]** has proposed an integrated approach for road segmentation. This method consists of three stages. In the first stage, the non-road regions in the image are removed by using the watershed transform filters. Then the closing operation is done to extract the structure of the road network, . In the next stage, the graph is built which shows the relationship between the watershed lines. Finally, Markov random field is defined on that graph which will extract the road networks in the satellite images. Mena et al. [14] proposed an automatic road detection method for the rural and semi-urban regions. In this method, there are four modules such as pre-processing module, binary segmentation based on texture progressive analysis, vectorization of the binary image by means of skeletal extraction and morphological operations, and performance measures evaluation by comparing with the true maps.
**Boshir et al. [15]** has implemented an automatic road extraction method which uses road intersection model. The process of detecting the road intersection is done in two modules. Initially, road network is detected using various morphological filters and then the road intersection are extracted to check on the orientation of the roads. This algorithm is implemented on different images to evaluate the correctness of the method.
**Jun Zhou in his paper [16]** has proposed a system which updates the roads in the map be comparing the aerial images with the map to detect the new roads. Their method could not be fully automated as these algorithms are not reliable. Human interactions are needed for the final check of the maps.

## 3. METHODOLOGY OF PROPOSED WORK

The detailed methodology of proposed work is given in Figure 1. This includes pre-processing, pre-filtering, gradient operation, morphological operation and coloring.

### Pre –Processing

Initially we convert the given satellite image SI into a Gray scale image $\mathbf{SI_G}$. The gray scale image many consists of small objects. So we remove the small objects by applying the morphological operation on gray scale image such as erosion and dilation. Morphological operation are mainly used for extracting image components used for future extraction such as boundaries, skeleton and convex hull.

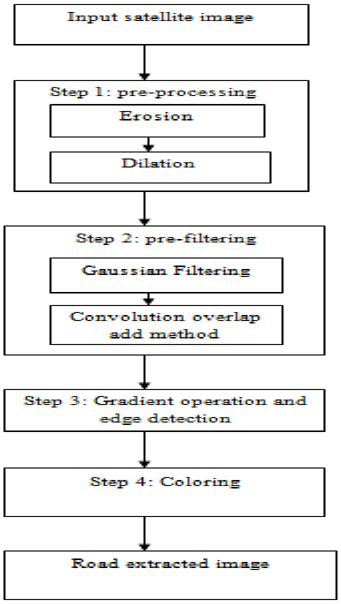


Figure 1: Methodology of proposed work

Dilation and erosion are the fundamental tools of morphological image processing. Dilation operation grows or thickens the objects in gray scale image. Let **SI** $_G$ be an image, and B is the structuring element, then the dilation is represented as follows

$$SI_G \oplus B = \{Z \mid (\hat{B})_z \cap y \neq \emptyset\} \quad \text{.....(1)}$$

Morphological erosion shrinks or thins objects in a binary image. The extent of this shrinking is controlled by structuring element. The erosion of dilated image **SI**$_D$ by B is denoted as follows.

$$SI_D \ominus B = \{Z \mid (B)_z \subseteq Y\} \quad \text{........................(2)}$$

**Pre –filtering**

The pre-filtering process is used for removing certain types of noise from the satellite image. For pre-filtering the following algorithms is used.

Here we propose a pre-filtering process based on the **Difference of Gaussian** (DoG) as in equation 3.Then we merge the images using convolution overlap add method. For the erode image **SI**$_E$ we apply **DoG** as follows.

$$\Gamma_{\sigma 1 \sigma 2}(x,y) = SI_E * \frac{1}{2\pi\sigma_1^2} e^{-(x^2+y^2)/(2\sigma_1^2)} - \frac{1}{2\pi\sigma_2^2} e^{-(x^2+y^2)/(2\sigma_2^2)} \quad \text{..............................(3)}$$

```
Convolution(img1,img2)
  {
    n1←length of img1
    n2←length of img2
   compute n←n1+n2-1
   y← array of zeroes(1,n)
   h1←(dog zeros(1,n2-1)
   n3←lemgth of h1
   y←array of zeros(1,n+n3-n2)
   h←Fourier Transform(h1)
    for i=1 to n2
       if i<=(n1+n2-1)
         compute x1 =appendzero
         array of size (1,n3-n2)to img1 of size(1,n3-n2)
     else
          compute x1=append zero
         array of size (1,n3-n2)to img1 (n1)
     end
     x2=fft(x1);
     x=x2*img2;
     x4=round(ifft(x3));
       if(i==1)
         normalize y(1:n3)=x4(1:n3)
      else
        normalize y(i:i+n3-1)=y(i:i+n3-1)+x4(1:n3)
     end
   end
 }
```

In image processing, **DoG** is an advance enhancement algorithm that involves the subtraction of one blurred version of an original image from another. In the simple case of grayscale images, the blurred images are obtained by convolving the original grayscale images with Gaussian kernels having differing standard deviations. Blurring an image using a Gaussian kernel suppresses only high-frequency spatial information. Subtracting one image from the other preserves spatial information that lies between the ranges of frequencies that are preserved in the two blurred images. Thus, the **DoG** is a band-pass filter that discards all random high frequency noise that is present in the original grayscale image.

After performing **DoG** we apply convolution by using **Convolution overlap add method.** It is a process of merging two images that is gray scale image **SI**$_G$ and image obtained after **DoG** according the algorithm as shown below.

**Gradient Smoothening**

i. For the convoluted image, perform the Image Smoothening using the gradient minimization method.
ii. For the smoothened image, use Canny edge detection technique. This will sharpen the road boundaries.
iii. Perform the morphological filling on the edge detected image in order to remove any noises within the road regions.
iv. Use area based noise removal which will remove the non-road region noises.
v. Apply morphological dilation on the binary image to thicken the road objects.

**Coloring**

Once the binary image is dilated, the road region pixels are acquired. These are the pixels which will fall under the road regions. In the original image, the respective pixel values are changed to any color, so that the output image will have the road regions in different color.

## 4. PERFORMANCE EVALUATION OF ROAD EXTRACTION.

The performance of the proposed road extraction of observed by calculating the performance measures such as completeness, correctness and quality.

The matched extracted road data are calculated as true positive(TP).and unmatched extracted data is calculated as false positive(FP).The unmatched reference data are calculated as false negative(FN).

**Completeness**

It is the ratio of matched reference road data with total length of reference road map as shown in equation 4

Completeness %= �� / (��+��) * 100 …….. **(4)**

**Correctness**

It gives the percentage of correctly extracted road i.e. ratio of matched parts of extracted road with total length of extracted road as shown in equation 5

Correctness %= �� / (��+��) * 100 ………… **(5)**

### 4.5 Quality

It considered both completeness and correctness of the extracted data as shown in the equation 6

Quality%= �� / (��+��+��) *100 ………… **(6)**

## 5. EXPERIMENTAL RESULTS

The experimental results of the proposed system on the satellite images are given in the below figures. The resultant images from various steps in the proposal are shown. The gray scale image (Figure 2b) of the input file (Figure 2a) is pre-processed to get the eroded image. The erode image is the input to the Gaussian Filter which will be convoluted to remove the high frequency noises (Figure 2c).The morphological operations are performed on the Gaussian Convoluted image in order to get the road extracted binary image (Figure 2d). Using the road region pixel information from the binary image, the respective pixels are colored to get the output image road extracted (Figure 2e)


Figure 2a: Input Image


Figure 2b: Gray Scale Image


Figure 2d: Binary Road Extracted Image


Figure 2c: Gaussian Convoluted Image


Figure 2e: Road Extracted Image

Completeness, Correctness and Quality are the three performance measures used to evaluate the output. These performance measures are calculated by comparing the output image with the ground truth road as reference data. The average values for completeness, correctness and quality for the proposed system are approximately92%, 93% and 92% respectively. The output is compared with 2 other existing systems for the road extraction as shown in the Figure 3.

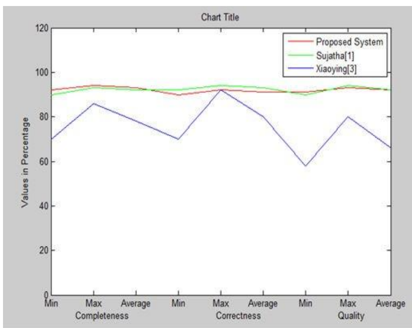


Figure 3: Comparison Plot for performance measures

## 6. CONCLUSION

The proposed system includes the following steps such as pre-filtering, gradient smoothening and coloring. Gaussian filtering is applied on the image in order to remove the high frequency noises. Canny edge detection algorithm is used in order to fine tune the road region edges. Morphological filling is applied on the convoluted image to obtain the road extracted binary image. The pixel values for the road region are extracted from the binary image and respective pixels are colored in the original input image. The performance measures are calculated and are compared with the existing systems to evaluate the effectiveness of the new proposed system. The values are encouraging.

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