**Semi- Automated road detection using Morphological Segmentation and Connected Component Analysis**

**CONTENTS**

* Abstract
* Proposed System
* System Requirements
* Modules
* Module Description
* System Architecture
* Literature Survey
* References

**ABSTRACT**

Extraction of map objects such roads, rivers and buildings from high resolution satellite imagery is an important task in many civilian and military applications. It is a process which uses high resolution satellite images to extract road like features accurately to give effective and reliable information to the geographic information systems. In this paper we have explored different algorithms with better efficiency and accuracy. We have categorised them as semi-automatic and automatic. Road extraction can take place for two kinds of roads namely: urban and non-urban roads. Urban roads are more complex to analyze because of their architectural complexity, occlusions created by trees, heavy traffic and extensive network, whereas non-urban roads are easier to analyze because of less structural complexity. We present a semi-automatic approach for road detection that achieves high accuracy and efficiency. This method exploits the properties of road segments to develop customized operators to accurately derive the road segments. The customized operators include directional morphological enhancement , directional segmentation and thinning. We have systematically evaluated the algorithm on a variety of images and carefully compared it with the techniques presented in literature. The results demonstrate that the algorithm proposed is both accurate and efficient. The data and performance measures such as completeness, correctness and accuracy are calculated together with other parameters which are : PSNR, NCC and SC. The proposed model is compared with other algorithms and a statistical analysis of the comparison is presented.

**Proposed System**

We present a method to extract roads from high resolution images using a multi-step approach. The proposed algorithm uses a semi-automatic approach for road detection with focus on accuracy and efficiency. The main steps in our algorithm are: road enhancement, road segmentation, hole filling, small region filtering, length based region filtering, small branch removal method and road segment linking. This algorithm uses semi-automatic approach to give the desired results which have high accuracy and efficiency.

**MODULES**

* Preprocessing
* Road enhancement
* Adaptive thresholding
* Connected Component analysis
* Morphological closing
* Morphological opening
* Thinning
* Hole filling
* Small region filtering
* Length based region filtering
* small branch removal method
* Road segment linking
* Performance measures

**PREPROCESSING**

* In this module noise removal process in done.
* Removing noise process is done by Gaussian filter.
* A one-dimensional kernel is used to blur the image in only the horizontal or vertical direction. In the second pass, the same one-dimensional kernel is used to blur in the remaining direction. The resulting effect is the same as convolving with a two-dimensional kernel in a single pass, but requires fewer calculations.
* In this technique we try to improve the visual effect in the image to make geographic interpretation easier. It also helps to improve contrast between the desired image of the road that is our target and background of the image. A good enhancement function helps to reduce the brightness of dark road structures and has no effect on the non-target parts. The technique which is used here is directional morphological operations, which include erosion, dilation, opening and closing.

**ROAD ENHANCEMENT**

The goal of the enhancement step is to improve the visual effect in the image to facilitate geographic image interpretation and to improve the contrast between the target and the background for high level processing. A good enhancement operator will significantly reduce (or increase) the brightness of dark (or bright) road structures in the original image but has no effect on non-target pixels. We propose an enhancement technique based directional morphological operations: erosion, dilation, opening and closing.

**ADAPTIVE THRESHOLDING**

* Satellite image is converted into gray image, and road region is segmented from that image using histogram analysis. Adaptive global thresholding is applied to remove the non-road pixels and segment-approximated road region from the satellite image.
* The histogram of the satellite image is analyzed and divided into four main sections to obtain the desired threshold value for segmentation.
* The histograms are divided based on mean value (*M*) of all the pixel intensity values in an image. First section identifies dark objects of an image such as dark vehicles, shadows, lake, muddy ponds, etc. Second section groups the pixels having intensities from half of the *M* value to *M* value, and this section identifies dark gray shade objects like trees, grasslands, etc. Third section includes the pixels from *M* value to half of maximum intensities, and these pixels belong to bright gray objects such as roads, lane markers, etc. The last section groups the pixels that lie between half of maximum intensity and maximum intensity, and this section can identify bright objects like concrete cement road, bright vehicles, etc.
* The pixels that lie in that region are assigned to value 1 and all the remaining pixels are made to 0. Now, gray image is converted into binary image in which road regions appeared in white and all other pixels appeared in black.

**Connected Component Analysis**

* For any pixel in an image, the set of pixels that is connected to that pixel is called connected component of an image. Any set of pixels which is not separated by a boundary is called connected pixels. Each maximal region of connected pixels is called a connected component. The connected components partition an image into segments. The analysis of connected components is mainly used for many automated image processing applications such as object extraction, road map extraction, line detection, etc. Connected components can be extracted using morphological operations.
* Connected components of an image can be extracted by combining dilation and the mathematical intersection operation. Connected component labelling works by scanning an image, pixel-by-pixel (from top to bottom and left to right) in order to identify connected pixel regions, *i.e.* regions of adjacent pixels which share the same set of intensity values *V*.
* The connected components labeling operator scans the image by moving along a row until it comes to a point p (where p denotes the pixel to be labeled at any stage in the scanning process) for which V={1}. When this is true, it examines the four neighbors of p which have already been encountered in the scan (i.e. the neighbours (i) to the left of p, (ii) above it, and (iii and iv) the two upper diagonal terms). Based on this information, the labelling of p occurs as follows:

If all four neighbours are 0, assign a new label to p, else

if only one neighbour has V={1}, assign its label to p, else

if more than one of the neighbours have V={1}, assign one of the labels to p and make a note of the equivalences.

* After completing the scan, the equivalent label pairs are sorted into equivalence classes and a unique label is assigned to each class. As a final step, a second scan is made through the image, during which each label is replaced by the label assigned to its equivalence classes. For display, the labels might be different grey levels or colours.

**Morphological Closing**

* Closing is an important operator from the field of [mathematical morphology](https://homepages.inf.ed.ac.uk/rbf/HIPR2/matmorph.htm). Like its dual operator [opening](https://homepages.inf.ed.ac.uk/rbf/HIPR2/open.htm), it can be derived from the fundamental operations of [erosion](https://homepages.inf.ed.ac.uk/rbf/HIPR2/erode.htm) and [dilation](https://homepages.inf.ed.ac.uk/rbf/HIPR2/dilate.htm). Like those operators it is normally applied to [binary images](https://homepages.inf.ed.ac.uk/rbf/HIPR2/binimage.htm), although there are [graylevel](https://homepages.inf.ed.ac.uk/rbf/HIPR2/gryimage.htm) versions. Closing is similar in some ways to dilation in that it tends to enlarge the boundaries of foreground (bright) regions in an image (and shrink background color holes in such regions), but it is less destructive of the original boundary shape. As with other [morphological operators](https://homepages.inf.ed.ac.uk/rbf/HIPR2/morops.htm), the exact operation is determined by a [structuring element](https://homepages.inf.ed.ac.uk/rbf/HIPR2/strctel.htm). The effect of the operator is to preserve *background* regions that have a similar shape to this structuring element, or that can completely contain the structuring element, while eliminating all other regions of background pixels.
* Closing is opening performed in reverse. It is defined simply as dilation followed by erosion using the same structuring element for both operations. The closing operator therefore requires two inputs: an image to be closed and a structuring element. Graylevel closing consists straightforwardly of a graylevel dilation followed by graylevel erosion.

Closing is the dual of opening, i.e. closing the foreground pixels with a particular structuring element, is equivalent to closing the background with the same element.

* One of the uses of dilation is to fill in small background color holes in images, e.g. `pepper noise'. One of the problems with doing this, however, is that the dilation will also distort all regions of pixels indiscriminately. By performing erosion on the image after the dilation, i.e. a closing, we reduce some of this effect. The effect of closing can be quite easily visualized.

**Morphological opening**

* The basic effect of an opening is somewhat like erosion in that it tends to remove some of the foreground (bright) pixels from the edges of regions of foreground pixels. However it is less destructive than erosion in general. As with other morphological operators, the exact operation is determined by a structuring element. The effect of the operator is to preserve foreground regions that have a similar shape to this structuring element, or that can completely contain the structuring element, while eliminating all other regions of foreground pixels.
* Very simply, an opening is defined as erosion followed by a dilation using the same structuring element for both operations. See the sections on erosion and dilation for details of the individual steps. The opening operator therefore requires two inputs: an image to be opened, and a structuring element. Graylevel opening consists simply of a graylevel erosion followed by a graylevel dilation. Opening is the dual of closing, i.e. opening the foreground pixels with a particular structuring element is equivalent to closing the background pixels with the same element.

**HOLE FILLING**

* Some regions identified after segmentation have holes due to noise. To overcome this problem of closing the non-road regions (crossing circles) in roundabouts, we propose a simple and efficient algorithm. The segmented image is a binary image with road pixels labeled as 1’s and non-road pixels as 0’s. For small hole filling, we first invert the segmented image. We search all regions in non-road image and compute the areas by a recursive scanning method proposed in . We then delete the small regions and invert this image. Some regions identified in previous steps have holes present due to noise. To deal with this a simple algorithm is used. The output of segmentation is an image which is binary in nature and has road pixels as 1’s and non-road pixels as 0’s. For small holes we invert the image and search all regions to compute area by recursive scanning method.

**SMALL REGION FILTERING**

* Small regions that do not belong to any road are distributed all over the image. These regions are not of interest when the focus is on road extraction. Therefore, they are removed by a simple filtering technique on the basis of their area, i.e. regions whose area is less than a threshold are eliminated from further processing.
* Small regions which are not the part of the road are present in the output image. These areas are removed effectively by using simple filtering techniques which are based on their area. The region having area less than a threshold value is eliminated.

**Length based Region Filtering**

* We then remove two kinds of unwanted linear segments to improve the linear representation of the roads in the image.
* In this technique linear structures having lengths less than minimum threshold are eliminated and also the long linear structures which are isolated are removed from further processing.

*Category 1: Regions corresponding to linear structures*

whose length (counted as number of pixels) is less than the minimum threshold L^T are first eliminated.

*Category 2: The goal here is to eliminate long linear structures* that are isolated. After minor branch removal, we determine the end pixels of the thinned version of the regions.

**Branch Removal**

* Many small non-road linear structures are associated with the main road skeleton. These are characterized by being connected to the main road at one end and free at the other. The lengths of these structures are significantly smaller in comparison with the length of the main road. These minor processes manifest as small branches in the thinned image. To accurately determine the main road, these small unwanted branches must be removed.

**SEGMENT LINKING**

* Two segments to be merged are identified, we locate the pixels that need to be mapped to road pixels. Since road structures are regions (not lines) the linked portion will also be a region.
* In this step the discontinuities are identified so that we can connect them on the basis of their orientation and distances. Once the segments that we have to merge are identified, pixels are located which will be mapped on road pixels.

**SYSTEM ARCHITECHTURE**

**Input Satellite Image**

**Adaptive Global Thresholding**

**Connected Component analysis**

**Morphological Closing**

**Morphological opening**

**Morphological thinning**

**Performance measures**

**Performance Evaluation Parameters**

The performance evaluation of the target image with the output image is done using the peak signal to noise ratio, Normalised cross co-relation, structural content, completeness, correctness and accuracy.

**1.** **PEAK SIGNAL TO NOISE RATIO**

Peak signal to noise ratio often known as PSNR is used to measure the peak error. It calculates ratio between maximum power of signal that is possible and power of the noise that corrupts the given image. A higher value of PSNR shows that the image formed is of higher quality. But, like edge detection in some cases PSNR should be lesser to get appropriate results. It is calculated as: PSNR = 10\* log10 (R2 /MSE) R is the maximum possible variation in the input image. R is 255 if it has a data type which is 8 bit unsigned integer.

**2. Normalised cross correlation**

cross-correlation is a measure of similarity of two series as a function of the displacement of one relative to the other. This is also known as a sliding dot product or sliding inner-product

**3. Structural Content**

Structural content calculates image quality degradation caused by processing such as data compression or by losses in data transmission. It is a full reference metric that requires two images from the same image capture— a reference image and a processed image. The value of SC should be low.

**4. Completeness**

Completeness is defined as the ratio of total number of true positive pixels with that of summation of all the true positive pixels and false negative pixels.

true positive(TP):indicates the pixels which are correctly detected by the algorithm

false negative(FN): indicates the pixels which should be detected as road pixels but are not detected as such. Another term used in place of completeness is the sensitivity of the image.

**5. Correctness**

Correctness can be defined as the ratio of no of true positive pixels to that of the sum of the true positive pixels and false positive pixels.

false positive(FP): indicates the pixels which are not actually part of the road but are detected as road. Another term used in place of correctness is specificity.

**6.Accuracy**

Accuracy of the image is defined by the ratio of sum of true positive and true negative pixels to that of sum of true positive , true negative, false positive and false negative pixels.

true negatives (TN): are described as those pixels which are a part of road but are not detected as road pixels.

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