SEGMENT EXTRACTION FOR PATH IDENTIFICATION FROM SATELLITE IMAGES BY VARIOUS ALGORITHMS

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***Abstract* -** Road Extraction from High resolution satellite images plays an important role because road networks are essential information due to their wide usage in various applications such as urban planning, cartography, industrial development, traffic management and map updating. Although huge number of works dealing with this issue the results remain very limited and there exists the lack of information caused due to the presence of artifacts such as shadows or buildings, trees on the roadsides and cars. This project introduces a new technique to solve the problem of road extraction from high-resolution remote sensing images by pre-processing the data using wavelets to obtain the denoised segments and then detecting the edges based on modified watersheds thereby reconstructing the road network. This technique produces the proper extract of the road with higher efficiency and lesser time consumption.

Keywords – Multiscale analysis, Morphology, Remote Sensing, Road Extraction, Watershed Segmentation, Wavelet Transform.

I. INTRODUCTION

Satellite image processing is very important to extract useful information from satellite images. Many applications related to object detection from satellite images has become an essential component due to developing space imagery technologies. Hence Image segmentation is one of the most popular image processing tasks that are performed on satellite images. The objective of the segmentation process is to divide the image into certain regions with different characteristics. Detection of road networks from the satellite or aerial images is one of the kind and also a popular research subject. Roads belong to the infrastructure of modernization in daily living as a key component of the transportation systems. They are significant in both the military field and common daily living. Due to the development of the remote sensing technology, road extraction has become important in digital photogrammetry. Road extraction can provide references for city planning, map updating, land resource management, database as well as guidance during emergencies and other disaster rescue operations. Road extraction algorithms can be broadly classified as local or global approaches where the information is extracted from the current pixel and its immediate neighborhood inorder to identify the pixel belonging to the road network. Local methods are very useful, especially when the precision aspect is less important than the execution time aspect. On contrary, while considering only the local information and the non-integration of global information about the objects to which these pixels belong produce misclassified pixels, due to the noise resulting from the very high resolution of satellite images. Global approaches use the interpretation of pixel combinations in images for road extraction. The linearity and the parallelism of edges are a valuable source of information in the road extraction process. The use of global information in the road extraction process has remarkably improved results compared to local approaches. However, the choice of appropriate parameters for applying these techniques remains a challenging problem and this leads to an under or over segmentation of the image. Local and global approaches cover most of the current researches in this field. These methods consider roads as invariant objects regardless of the observation scale. In practice, however, in the pattern recognition field, it is important to identify the most appropriate scale for extraction and thereby avoiding an over- or under segmentation of the desired objects. Various road extraction algorithms have been proposed over the past decades, including edge and line detection. But the methods proposed so far does not produce exact information due to the shadows along the roadside. In this paper, a different road extraction technique has been proposed where, in the first stage preprocessing is done which uses modified watershed to efficiently detect the edges and avoids over segmentation and in the second stage final road is extracted based on multiscale image analysis using wavelet transform. Here wavelet transform is employed since it characterizes the edges of roads in high-resolution remotely sensed images.

II. RELATED WORK

The methods proposed to solve the problem of road extraction vary in terms of inputs based on multispectral images, radar images, ground truth and a digital terrain model. Also in terms of image resolution (medium resolution, high-resolution or HR, and very high resolution or VHR), and features selected for the road identification process such as edges, radiometry, texture, geometry etc.,

Based on this several authors have attempted to classify road extraction methods In [10], mathematical morphology is used to refine results obtained by applying fuzzy logic membership rules. Anil and Natarajn [1] used a topological derivative and mathematical morphology for road extraction from remotely sensed images. Another interesting technique for road extraction is to identify segments [3], edges [8], [5], and ridges [6] that belong to the roadsides. In [5] Jinxin *et al.* proposed an automatic extraction of road networks based on edge extraction and the k-means clustering algorithm. In some works, the texture is also used for the identification of structures belonging to roads. Mena and Malpica [9] benefit from the mathematical framework provided the evidence theory to fuse results from several texture measurements. In [15] Texture and spectral information are fused to provide a robust method for road extraction by Xin *et al.* In [2], Inglada *et al.* proposed a novel method for road extraction from VHR images, based on radiometric information provided by the spectral angle. In [4], multikernel SVM (M-SVM) for multi-index learning, a morphological building index, a morphological shadow index, and variation indices is employed based on the wavelet transform to separate the road class from other classes. Kirthika and Mookambiga [6] proposed a neural network classifier to combine texture measurements and spectral parameters in the road extraction process. An object-based image classification approach is proposed by Shackelford *et al.* [13]. Several authors have proposed an chain base processing on image segmentation, followed by region classification to identify the road surface. A new region growing-based method for road network extraction from synthetic aperture radar (SAR) images is proposed in [7].In that approach, a weighted ratio line detector(WRLD) is used to extract road features; ratio and direction information are then merged to obtain road seeds; and finally, a region-growing algorithm is adopted to construct the road network.

This paper introduces a new technique to solve the problem of road extraction from high-resolution remote sensing images by using wavelets and to detect the edges based on modified watersheds.

III.PROPOSED WORK

With the evolution of google map and GPS navigation systems, road network extraction from satellite images has become a vital research area. The availability of commercial HR satellite imaging sensors provides a new data source for road extraction. The focus of the proposed work is to develop a road extraction method which accurately extracts proper features from complex satellite images despite noise and other occlusions.

A. PRE-PROCESSING

The goal of preprocessing is to improve the quality of the image. Most of the time, a filtering step is used to reduce noise and small disturbances. Initial processing on the raw data is usually carried out for correcting any distortion due to the characteristics of the imaging system and its conditions. Based on the user's requirement, some standard correction procedures may be carried out by the ground station operators before the data is delivered to the end-user. These procedures include radiometric correction to correct uneven sensor response over the whole image and geometric correction to correct geometric distortion due to Earth's rotation and other imaging conditions (such as oblique viewing). The image may also be transformed to tune it to a specific map projection system. Furthermore, if accurate geographical location of a specific area on the image needs to be known, ground control points (GCP's) are used to register the image to a precise map (geo-referencing).

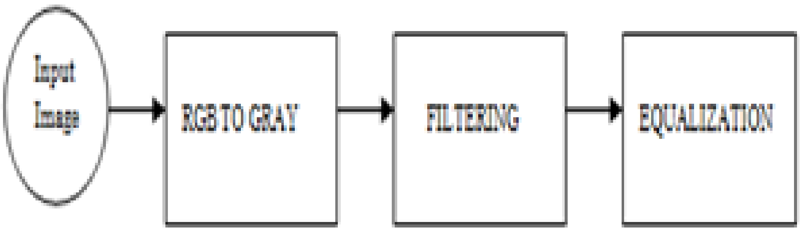

Fig. 1: Pre-processing

"Preprocessing is a preparatory phase to improve image quality as a basis for further analysis"

B. MULTISCALE ANALYSIS USING WAVELET TRANSFORM

In view of the fact that satellite images are finite energy(i.e. square integral) functions a wavelet transform exists. Wavelet transform is useful in road detection because roads have clear edges in high-resolution remote sensing images. Wavelet transform combines the spatial and the frequency domain analysis and wavelet-based edges analysis is naturally multiscale and multiresolution. It has been show that in multiscale and multiresolution analysis noise has a much weaker correlation between scales than the wavelet coefficients of the edges , so wavelet transform is useful in edge detection.

The basic method of the wavelet transform is selecting a function whose integral is zero in time-domain as the basic wavelet. By the expansion and translation of the basic wavelet, we can get a family function which constitute a framework for the function space. We decompose the signal by projecting the analysis signals on the framework. The signal in original time domain can get a time-scale expression by several scaling in the wavelet transform domain. Then we are able to achieve the most effective signal processing purpose transform domain. Time frequency analysis plays a major role in image processing. Because of its good time-frequency localization characteristics the Wavelet Transform (WT) has gained widespread acceptance in signal and image processing.

Wavelet filters are especially suitable for applications where scalability and tolerable degradation are important. Wavelet transform decomposes a signal into a set of basic functions. These basis functions called wavelets. Wavelets are obtained from a single prototype wavelet called mother wavelet by dilations and shifting.

Images are signals having high frequency components for short durations and low frequency components for long duration and therefore wavelet analysis plays a leading role in the pre-processing stage of images. Since satellite images are finite energy functions a wavelet transform exists. The intensity of the features to be segmented in an urban area is not a constant value, because roads, buildings, vehicles and shadows can cause rapid changes to the image intensity. Because of the above mentioned features, wavelet filters are used in the proposed work and it is illustrated as follows

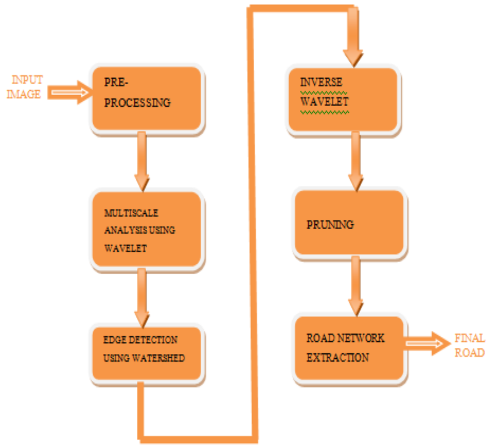

Fig. 2: Work Flow

C. DISCRETE WAVELET TRANSFORM

Discrete wavelet transform (DWT), transforms a discrete time signal to a discrete wavelet representation. The wavelet function is given by two functions that is, a scaling function Φ(t) and wavelet function Ψ(t),representing a low pass filter h(n) and high pass filter g(n) respectively.

$$A,L[n] = \sum_{k=0}^{K-1} A-1,L[2n-k]H[k] \qquad (1)$$

$$A,H[n] = \sum_{k=0}^{K-1} A-1,H[2n-k]G[k] \qquad (2)$$

If L and H represents low pass and high pass responses, row wise and column wise convolution of the original image *A* is done by the previous equations.

Haar and Daubechies wavelets

A Haar wavelet is the simplest type of wavelet. In discrete form, Haar wavelets are related to a mathematical operation called the Haar transform. The Haar transform serves as a prototype for all other wavelet transforms. Like all wavelet transforms, the Haar transform decomposes a discrete signal into two sub-signals of half its length. One sub-signal is a running average or trend; the other sub-signal is a running difference or fluctuation

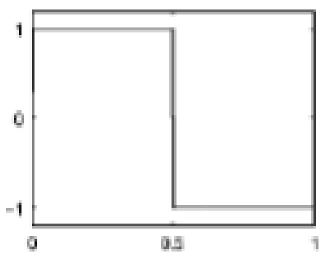

Fig. 3: Haar wavelet

Haar is a special case of daubechies .db1 is same as the above Haar wavelet.Ingrid Daubechies, is one of the brightest stars in the world of wavelet research, what are called compactly supported orthonormal wavelets thus making discrete wavelet analysis practicable.The names of the Daubechies family wavelets are written dbN, where N is the order, and db is the “surname” of the wavelet.The db1 wavelet is the same as Haar wavelet , as mentioned above.The wavelet functions of the next nine members of the daubechies family is shown below:

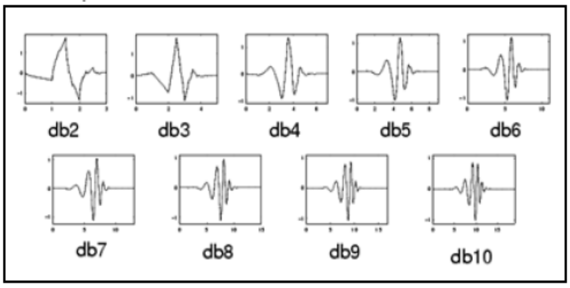

Fig.4: Daubechies Wavelet family

D. MORPHOLOGICAL OPERATORS

Morphology is a tool for extracting image components that are useful in the representation and description of region shape, like boundaries, skeletons, and the convex hull. Morphological operations preserve the basic properties of object while removing unwanted features.

Hence Mathematical morphology (MM) is a technique for the analysis and processing of geometrical structures, based on set theory, topology, lattice theory and random functions. MM is most commonly applied to digital images, it can be employed as well on graphs, surface meshes, solids, and many other spatial structures. The basic morphological operators are dilation, erosion, opening and closing. After segmenting the image, several classes are obtained which represent urban and non urban objects. The road network objects are selected, and subjected to a repetitive and equal number of morphological operators.

E. DILATION

The dilation operations are fundamental to the morphological image processing. Dilation is an operation that grows or thickens objects in a binary image. The objective of this operator is to enlarge the foreground and to shrink the background. The specific manner and extent of thickening is controlled by a shape referred to as a structuring element. Mathematically, dilation is defined in terms of set operations. The dilation of A by B, denoted as A⊕B

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

Here Φ is the empty set, A represents the set A, B is the structuring element, A⊕B represents the Dilation of set A by B .

F. THE WATERSHED SEGMENTATION

Watershed algorithm is based on morphological process although it can be mixed up with edge based segmentation to yield a hybrid technique. In geography, watersheds are the ridge line that divides different areas called catchment basins drained by different river systems. In mathematical morphology, a gradient image may be considered as a topological surface where the numerical value of each pixel indicates the evaluation of their points. The set of pixels along which the gray levels changes sharply gives rise to an edge.Therfore ,a gray scale image can be interpreted as the topographic image of landscape. This is accomplished (the image intensity) as an altitude.

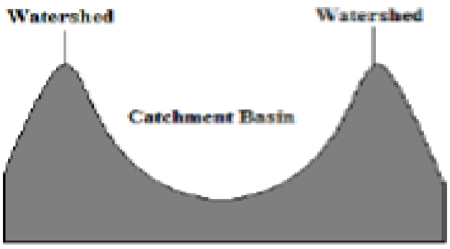

Fig. 5: Watershed segmentation-local minima of gray level yield catchment basins, local maxima define the watershed lines.

Using the features of these images, the technique of digital image processing called Watershed Transform. It consists in placing a water source in each regional minimum called catchment basins to flood the relief from sources, and build barriers while different sources are meeting. The resulting set of barriers constitute a watershed by flooding manner, i.e., the set of pixels along which the gray levels changes sharply gives rise to a watershed edge as shown in fig.5.The watershed algorithm applies the above ideas to solve a variety of image segmentation problems.

a. Watershed segmentation using distance transform

For digital image segmentation, the distance transform method is commonly used in conjunction with the watershed The distance transforms of a binary image is the distance from every pixel of the object component which is black to the nearest white pixel. In binary images there are only two gray levels 0 and 1 where 0 stands for black and 1 stands for white. Only one catchment basin will appear in the binary image's topographic surface only when two black blobs are connected together. In this paper, the distance transform along with sobel edge detector have been used to preprocess the image to make it suitable for watershed segmentation. In below, a binary image matrix, and its corresponding distance transform is shown below

1	1	0	0	0
1	1	0	0	0
0	0	0	0	0
0	1	1	1	0

(a)

0.00	0.00	1.00	2.00	3.00
0.00	0.00	1.00	2.00	3.00
1.00	1.00	1.41	2.00	2.24
1.41	1.00	1.00	1.00	1.41
1.00	0.00	0.00	0.00	1.00

(b)

Fig. 6: (a) shows a binary image matrix, and (b) shows the corresponding distance transform

G. PRUNING

The Pruning algorithm is a technique used in digital image processing based on mathematical morphology(MM).It is used as a complement to the skeleton and thinning algorithms to remove unwanted parasitic components. In this case parasitic components refer to branches of a line which are not key to the overall shape of the line and should be removed. These components can often be created by edge detection algorithms or digitization. The standard pruning algorithm will remove the branches that are short than the given number of points. The algorithm starts at the end points and removes a given number (n) of points from each branch. After this step it will apply dilation on the new end points with a (2N+1)(2N+1) structuring element of 1's and will intersect the result with the original image. Application of pruning to simplify a shape which extracts the skeleton is shown below

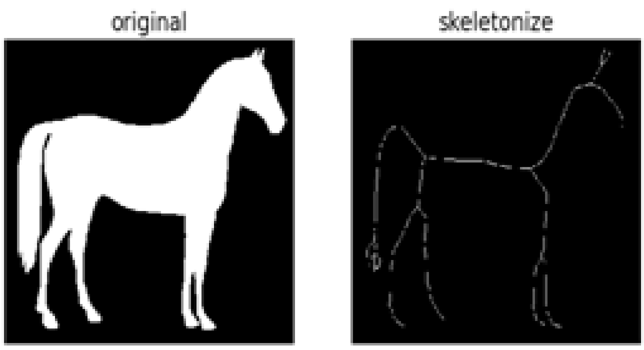

Fig. 7: Application of pruning

IV. EXPERIMENTAL RESULTS

In order to assess the performance of this approach for extracting the road ,the experiment is conducted using MATLAB with few different data sets which has High resolution satellite images. Furthermore, the evaluation criteria such as sensitivity, specificity, accuracy and it processing time is also illustrated from the obtained results.

In this experiment, pre-processing is applied to each band of the input image (a) converting rgb to grey (b) and which removes noise and outputs a smoothed image as shown below

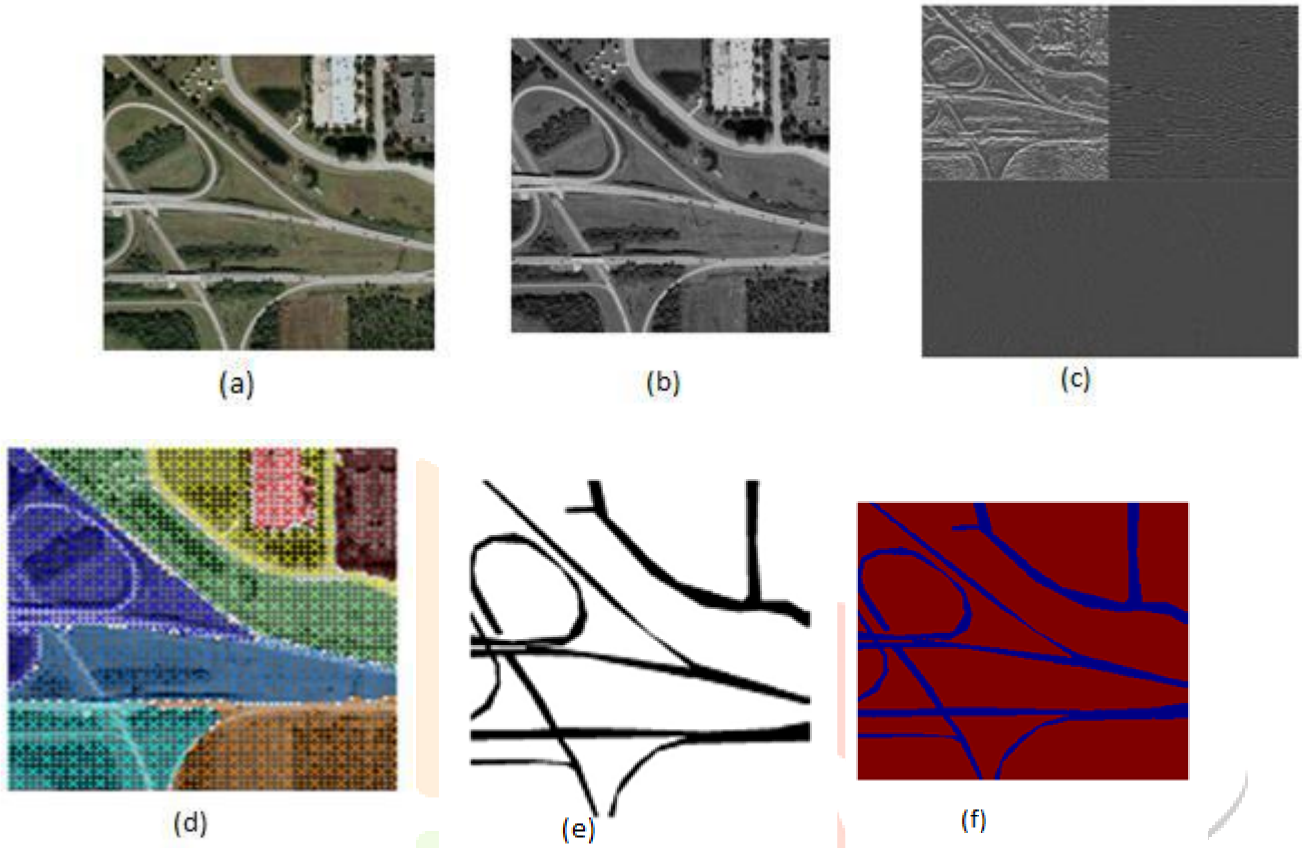

Fig.8 : (a)input image (b)grey scale image (c)Multiscale analysis (d) watershed segmentation (e) Pruning (f) final road map

By multi-resolution analysis , image objects as the smallest processing entities are achieved(c), After that watershed segmentation is applied to avoid oversegmentation (d) , Then pruning is applied to get the skeleton of the image (f) and final road is obtained which is the result of proposed method. The evaluation results verify the efficiency of the proposed work as shown below:

Table 1: Evaluation results

Evaluation criteria	Obtained results	
	Previous method using beamlet	Proposed method
Sensitivity	95.1021	98.0017
Specificity	89.0242	95.5986
Accuracy	92.0516	95.1999
Processing time	0.8172	0.3030

V. CONCLUSION

This paper is devoted to the use of Wavelet transform for feature extraction associated with image pixels and the application of watershed segmentation. Since watershed algorithm was applied to an image then it will have over clusters in segmentation. To solve this first wavelet transform is applied after preprocessing to get the denoised segmented image, then watershed algorithm was applied to detect the edges and then applying the inverse of wavelet transform to reconstruct the segmented image with high resolution. A specific attention is paid to the use of Haar transform as a tool for image decompositon and image pixels feature extraction. Wavelets provide a mathematical way of encoding information in such a way that it is layered according to level of detail. Moreover, the proposed algorithm filters the noise more effectively thereby avoids over-segmentation than traditional watershed segmentation using distance transform algorithm.Hence this method produces the results with higher efficiency (98%) and lesser time consumption(0.30300secs)

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