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A Survey on Road Extraction from Satellite Images

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Abstract - Road extraction is the process of extracting roads from high resolution imagery and the process of extraction gives more accurate and reliable information for geographic information systems. Mainly the high resolution images are of two types: Multispectral image and Panchromatic image. Multispectral images are the one that captures image data at specific frequencies or wavelength interval. Each individual image usually has the same physical area but have different spectral band and the wavelengths are separated using filters. While panchromatic image is a single band image generally displayed as shades of gray and sensitive to all visible colors. For efficient identification, high spatial and spectral information in a single image are needed. Hence fusion of multispectral and panchromatic images is needed to convey more information. This paper presents a survey of various road extraction techniques which are used to extract roads from high resolution images.

Keywords – *Road Extraction, Multispectral Image, Panchromatic Image, Fusion.*

1. Introduction

Roads are one of the important man-made objects which have greater significance in transportation. The road network database must be up to date with the current situation and is important to update the database for road maps. The conventional methods for road extraction are very expensive and time consuming. Remote sensing technology is highly effective in providing accurate information for the extraction and updating of roads. High resolution images are obtained from remote sensing methods and the methods of processing are also important to produce accurate results. Remote sensing technologies mainly uses the method of segmentation for extraction of different objects such as roads, buildings etc from the high resolution satellite images. The high resolution satellite images are processed by multi-resolution segmentation, which deals with high resolution imagery. The segmentation uses classification process which segments the remotely sensed data to different groups based on their characteristics, and the groups called classes. Classification uses decision rules for dividing the data into different classes. Clustering is also a segmentation technique which groups the data with similar characteristics, which are called clusters. Morphological operations are important for refining the results obtained from segmentation to obtain better road extraction results. Morphological operations contracts or dilates the pixel values to obtain an image which is better than the segmented image. The proposed works on road extraction are based on different segmentation techniques and the result of segmentation can be further processed using morphological operations. Road extraction process can be done in the following steps: the pixels in the images are segmented into different groups. The segmented roads are further refined using road class refinement and roads can be efficiently identified using the method of road line extraction. The road lines can be easily identified and can determine the accuracy of extracted road network. Finally, the road network is formed from the extracted lines.

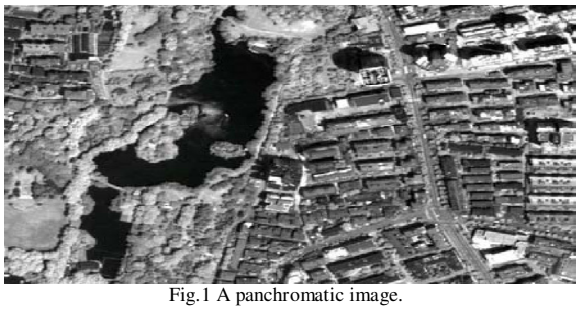
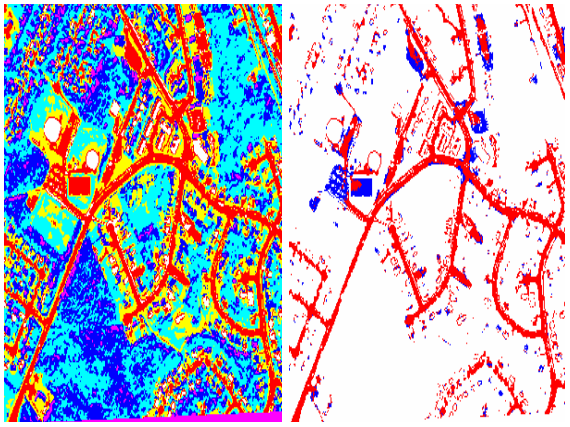


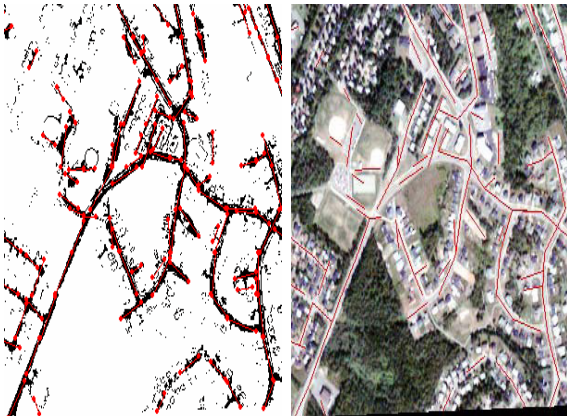
Fig.1 A panchromatic image.

Fig.2 A multispectral image.

(a)Original image.



(b)Segmented image. (c)Refinement of classes.



(d)Centre line extraction. (e)Road network formation.

Fig.3 A Method for Road Extraction.

The quality of extracted centre line examines the efficiency and accuracy of classification. The road centre lines must be accurately located based on the extracted road pixels. The lines having similar features as that of centre lines are grouped into the class of centre lines.

2. Literature Survey

For classifying the remote sensing data appropriate classification methods are needed. Appropriate methods can only classify high resolution remote sensing data accurately and efficiently. Traditional classification methods for remote sensing data are mainly of two types: object-oriented classification method and pixel-based classification method.

Table.1 Comparison of classification methods

Method	Color/ Spectral	Form/ Shape	Area/ Size	Texture	Context
Pixel-based	Yes	No	No	No	No
Object-oriented	Yes	Yes	Yes	Yes	Yes

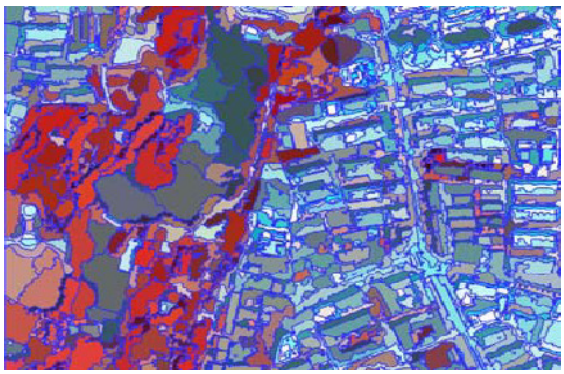


Fig.4 Image segmentation.

2.1 Object-oriented Classification Method

Object-oriented approach provides an efficient method for the classification of remote sensing data. Object-oriented approach uses processing units as image objects instead of using single pixels. The complete image is segmented into meaningful pixel groups, called segments. Here knowledge-based classification rules, which include spectral, spatial, contextual and textual information, are used for classification. Object-oriented classification approach consists of multi-resolution segmentation and knowledge based classification. Segmentation uses the region-growing technique, which merges the adjacent pair of image objects to form bigger segments based on their similarities until a user-defined threshold is reached. Then classification process assigns objects to certain classes based on class description. The advantages of object-oriented method is that the image is considered as image objects. This improves the classification efficiency for high resolution data. But it is

difficult to take a single pixel which is necessary to interpret an image.

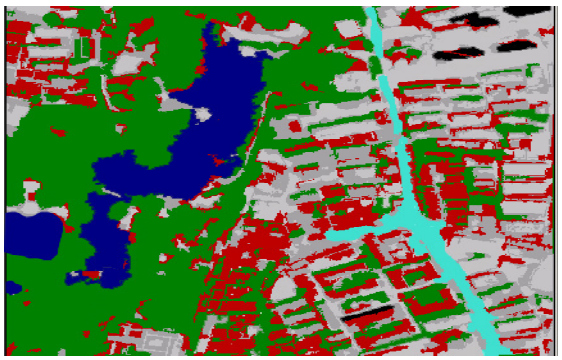


Fig.5 Result of object-oriented classification.

Mourad Bouziani et.al. [1] describes an object-oriented classification approach for a high-resolution remote sensing data. Initially, a per-pixel maximum-likelihood classification method is used to classify individual pixels. Next a multi-spectral segmentation uses classification algorithms to classify image objects. Region-growing algorithm starts from seed points and group the adjacent pixels based on homogeneity criterion. Then the segmentation results are used in a rule-based classification for identifying needed pixels. The object-oriented classification method produces a better result than the pixel-based classification. But for some class of values the maximum-likelihood classifier produces error causing results and also the selection of seed points are sometimes difficult. The distance between adjacent pixels is defined as,

$$D_{sk}(i,j) = |V_{i,k} - V_{j,k}| \quad (1)$$

where D_{sk} is the distance between adjacent pixels, $V_{i,k}$ is the value of the pixel i in band k and $V_{j,k}$ is the value of the pixel j in band k. The number of pixels which are wrongly segmented with respect to the total number of pixels in the image is the error of segmentation and is defined as,

$$E_T = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} NP_{i,j} - \sum_{k=1}^{N} NP_{k,k}}{\sum_{i=1}^{N}\sum_{j=1}^{N} NP_{i,j}} \quad (2)$$

where N is the number of segments, $NP_{i,j}$ is the number of pixels in j segment that is assigned to i segment, and $NP_{k,k}$ is the number of pixels assigned to good segments.

M.Kumar et.al. [2] proposes an integrated approach for extracting the road network from high resolution satellite imagery. The fusion of panchromatic and multispectral images is used for multi-resolution segmentation. Then classification process is done based on a fuzzy rule base. Finally, morphological operations are used to refine the obtained result. The method is effective in producing accurate roads from high resolution imagery. But in this method, the obstacles on road and shadows of large buildings make the road extraction process difficult.

Neha Gupta et.al. [3] proposes an object-oriented classification approach using the eCognition software, which extracts information as a hierarchy of image objects. Multi-resolution segmentation approach uses a bottom-up region-merging technique for classifying the image as a group of image objects. Nearest neighbour classification approach is used to classify the image objects to different classes. The result of classification can be defined as,

$$d = \sqrt{\sum_f \left[\frac{V_f^{(s)} - V_f^{(o)}}{\sigma_f}\right]^2} \quad (3)$$

where s and o are sample object and image object respectively. $V_f^{(s)}$ is the feature value of sample object, $V_f^{(o)}$ is the feature value of image object and σ_f is the standard deviation of feature values. High classification accuracy is obtained for high resolution image but the accuracy depends on the classification method used.

Sun Xiaoxia et.al. [4] proposes an object-oriented method based on eCognition. The high resolution image is initially segmented into different groups. Then the segments are classified on the basis of nearest neighbourhood classifier. The object-oriented classification improves the classification accuracy, but the shadows and vegetation are classified as water.

Xinliang Li et.al. [5] proposes a combination of object-oriented method with the nearest-neighbour technique. Firstly, the image is segmented into object features, and then the object features are compared with the result of nearest neighbour classification method. The decision rule for nearest neighbourhood classifier is defined as,

$$\lambda = \|x - M_j\|^2 - \|x - M_i\|^2 \quad (4)$$

where M_i and M_j are two centres, and x is the classified object. If λ>0, then x belongs to i and else x belongs to j. The classification efficiency is improved when the object-oriented classification methods are used. But the efficiency of proposed method is less because single-scale segmentation is used instead of multi-resolution segmentation.

2.2 Pixel-based Classification Method

Pixel-based classification is the method which does classification based on a single pixel and is limited for high resolution data. The maximum-likelihood classification method is mainly used to classify the images. Pixel-based classification is a traditional

method, which uses supervised or unsupervised classification. This identifies each pixel values and the features related to each pixel value. Pixel-based classification operates on single pixels which are necessary to interpret an image but it produces unexpected classification results for high resolution imagery.

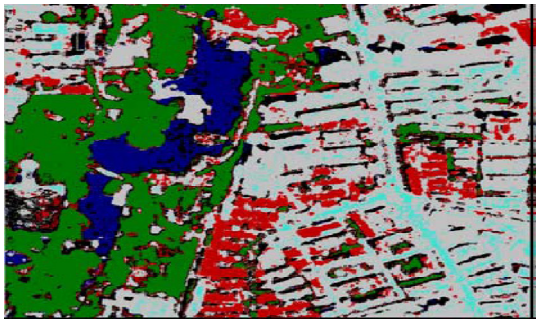


Fig.6 Result of pixel-based classification.

Uwe Bacher et.al. [6] proposes an automatic supervised classification approach which classifies the images assigning membership values for each pixel. The fuzzy-based classification assigns membership values for each pixel. Then the road lines are extracted and the extracted segments are verified. The verification of individual image channels causes a redundancy and fusion from different channels are used to avoid this redundancy.

Yiting Wang et.al. [7] proposes a new approach to extract roads accurately and efficiently by considering both spatial and geometrical features of roads. Initially, unsupervised classification process enhances the spectral features of the image. Then clustering divides the image into two classes: one contains road information and the other contains non-road information. Based on road connection algorithm, the road pixels and non-road pixels are separated. The results are further refined using different morphological operators. Advantages of this clustering method are: higher in automation, less costs and computational expenses. The method of automatic road extraction is simple and accurate, but the efficiency of clustering depends on the number of clusters.

Irene Walde et.al. [8] proposes a fully automated segmentation for segmenting the training data into different groups. The method of classification extracts the needed areas without any human interaction. The method uses contextual properties of different classes and can be extended for any amount of data. Contextual information improves the classification accuracy for any amount of training data. The benefits of using contextual information are that the classification method can be used for specific problems.

Qiaoping Zhang et.al. [9] proposes an automated framework for road network extraction from high resolution multi-spectral imagery. The pixels are classified by segmentation using a spectral clustering algorithm and then pixels are identified by a fuzzy logic classifier. The detected road class is then refined by road class refinement algorithm using Angular Texture Signature (ATS). Then road segments are finally grouped to form the road network. This method provides a better automation but some portions of the main road are missing due to this road class refinement algorithm. Also ATS based refinement has to be improved to reduce the misclassification between road and similar road objects.

Pete Doucette et.al. [10] proposes an automated method which initially extracts the road centre-line pixels by anti-parallel edge centre-line extraction(ACE). Then a node-based representation of the extracted pixels is generated through self-organizing road mapping (SORM). Then the road topology is constructed by linking the SORM nodes based on a fuzzy model and finally, the topology is refined using morphological filtering. The method is efficient for processing, but the selection of sufficient number of road training samples is crucial for extraction of roads.

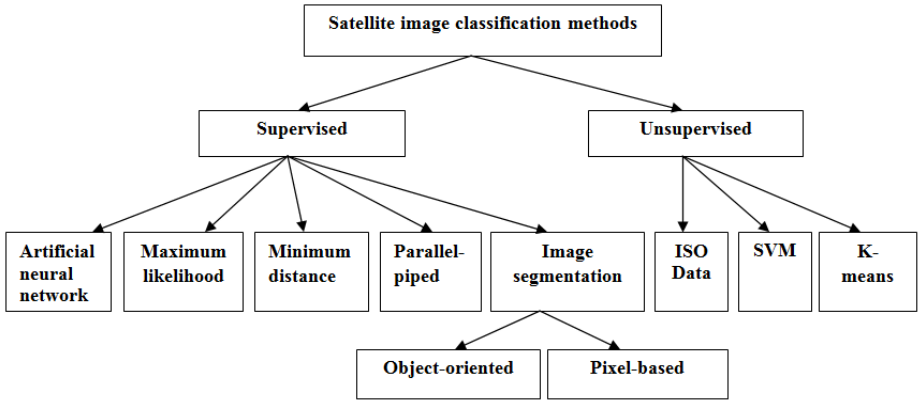


Fig.7 Classification methods for satellite images.

3. Challenges

Automatic road extraction provides a vital role in saving time and labour to a great extent in the field of geographic information systems (GIS). Most of the road extraction methods use the method of segmentation and which requires a seed point as the starting point, and is generally provided by users. The very high spatial resolution (VHSR) has very low spectral resolution and therefore different materials have similar spectral signatures making the discrimination difficult. Also the extraction of roads from dense urban areas using high resolution images is difficult due to high complexity in image scenes and occlusions caused by buildings, trees and their shadows. If the automation level is low, then the performance is limited and it is difficult to extract road networks and the needed accuracy is not obtained.

4. Conclusions

Road extraction from satellite images is a challenging area due to its complexity. Road extraction identifies the road pixels from high resolution images and can be used in a variety of applications such as map implementation, traffic management, vehicle navigation, crop estimation etc. From the comparison of object-oriented and pixel-based classification methods, the object-oriented classification provides a better segmentation for high resolution satellite imagery. The meaningful segments, called objects in object-oriented segmentation provide semantic information which is necessary to interpret an image.

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