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Review Article

A review of road extraction from remote sensing images

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ABSTRACT

As a significant role for traffic management, city planning, road monitoring, GPS navigation and map updating, the technology of road extraction from a remote sensing (RS) image has been a hot research topic in recent years. In this paper, after analyzing different road features and road models, the road extraction methods were classified into the classification-based methods, knowledge-based methods, mathematical morphology, active contour model, and dynamic programming. Firstly, the road features, road model, existing difficulties and interference factors for road extraction were analyzed. Secondly, the principle of road extraction, the advantages and disadvantages of various methods and research achievements were briefly highlighted. Then, the comparisons of the different road extraction algorithms were performed, including road features, test samples and shortcomings. Finally, the research results in recent years were summarized emphatically. It is obvious that only using one kind of road features is hard to get an excellent extraction effect. Hence, in order to get good results, the road extraction should combine multiple methods according to the real applications. In the future, how to realize the complete road extraction from a RS image is still an essential but challenging and important research topic.

1. Introduction

Since the first American land observation satellite launched in 1972, all kinds of technologies applied to the RS image processing have developed rapidly, including image compression, transmission, classification, fusion and understanding. All of those high resolution RS images such as IKonos, QuickBird, WorldView and GeoEye create a quick and economical way to access the newly acquired geographic information, and lay a very important basis for the further applications of RS technology.

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The applications of the high resolution RS image processing mainly include the following aspects: city remote sensing, basic geographic mapping, environmental monitoring and assessment, precision agriculture, and public information service, etc (Wang et al., 2013). The goal of the RS applications is to extract information and identify interested targets to complete image understanding. The road extraction from a RS image is a challenging but important research topic. Roads are the backbone and essential modes of transportation, providing many different supports for human civilization. The research of road extraction is of great significance for traffic management, city planning, road monitoring, GPS navigation and map updating, etc (Shi et al., 2014).

This paper makes a summary of different road extraction methods from RS images for nearly 30 years. Meanwhile, it also focuses on the new achievements and results in recent years.

The rest of this paper is organized as follows: Section 2 describes road features, road model, the existing difficulties and interference factors of road extraction techniques. Section 3 shows different road extraction methods and the main research results. The conclusions are presented in Section 4.

2. Road features and models

The difficulties of road extraction from RS images lie in that the image characteristics of road features can be affected by the sensor type, spectral and spatial resolution, weather, light variation, and ground characteristic, etc. In practice, a road network is too complex to be modeled using a general structural model. Hence, the analysis of road features and road models is very important. In the following part, these two aspects will be described.

2.1. *Road features*

In general, we have to make an image enhancement so as to extract useful information from a RS image. A road in a RS image appears as elongated geometric features with slowly changed gray values. As described by Vosselman and Knecht (1995), the road features in an image are summarized from four different aspects. Based on their description, the road features in an image can be concluded as follows:

(1) Geometric features

A road has a stripe feature its width does not suddenly vary much and its length is not as short as its width. The ratio between length and width is very large. The road junctions usually can be presented as the signs of “T”, “Y”, or “+”.

(2) Photometric features

Photometric features are also known as radiation features. It means there are two obvious road edge lines, and the edge gradient is larger. Meanwhile, the gray values or colors of roads are relatively consistent and change slowly, but they are very different from those of the neighboring non-road areas such as trees and buildings, etc.

(3) Topological features

Generally, a road has intersections. The road network is not suddenly interrupted.

(4) Functional features

A road has specific functions in the real world. In order to realize those functions, it must have some constraint conditions.

(5) Texture features

Textures in an image have the regional characteristics, which are a kind of visual features to reflect the homogeneity phenomenon in the image. It has nothing to do with the color and intensity information. The essence of texture features is to find the spatial distribution of pixel gray levels in the neighborhood (Wang et al., 2014).

Different road features in an image have different properties for road extraction. Geometric features have the direct relationships with the road shapes. Photometric features are close to the road gray levels or colors. Topological features and functional features are relatively simple but hard to apply in real applications.

In practice, many road extraction methods use multiple road features rather than only one feature. However, due to the influence of illumination, shadow and occlusion, a road in an image does not have all the features mentioned above, which makes it difficult to extract road from a RS image.

2.2. *Road model*

The road model establishment can help us extract road more effectively. Baumgartner et al. (1999) proposed a classical road model according to the form of road in a RS image, which is shown in Fig. 1.

In practice, the RS image quality can be affected by different factors such as the sensor type, spectral and spatial resolution, weather, light variation, and ground characteristic, etc. Hence, the following interference factors must be considered (Herumuti et al., 2013; Shi et al., 2014; Zhang, 2007):

(1) The observed appearance of a road from a RS image has large variations (spectral reflectance, objects shadow, occlusion, and contrast), which makes the image segmentation more difficult.
(2) In the bad weather, the vague gray value difference between road and background makes the road edge fuzzy, which leads to a bad segmentation result.
(3) The road width is designed at different levels to meet different requirements. All roads with different widths and lengths intersect together.
(4) Discontinuous phenomenon is easy to appear because of the influence of object shadow, occlusion, especially the influence of tunnel and underground.

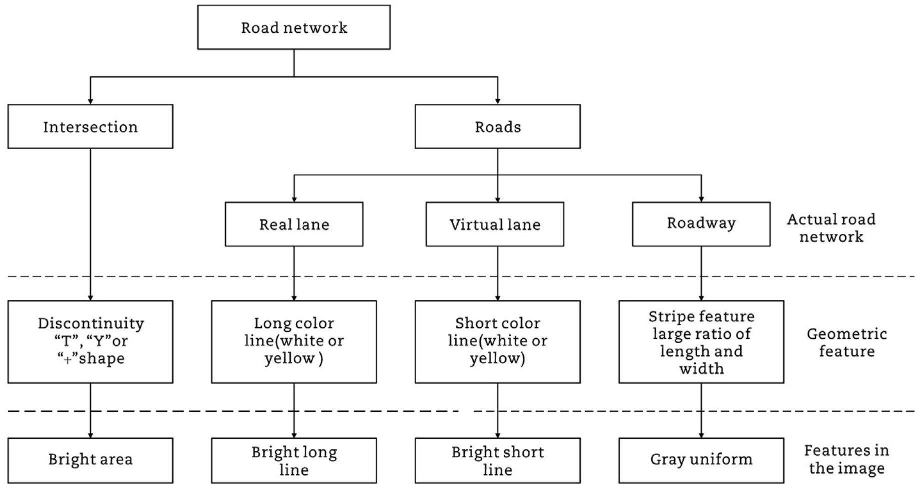

Fig. 1 – Classical road model.

(5) A RS image includes a large amount of information. Furthermore the speed, accuracy, completeness and correctness of the road extraction algorithm should be taken into account.

Fig. 2 shows the RS images including a main road, a large area of water, several tree blocks, grass blocks, and other areas.

In light of different areas (city, suburb or rural), different images (aerial or RS images), and different types of roads (highways, rural roads or streets), many scholars put forward different road extraction methods.

In the next section, the recent research achievements of these different methods will be discussed and classified. The advantages and disadvantages of the algorithms are listed in Table 1.

3. Road extraction methods

Although many researchers have classified the road extraction methods, it is still difficult to classify them in detail due to various applications. In a qualitative survey, it can be found that most of the methods suggested in literature for road extraction consist of one or more types of algorithms: classification-based, knowledge-based, mathematical morphology, active contour model, and dynamic programming, etc. In the following section, the research results of various methods are briefly summarized.

3.1. *Classification-based methods*

Classification-based methods usually use the geometric features, photometric features and texture features of a road. The classification accuracy is far from satisfactory because of the misclassification between road and other spectrally similar objects such as building blocks, field blocks, water areas and parking lots, etc. According to the use of labeled training samples, the classification-based methods can be divided into supervised and unsupervised.

3.1.1. *Supervised classification methods*

Supervised classification methods are to train the labeled samples. To a large extent, the accuracy of supervised classification methods relies on the selected features and labeled samples. In general, the supervised classification methods are

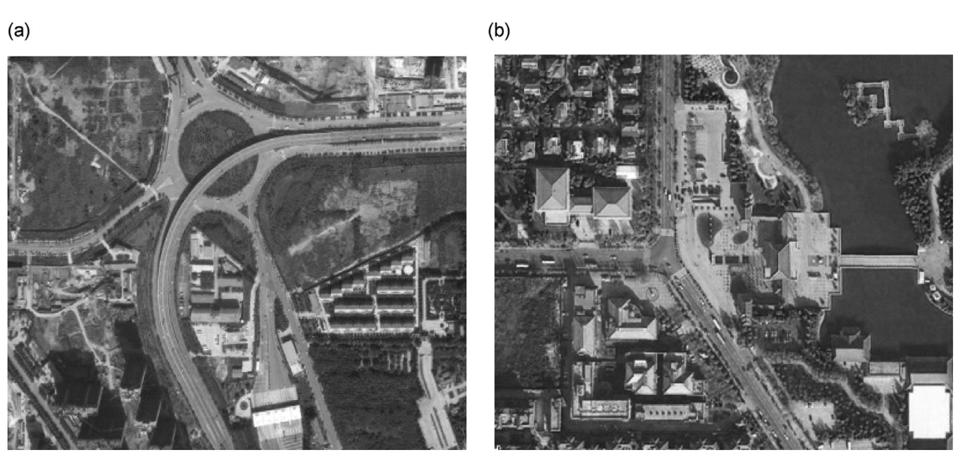

Fig. 2 – Examples of two RS images. (a) Road mainly with grass. (b) Road mainly with water and buildings.

Table 1 – Comparison of different road extraction methods.

Algorithm	Road feature	Sample	Disadvantage	Performance accuracy or correctness (%)
ANN	Intensity, edge, spectrum	1–2	Discontinuity, noisy, over-fitting	95
SVM	Intensity, edge gradient, length, width	3–6	Require more samples, low precious	13–35
MRFs	Mean intensity value, texture	5	Manual intervention	63.5–93.4
Mean shift	Histogram of the HIS image	1–8	Over-segmentation, long literation time	86–90
Knowledge-based methods	Intensity, edge	2–4	Over-segmentation, susceptible to occlusion and shadow	70–79
Mathematical morphology	Geometric feature, direct of line	3–4	Discontinuity, susceptible to structural elements	91.76
Active counter model	Intensity gradient	3	Depend on the seed point selection	95–99
Filtering and group	Direct of line, intensity	2–6	Rely on the prior knowledge	80–98

as follows: artificial neural network (ANN), support vector machine (SVM), Markov random fields (MRFs) classifier and maximum likelihood (ML) classifier.

(1) ANN classification methods

The ANN is inspired from a biological neural system. It is also a computational model that is composed of nodes (or neurons), which are connected to each other. In the late 80's, Heermann and Khazenie (1992) proposed the back propagation (BP) algorithm, which makes a rapid development of the road extraction methods based on neural network.

The early work was mostly based on the spectral and contextual information of the image pixels using BP neural network and the improved model to classify directly. Tu-Ko (2003) presented a robust approach of road centerline delineation, in which a neural network was trained with the spectral and edge information. Although the extraction results include many non-road edge segments, the system can achieve good results on the whole. A BP neural network method was used by Mokhtarzade and Valadanzoej (2007). Through entering different parameters, they were able to get the optimal input vector and test a variety of network structures with iteration time. The optimal network structure and the termination condition in training can be finally established under these conditions, but the process of the input parameters is relatively tedious.

The BP neural network was applied to road detection by Kirthika and Mookambiga (2011). At first, the spectral information for road detection was used. Then different texture parameters including the contrast, energy, entropy and homogeneity for each pixel were computed by using the gray level co-occurrence matrix (GLCM) from the source image, and a pre-classified road raster map was produced. To optimize the system functionality and to evaluate the impact of contributing texture parameters on road detection, the extracted texture parameters were integrated with the spectral information. The final road map is as shown in Fig. 3.

However, the disadvantages of the BP neural network methods include the following aspects: the convergence speed is slow; it needs more training samples; it is more likely to get into the local minima; it declines faster in performance with the increasing categories; and it is easy to become over-fitting, etc. Hence, many novel or improved neural network models have been used for road extraction from RS images. For example, the radial basis function neural network, fuzzy neural network, spiking neural network and hybrid neural network (George et al., 2013; Li and Chen, 2014).

(2) SVM classification methods

The SVM is a supervised learning method, which was firstly proposed for classification and regression analysis. The basic meaning can be described as follows: through the nonlinear transform of the kernel function to transform the low dimensional space to the high dimension space, it constructs the minimal generalization error linear discriminant functions in the high dimensional space so as to realize linear or nonlinear classification in the low dimensional space.

Yager and Sowmya (2003) exploited the SVM classifier by using edge-based features such as gradient, intensity, edge length, but the correctness is relatively low as many researchers reported. Melgani and Bruzzone (2004) used the SVM methods to conduct the classification of a high resolution RS image. In many cases, the classification methods of SVM are better than those of the radial basis function neural network and *K*-nearest neighbor classifier in terms of the accuracy, stability and robustness.

The road and building detection using multiclass SVM method was proposed by Simler (2011). The suggested approach includes image segmentation and classification algorithms, which are especially well adapted to multispectral data. And the both spatial and spectral information are used at the object level. Fig. 4 is the detection results.

The SVM methods have advantages of the structural risk minimization and the good generalization ability, which are widely used in object detection from a RS image. However, there are difficulties to use the SVM methods, such as the estimation of kernel functions, the choice of the dimensional space and training samples, etc.

(3) MRF classification methods

The MRF belongs to a branch of probabilistic theory, and it can well explain the correlation of physical phenomena. The

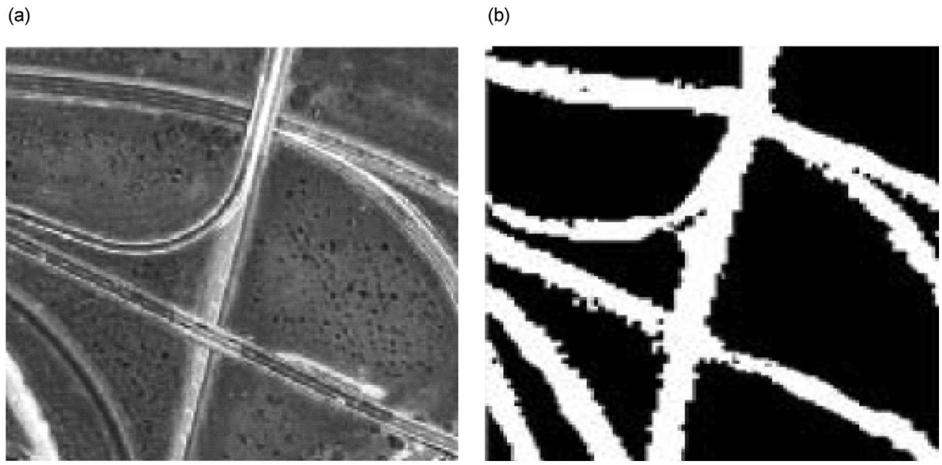

Fig. 3 – Road map. (a) Ikonos input date. (b) Final road map.

pixel interaction in an image has a spatial correlation, so the image can be effectively analyzed by the MRF through describing the texture statistical characteristics by the conditional probability distribution function. The MRF is widely applied to edge detection, image segmentation, restoration and reconstruction and so on (Yousif and Ban, 2014).

Tupin et al. (1998) used a two-step algorithm to extract a linear road from a RS image. First, the road candidate segments were extracted with a linear detector in its local area. Then, the real road segments were selected and connected based on the MRF. Wang and Luo (2005) proposed a road network extraction method based on the Markov random texture model and the SVM classifier. The semi-automatic road extraction method is mainly used for the "synonyms spectrum" phenomenon. It uses the texture features for training but needs the human intervention.

A road extraction method was established based on a MRF and hybrid model of the SVM and Fuzzy *C*-Mean (FCM) (Zhu et al., 2011). In the paper, the author used two algorithms for the urban RS images: the MRF and hybrid model of the SVM and the FCM. On one hand, it used the MAP-MRF framework to adapt the sampler training and to get the factor of a model. The accuracy of road extraction was 85.43%. On the other hand, the SVM plus the FCM model was studied and integrated together. Firstly, an image was clustered by the FCM. The clustering accuracy increased by sampling accuracy. Secondly, the clustering result was classified by the SVM. The accuracy of road extraction was 94.57%. Fig. 5 presents the two algorithm results.

From the above analysis it can be seen that the complex relationship among the extraction objects in a RS image makes it difficult to be accurately modeled by only using the MRF model. Hence, the hybrid probability model is expected to achieve good results in complex object detection from RS images.

(4) ML classification methods

The ML classification, namely Bayes classification, is one of the mostly used supervised classification methods. It uses the Gaussian probability density function and calculates the attribution probability for each pixel, then puts the pixels to the maximum probability categories (Zhou et al., 2006).

Recently, in order to improve the classification accuracy, the combination of different classifiers has become an important research topic. The essence is to train different classification models in the same samples, then to combine these classification results. The popular classifier combination technologies are bagging algorithm and boosting algorithm (Chen, 2006).

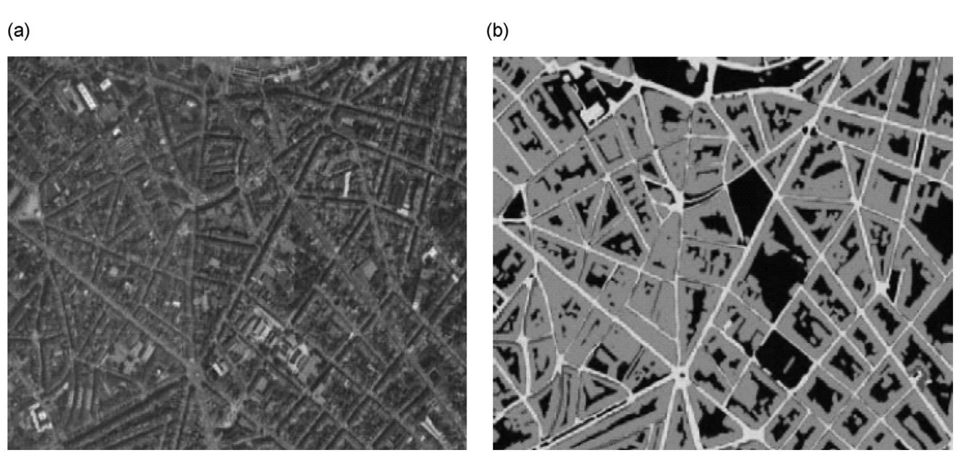

Fig. 4 – Road network detection. (a) Original road network image. (b) Detected road network.

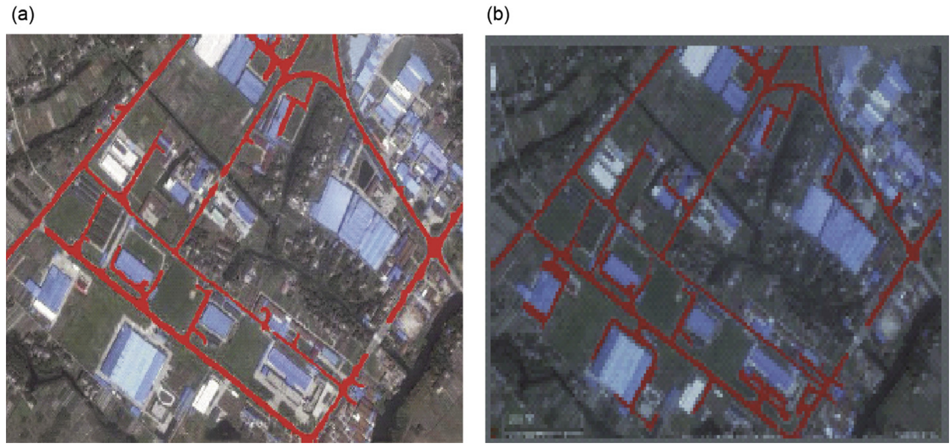

Fig. 5 – Two algorithms for road extraction. (a) MRF-based result. (b) SVM and FCM-based result.

3.1.2. *Unsupervised classification methods*

Unsupervised classification methods do not need training samples, which have many advantages in solving classification problems. However, the accuracy of the methods is lower than that of the supervised classification methods in general. Instead, the unsupervised classification methods are often used in knowledge discovery, parameter determination, characteristic analysis and other preprocessing steps. The most common algorithms are various clustering algorithms, which include *K*-means, spectral clustering, mean shift and graph theory, etc. However, this paper only focuses on the mean shift method and the graph cut method.

(1) Mean shift

The mean shift algorithm is a non-parameter iterative algorithm based on kernel density estimation (Yang et al., 2003). It has many advantages, such as it does not need to assume the type and the number of data distribution, and it does not depend on the selection of starting point of data. So it has been widely used in the field of pattern recognition, image smoothing and image segmentation, etc.

Miao et al. (2014) suggested a semi-automatic method to detect road networks from high resolution satellite images. Firstly, the geodesic method was used to extract the initial road segments to link the road seed points prescribed in advance by users. Secondly, the road and non-road classes were separated by a further direct threshold operation. Finally, the geodesic method was used once again to link the foregoing road seed points to generate a kernel density estimation map. However, the seed points needed to be manually selected. The experimental result is shown in Fig. 6.

The mean shift algorithm does not require any prior knowledge and has high efficiency and stability, especially suitable for the object detection from RS images. However, the current research work in this area is relatively limited.

(2) Graph theory

The clustering method based on graph theory is a new research topic on image segmentation (Pan et al., 2009; Pawar and Zaveri, 2014). The graph theory is a branch of discrete mathematics, which makes graph as a research object to study the theory of vertex and edge. The principle is described as follows: the image is viewed as a weighted graph, in which the vertex is corresponded to a pixel or a region; the edge weight is calculated by the difference or similarity of different vertex; finally, the result is obtained using the matrix eigenvectors and eigenvalues.

Tao and Jin (2007) presented a graph division method as the segmentation criteria to distinguish objects and background. The paper adopts the weight matrix based on gray level to describe the relationship between pixels. The system performance is excellent. Liu and Wang (2008) proposed an interactive image segmentation method based on graph theory. It can quickly get the probability model of image textures, colors, and edges.

Cem and Beril (2012) used a road extraction approach based on probability and graph theory. The system has three main modules: probabilistic road centerline extraction, road shape extraction module, and road network formation based on graph theory. These three modules can be used sequentially or alternately according to the actual situation. A lot of experiments have been carried out using the different images such as Geoeye, Ikonos, and QuickBird, to show the advantages and disadvantages of the system. As shown in Fig. 7, one example of the test results is presented. It can be seen that the system has good stability and accuracy.

The image segmentation method based on graph theory has the advantages of capturing global features and deals with complex data types. However, it mostly adopts the concept of matrix spectrum and uses the eigenvalue and eigenvector of a similarity matrix to conduct image segmentation. Moreover, the processing procedure becomes complex with the increase of the number of vertex. Hence, the method has not been widely used in RS image segmentation.

3.2. *Knowledge-based methods*

It is difficult to extract road from RS images only using the local spectrum and texture information. Due to the stripe

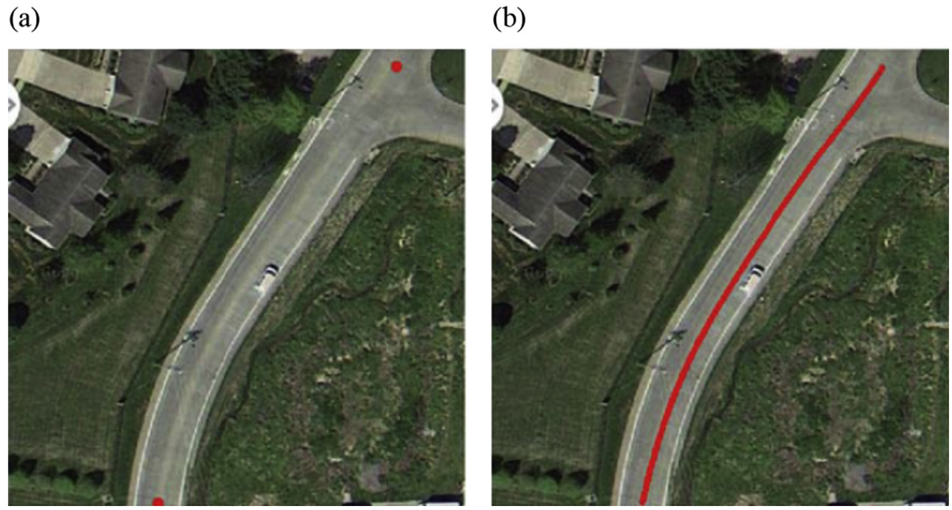

Fig. 6 – Road detection by a semi-automatic method. (a) Original image with different seed points. (b) Results by Miao algorithm.

structure of the road making it hard to describe the eigenvector, the data could not be input to the classifier directly. So parameter models such as the energy function can be used to operate on the maximum value of the energy function. The common parameter models usually extract some structural elements according to the relationship among them, and to detect the specific structure so as to realize the object detection finally.

Wang and Zheng (1998) proposed a detection method for road and bridge detection from SAR images by using geometric features to extract general objects. Then the mathematical morphology and Hough transform were adopted to extract the small regions and to connect the discontinuous segments. Shen et al. (2008) presented a road tracker based on the angular texture signature. However, it could only track long ribbon roads on a gray level image, and the current shortage was that the algorithm might not work on a road cast by many shadows and occlusions in complex scenes.

Hu et al. (2007) used a toe-finding algorithm to find the dominant directions of the road footprint, and made it possible to initialize and track a road segment automatically. This algorithm can almost remove portions in the road network that do not appear to be a road segment. However, the multidirectional road tracker suffers from over-extraction. Fig. 8 shows one example of the extraction results.

Though the knowledge-based methods mentioned above have been applied to road extraction from RS images, they have the disadvantages of over-extraction, susceptible to occlusions and shadows, etc.

3.3. *Mathematical morphology methods*

The mathematical morphology has caused widespread attention in the academic circles, such as image processing, pattern recognition, computer vision and other fields. In the 1980s, researchers started to use mathematical morphology on road extraction, after then all kinds of road extraction methods based on the mathematical morphology have been proposed (Valero et al., 2010; Zhu et al., 2005). However, mathematical morphology methods usually combine with other methods for image segmentation.

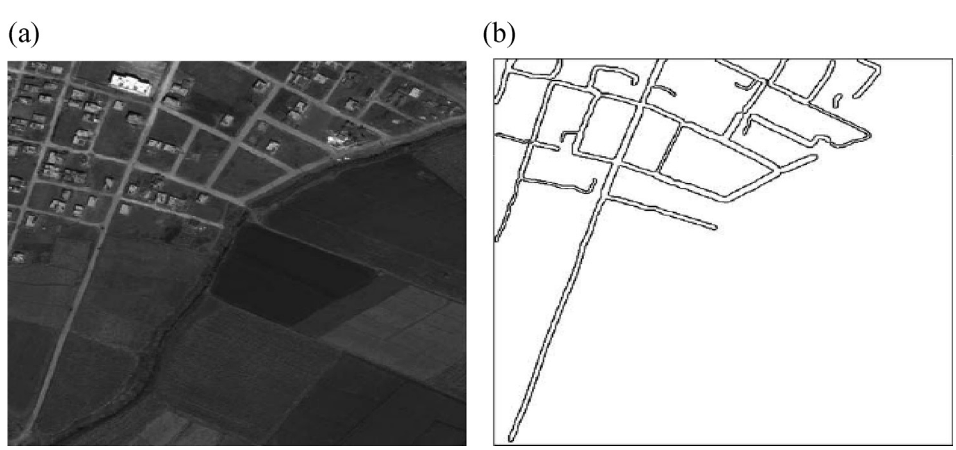

Fig. 7 – Road detection by Cem algorithm. (a) Ikonos image. (b) Road network detected.

(a) (b)

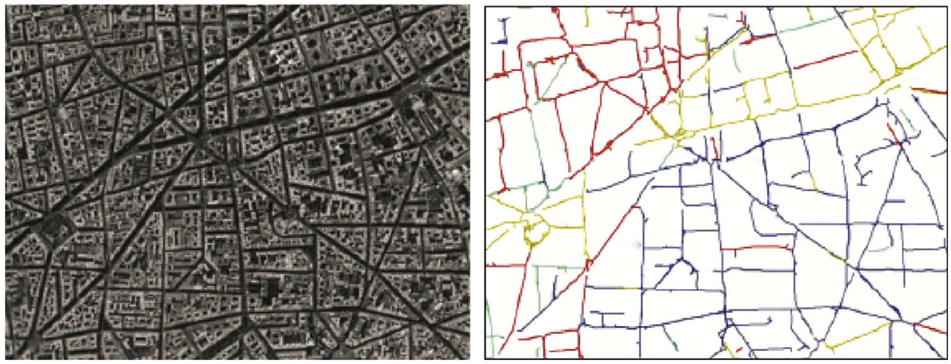

Fig. 8 – Road network extraction by Hu algorithm. (a) Original road network image. (b) Extraction result.

Zhang et al. (1999) put forward a method to extract road networks using the combination with mathematical morphology operations. In the preprocessing stage, an image was firstly segmented into the road network regions from the surroundings, followed by a morphological trivial opening operation. This method preserves the elongated road areas and filters out almost all the small paths and small clusters of noise. The limitation is that the road gaps still exist. Zhu et al. (2004) used an approach for detecting road networks mainly based on the gray level mathematical morphology. The method can get better results especially when the images are vague or fuzzy due to bad weather or other factors.

Ma et al. (2012) proposed an automatic road extraction method for vague aerial images. The quality of images can be affected by different factors such as camera vibration, weather, and light variation, which make it difficult for image segmentation and road tracing. Firstly, multi-scale retinex (MSR) algorithm was adopted to enhance the high-resolution but low-contrast image. Then, the enhanced image was segmented by improved Canny edge detection operator. Subsequently, the Hough line transform and the morphological operators were used, such as skeleton, junction detection, and endpoint detection to regulate linear and curved road segments. At last, through the experiments and comparison with other methods (Otsu threshold, graph-based algorithm, merge and split, etc), it was shown that this method was feasible and effective. Fig. 9 shows the detection results.

Mathematical morphology methods demonstrate certain advantages, which make the methods widely used in road extraction from RS images. In practice, the image segmentation results are greatly affected by the choice of structure elements (shape and size). Due to the uncertainty of the structure elements, it is difficult to only use a mathematical morphology method to get high accuracy and good extraction results.

3.4. *Active contour model*

Active contour models include parameter active contour model and geometric active contour model, and they are respectively represented by snake and level set. The principle of the models is to use a continuous curve for expressing the object profile, and to define an energy function in order to make the process of image segmentation turn into the minimum value of the energy function. The value can be achieved by solving the Euler's equation. Once the energy reaches to the minimum, the object profile can be achieved.

(a) (b)

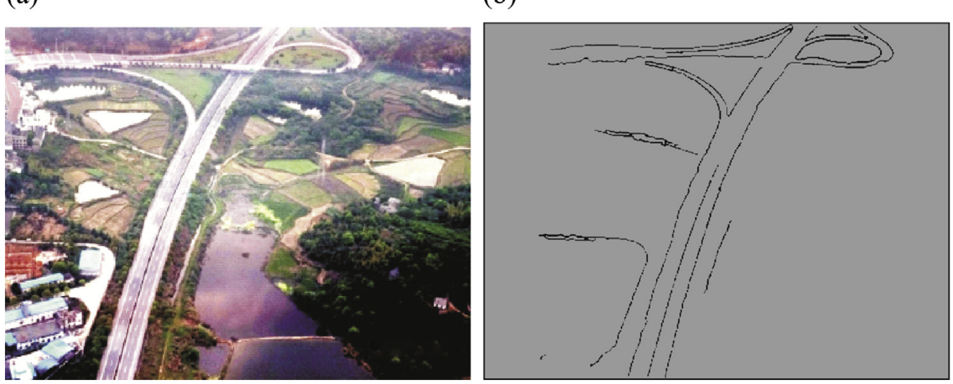

Fig. 9 – Road extraction by Ma algorithm. (a) Original aerial image. (b) Final road tracing results.

(1) Snake

Snake model was firstly proposed by Kass et al. (1988). After that, many methods of image segmentation, understanding, and recognition based on active contour model have been widely used. The main idea of snake model can be concluded as follows: it takes some control points to form certain shape as a template and uses the elastic deformation of the template, to match it to local features in the image. That is, the energy function gets into minimum and completes the image segmentation.

Anil and Natarajan (2010) presented a novel approach using the snake model to extract road. First, the relaxed median filter was used to remove the noise by preserving the edges. Then the operator input initial seed points on the road were extracted and the snake model was used to extract the road. Fig. 10 shows the detection results.

At present, many snake models have been applied to the road extraction, including LSB-Snakes (Gruen and Li, 1999), Ribbon snakes (Fua and Leclerc, 1990), multi-scale snakes (Peteri and Ranchin, 2003), and so on. The LSB-Snakes method is suggested by Swiss Federal Institute of Technology Geography Photogrammetry and Machine Vision Laboratory. It is a semi-automatic road extraction method based on least squares B-spline and it combines the least squares method and snakes model together. The working procedure can be described as follows: firstly, some initial seed points are given manually on the road; then spline curves are constructed with these points using the least square method, and an appropriate width is set to obtain initial road; finally, the road centerline is obtained by image matching, GIS data support and other operators. The LSB-Snakes method can combine the road linear feature and the image features together, and it is one of the useful methods to extract road from RS images.

(2) Level set

Level set was firstly proposed by Osher and Sethian (1988). It is a numerical analysis method using partial differential equations to solve the problem of curve evolution, and it is applicable to any dimension space.

Applying the level set method to a road image segmentation from a RS image, Hinz and Baumgartner (2003) combined the multi-spectral characteristics with road geometry to construct a new speed function; He mainly used the prior knowledge in order to realize the road feature extraction. Niu (2006) studied a method that integrated the boundary gradient with the area information to construct a model. The level set method is used to get the road network. According to the road characteristics, Ma et al. (2006) established an appropriate level set model, and used a fast marching method to combine the image intensity gradient threshold to obtain the initial contour curve of the road, then adopted the curvilinear motion to achieve road image segmentation.

Abraham and Sasikumar (2013) provided an efficient algorithm based on fuzzy inference system for road network extraction from degraded satellite images. Firstly, a wavelet filter was used to smooth the image because roads, buildings, vehicles and shadows cause rapid changes for the image intensity. Secondly, the watershed segmentation algorithm was used to compute the extended minima transform of the gradient image and impose the regional minima on the gradient image. Thirdly, an image was reconstructed by performing the inverse wavelet transform with the help of reconstruction filters. Finally, the mean and the standard deviations were chosen as two linguistic variables for the fuzzy system, and then the Hough transform was chosen as the third variable. Fig. 11 shows one of the experimental results.

Using the level set method combining with other types of road extraction methods (such as morphology and clustering) is also a main trend to make good image segmentation results on RS images.

3.5. *Dynamic programming and grouping*

Dynamic programming is a branch of operational researches, which applies a mathematical method to solve the

Fig. 10 – Road extraction by Anil algorithm. (a) Original test image. (b) Extracted road.

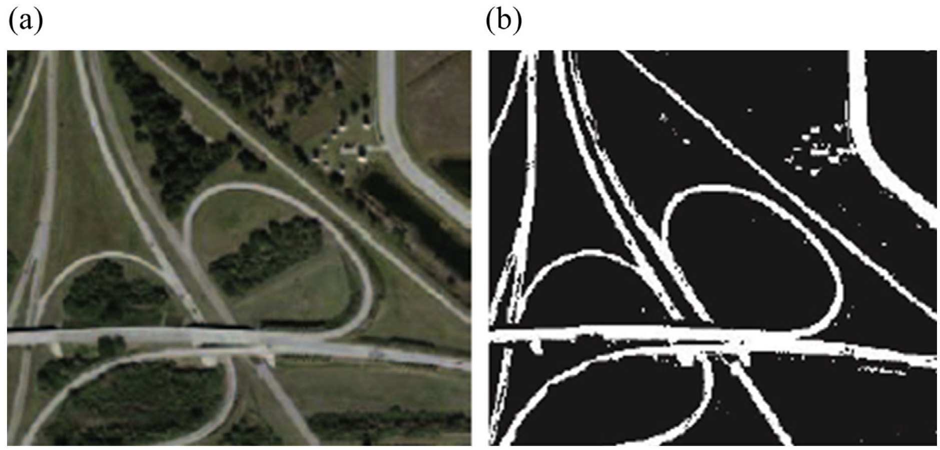

Fig. 11 – Road and road network extraction results. (a) Input image. (b) Output image.

optimization decision process. In general, a parameter model of the road should be given and expressed as a cost function, then dynamic programming is taken as a computational tool to determine the optimal path among the seed points. Barzohar and Cooper (1996) suggested an automatic road extraction algorithm from an aerial image using dynamic programming and Kalman filter to track the road. It can detect roads in real time, even including the missing edge part and the occlusion by cars and bridges. However, this method has significant limitations, due to a lot of assumptions as the prior knowledge existing in the tracking process. Movaghati et al. (2010) put forward a detection model based on Extent Kalman filter and Particle filter, which use a clustering algorithm without considering road barriers. It can track all road intersection branches, but the result is greatly dependent on the parameter set in module.

3.6. *Comparison*

Table 1 shows the comparison of the different road extraction methods for RS images. The table includes algorithms, road features, number of test samples, disadvantages and performance (Das et al., 2011).

As described above, each of the algorithms has both advantages and disadvantages. It is difficult to use only one algorithm to get the high detection accuracy for image segmentation. So the road extraction methods should be studied with a variety of ways and combine different methods. In addition, the key problem of road extraction from RS images is how to describe the road features. Most of the existing methods describe a road as a linear or narrow bright band and can get a good detection result. However, with the increasing image resolution, more detailed road features along with the more noise interference (buildings, shadows, road obstructions) would appear, so the road objects should be described precisely. Hence, how to establish a good road model and extract the road quickly and accurately is a common concern of many researchers.

4. Conclusions

This paper systematically summaries and classifies the methods of road extraction from RS images researched in recent years. Part I introduces the background, significance and purpose of road extraction researches. Part II analyzes the existing problems and difficulties by describing the road features and road models. Part III makes a summary of the different road extraction methods, and gives conclusions including the basic principle, the advantage, and the disadvantages and the related research results.

In this paper, the road extraction is mainly for the main roads and feeder roads in a remote sensing image. Most of the previously developed road extraction methods could successfully recognize roads using different road features, which exhibit a homogeneous surface. However, in cases where surrounding objects like water, buildings, trees, grass and cars occlude the road or cast shadows, especially with influence of spatial structures such as overpass, the road extraction often fails, resulting in gaps and discontinuities in the detected road. Hence, how to extract road from RS images quickly and efficiently is of significance.

Reviewing the past work, scholars have put forward a lot of road extraction methods, but it is still difficult to get an ideal method to solve all the existing problems in roads extraction. Therefore, the further researches may need to include the followings:

(1) Due to the existing complex phenomena for roads, such as discontinuities, occlusion or shadows, near-parallel boundaries with constancy in width, and sharp bends, it is almost impossible to model all these situations and to incorporate them into a single module. Therefore, a multi-model should be established to extract road in RS images.
(2) From the comparison of different algorithms, it can be seen that only use one kind of road features is hard to get a good extraction effect. What is more,

the texture features would improve the detection accuracy.

(3) How to realize the completely automatic road extraction in a RS image is still an challenging and important research topic.

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