Review of Road Extraction Methods from SAR Image

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Abstract: Road extraction methods from SAR Image are important in the field of SAR image recognition and detection. In the past few decades, scholars at home and abroad have done a lot of experiments and researches. Through the analysis of the current situation, it firstly introduces the road characteristics of SAR image and basic strategies of road extraction. Then, the existing road extraction methods from SAR image are summarized. Finally, the prospective road extraction researches from SAR image are put forward.

1. Introduction

Image interpretation refers to the process of acquiring information from the images. SAR image interpretation, according to the standard of interpretation, is to identify the target from SAR image by the method of experience and knowledge and then make qualitative and quantitative analysis so as to get information like the target structure, distribution and function. In many targets, linear target is one important part. It includes information of road, river and pipeline, etc. Among them, road plays a key role in the modern transportation system. It constantly influence people's daily life and it is of great significance to the national economic development and basic geographic information construction. In optical image, road extraction is a classic subject of research. So far, it has made many achievements. However, SAR image is seriously affected by the related noises. Thus it is difficult to get good results using the existing road extraction methods. This paper makes a summary of the existing road extraction methods from the basic characteristics of SAR image road and analyzes the future development of road extraction.

2. The characteristics of SAR image road

There are many descriptions about characteristics of the road in the relevant literature of road extraction. Researchers usually describe them as the following types:

- Roads showed in both high and medium resolution images are long strip, and in the low resolution image is linear.
- The length of the road is much greater than the width.
- The change of the road width is relatively small.
- Generally, the change of road curvature is relatively small.
- The road has obvious edge (Except the road is keeping out).
- Generally, the difference of gray between the road and the adjacent area is relatively large.
- The road is continuous rather than suddenly disconnected. A road network can be formed if many roads connected to each other.

- Generally, there is affiliated information surrounding the road (such as street light, isolation zone and trees on both sides, etc.).

The above content generally covers the characteristics of the road. However, because of the unique imaging mode of SAR image, the road has its own characteristics. The radar echo of the road is slightly weak, so it appears dark without considering of road materials. In higher resolution when the road width is greater than a resolution cell, the SAR image road seems to be dark strip with a certain width; in lower resolution when the road width is less than a resolution cell, the SAR image takes unclear linear shape with the road surrounding information radar echo mixed [1]. The former can be extracted according to the information of homogeneity or shape of the road; the latter can be extracted according to linear information. If the trees on both sides of the road have scattering, the echo takes bright lines in the image. Thus the road can also be extracted through the identification of bright lines.

3. Strategies of road extraction from SAR image

According to Mena's [2] theory strategies can be divided into automatic and semi-automatic method.

Automatic extraction method, based on Marr's visual theory, is divided into three levels: low, medium and high. Due to the difference between SAR image and traditional optical image, early automatic extraction method contains only local detection and global connection. With further research, automatic extraction method is subdivided into five parts that are widely recognized. They are: pretreatment, low-level processing, middle level analysis, high-level recognition and optimized presentation. The details of these five levels can be illustrated by figure 1 below.
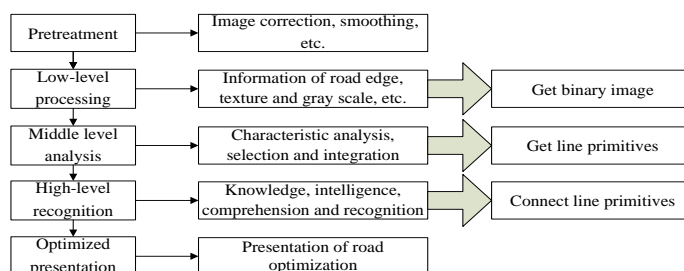
Figure 1. The general method of road automatic extraction.

Semi-automatic extraction method is performed with manual intervention [3]. Firstly, the operators initialize the road according to the characteristics of road and knowledge; then, under the supervision of the operator, the computer completes subsequent work according to the designed extraction methods. It is mainly based on the geometry information and radiation information of the road. Once the information is not so obvious (such as the road is kept out by the vehicle, building shadow or in the intersections), the extraction process is stopped to wait for the operator's instruction.

These two extraction strategies have their own advantages. For the moment, it is not easy to tell clearly which method is better, thus it is advisable to choose the proper method according to the characteristics of the image and the requirements of road extraction.

4. Research statuses

According to the road extraction strategies from SAR image, the review of recent SAR image road extraction can be conducted respectively from the automatic and semi-automatic extractions.

4.1. Research status of road automatic extraction methods from SAR image

According to the extraction technology, road automatic extraction methods from SAR image can be subdivided into the methods of data fusion, multi-scale transformation, segmentation and classification, edge detection and line detection, mathematical morphology and other methods.

4.1.1. The method of data fusion

In the interpretation of land use type, single data source information is limited. However, multi-source data fusion method not only keeps the spectrum information but also enhances the texture information

of the image. It is helpful to recognize all kinds of surface features [4]. Generally, there are two ways to extract road by the method of data fusion: one is to fuse image before the road extraction; another is to extract road separately from each image and then fuse the results. Lisini [5] realized the road extraction by adopting the characteristic-based fusion method, whose information includes the statistical information from classification and structure information from line detection. And then, he put forward several other fusion ways for road extraction. By employing the backscattering characteristic of X-band and P-band, these methods are suitable for road network extraction from airborne dual-band SAR image [6].

4.1.2. The method of multi-scale transformation
The roads in the high resolution image appear to be strips with obvious structure and rich information. But it is easy to be interfered by peripheral information. However the same road showed in the low resolution images appears to be a curve. Although the amount of information is decreased, the interference factors of extraction are also reduced. Therefore, some scholars put forward the concept of multi-scale, that is, to get rough information from low resolution images and detailed information from high resolution images in the process of extracting road information [7]. Negri [8] established a framework suitable for road network extraction from high resolution SAR image, that is, to perform multi-scale road detection first and then use Markov random field to optimize road network.

4.1.3. The method of segmentation and classification
Either optical image or SAR image, it is inevitable that noises interfere with the images and cause uncertainty. Nevertheless, the method of segmentation and classification is the effective way to solve this problem because it is helpful to reduce the unnecessary interference in the image information. Cao [9] used support vector classification to get environmental context information from SAR images for perceptual grouping of line characteristic. Finally, they realized road optimization through the Markov random field.

4.1.4. The method of edge detection and line detection
Apart from the intersections, roads in the remote sensing image basically can be regarded as the combinations of lines (including straight lines and curves). Roads in the low resolution images are single lines while in the high resolution images, double ones. According to such features, road extraction can be achieved through the edge detector and line detector. Jia [1] realized the road detection from high resolution SAR image through Hough transforms. And Cao [10] put forward constant false alarm rate (CFAR) edge detector, which is specialized for SAR image, to realize the road extraction. This edge detection method is proposed for low signal-to-noise ratio (SNR) of the SAR images and has achieved good results.

4.1.5. The method of mathematical morphology
In digital image processing, mathematical morphology is among the widely used technologies. The key of it is to determine the size of the structural elements and the operating sequence [7]. Zheng [11] firstly used threshold segmentation to process SAR image and then applied opening and closing operation in mathematical morphology to smooth the edge. Finally, after several pruning of the detailed images, the road information is obtained.

4.1.6. Other methods of automatic road extraction
In addition to the above-mentioned methods, there are other road automatic extraction methods. Jeon [12] applied the detection of the road line primitives and then connected roads with the genetic algorithm. Hedman [13] proposed the combination of the two road extractors: one for extraction of urban road, the other for extraction of rural roads. By the integration of these two extractors and optimization in the Markov random field, a complete road network is formed. Tupin [14] suggested the road network extraction method in dense urban from SAR image. In the experiment, it first extracted

road network with the potential energy group in the Markov random field and then made several multi-visual processes, combining the improved information from SAR images in different flight directions, to complete the road optimization.

4.2 .Research status of road semi-automatic extraction methods from SAR image
Different from automatic road extraction, semi-automatic road extraction is more accurate with manual work. For road semi-automatic extraction from optical images, scholars at home and abroad have done many researches and put forward a lot of methods, like rectangular template matching, active contour model and dynamic programming, etc. Unlike the development of the optical image road semi-automatic extraction method, SAR image road semi-automatic extraction method has fewer studies at home and abroad. Roughly, the following methods are applied.

4.2.1. Method based on fast marching level set
The method of level set has to constantly update point data of the function, which requires complicated calculations. However fast marching level set method improves it and reduces the complexity by marking points and locating the scope. Zhang[15] realized the road tracking of Terra SAR-X data by the fast marching algorithm. In the experiment, noises from the SAR image are reduced by minimizing the total variation in mathematics and the road tracking is achieved through fast marching level set algorithm. This method has less manual intervention but the extraction results are seriously disturbed by noises and road edge information.

4.2.2. Method based on template matching.
It requires a template rotating around a specified point. Then by calculating and analyzing the certain statistical characteristics of all the points at each position in the template, the advancing direction of the template is defined. Sun[16] realized strip road tracking from VHR SAR images by the method of average angle texture. In the process, firstly select seed points on both sides of the road and calculate out the template to achieve the road initialization. Then rotate the rectangle template and calculate texture mean value in all directions, at the same time, define the advancing direction by thresholds. Finally, complete the strip road extraction by manual correction. Cheng[17], in his article, mentioned that they have achieved road track from high resolution SAR image by using a circular template matching. In this experiment, firstly, select two points of the road and estimate the center point with the help of a circular template window. Then track the center of the road automatically and optimize it by parabolic model. This method can effectively eliminate the effect of vehicles, trees on the roads extraction.

5. Conclusions
In conclusion, scholars at home and abroad have done many researches about road extraction from SAR images at present. But there are still the following problems to be studied further due to the high complexity and difficulty of road extraction from SAR image.

- To make full use of the information in SAR images. The extraction methods mentioned above are mostly suitable for the optical image, not many for the SAR image. Although SAR image is complex, it contains a lot of information, such as coherent information, polarization information and polarize-coherent optimal information, etc.
- To establish an improved evaluation criterion. At present, there is no unified evaluation criterion for the road extraction research or the existing one is specially proposed for certain road or certain kind of image. It is not universal. Therefore, it is necessary to establish a sound evaluation criterion for the road extraction research.
- To realize the integration of extraction technology. With further study, there will be more and more road extraction methods. How to integrate these methods to build a unified road extraction system, according to the categories, types of images, complexity, etc., will be the future development direction of road extraction research.

Acknowledgments

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