UPGRADING FUNDAMENTAL GIS DATABASES FOR NAVIGATION FROM HIGH RESOLUTION SATELLITE IMAGERY

MA Li[a, b, *], LI Jiatian[c], CHEN Jun[b]

[a]School of Remote Sensing and Information Engineering, Wuhan University, Wuhan 430079, China – lymar@126.com
[b]National Geomatics Center of China, Beijing 100048, China
[c]Faculty of Land Resource Engineering, Kunming University of Science and Technology, Kunming 650093, China

Youth Forum

KEY WORDS: Road Extraction, Updating, Upgrading, Navigation, High Resolution

ABSTRACT: Upgrading fundamental GIS databases for navigation use is an important work for providing location-based services In this paper, we present a process for extraction road networks in urban city from panchromatic IKONOS imagery, which is one of the steps in a framework for extracting the roads for the upgrading of the existing data of a fundamental topographic database. Our four-stage process is including image classification based on SVM, road orientation estimation based on edge direction histogram, directional filter for the classified road pixels and the intersection extraction of road networks. An initial result is shown in this paper. Our next research may include matching of the extracted road nodes with the vector data in fundamental databases.

1. INTRODUCTION

Upgrading fundamental GIS databases for navigation use is an important work for providing location-based services (LBS). Many of the work are carried out mainly by field investigation at present, which is much cost and time consuming. High resolution satellite images make it possible to do some of the work partly automatically, namely the extraction of roads from high resolution imagery.

In our reasearch, we aim at extracting road networks in urban city for navigation use. We think road networks in city as net-works consist with road grids.Many road extraction methods are studied in recent years. (Mena, 2003) made a classification for the state of the art on road extraction for GIS update; (Quackenbush,2004) reviewed the techniques for extracting linear features from imagery, An overview of object extraction and revision by image analysis can be found in (Baltsavias, 2004). Some of the work are special focusing on road junc-tion/intersection/crossing) extraction (Price, 2000; Barsi, 2002; Gautama, 2004; Koutaki, 2004; Ravanbakhsh, 2007).

In this paper, we present a process for extraction road networks from panchromatic IKONOS imagery, which is one of the steps in a framework for extracting the roads for the upgrading of the existing data of a fundamental topographic database. A short summary of the framework is given in section 2. Our four-stage process on road extraction is described in detail in Section 3. Section 4 contains some results of experiments. The last section gives a summary and draws some conclusions for the presented work.

2. FRAMEWORK

In our approach, we make an analysis for the road networks in urban city. Based on the analysis of road properties, we design a framework for extraction urban road network.

2.1 Analysis of Urban Road Networks

We assume road networks in urban city as a grid network approximately. This means that the extracted road networks are not very irregular, and some small variations of geometry attributes are available. Figure 1 shows a typical imagery of the road networks in urban city.

In our research, we think the urban road networks in imagery have some properties as follows:

a) Road sections are interconnected. They meet at intersections, which are the main nodes of road networks.
b) Road sections are intersected perpendicularly approximately and several roads are parallel in road networks.
c) As a whole, road surfaces have similar spectral attribute in imagery.
d) Most of the roads are straight; several curved road sections are connected with other straight road sections at intersections.
e) Some other objects are highly related with road, such as vehicles, barriers, shadows, trees and buildings, etc.

Figure 1. Typical road networks in urban city

2.2 Strategy

The goal of our research is to extracting road networks in urban city for navigation use from high resolution satellite imagery. We first extracted the network nodes from imagery and get the original vector nodes from fundamental GIS databases, and then these two kinds of nodes are matched, with some verification of the extracted road nodes. The updated data with accurate road position is got finally. The strategy of our framework is shown in figure2.

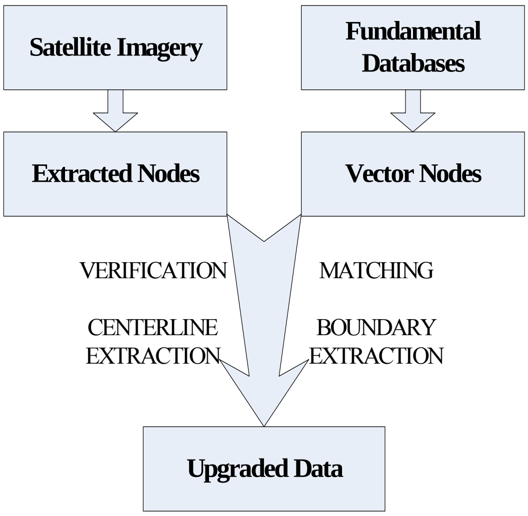

Figure 2.Upgrading framework

3. APPROACH

A four-stage procession is carried out for road extraction, which is one of the steps in our framework for extracting the roads for the upgrading of the existing data of a fundamental topographic database. The processes including image classification based on Support Vector Machine (SVM), road orientation estimation based on edge direction histogram, directional filter for the classified road pixels and the intersection extraction of road networks. Primary road nodes are extracted after processing.

3.1 Image Classification Based on SVM

We mentioned above that road surfaces have similar spectral attribute as a whole in satellite imagery, though there are some disturbances like vehicles, shadows and trees, etc. We first make a classification on the satellite imagery so that we can distinguish most of the road pixel from other objects. This is done by SVM classification.

Support vector machines are developed based on structure risk minimization (SRM) principle (Vapnik, 1995). It aims at reaching the minimum of the upper bound on the error probability of a classifier, by achieving a trade-off between the performance on the training set and the capacity. Given a training set, the SVM classifier obtains the optimal separating hyperplane in terms of generalization error (Figure 3).

Only a small number of sample data are needed for training a SVM classifier. This is especially important on semi-automatic extraction roads from imagery, due to that in specific areas, the material of road surfaces are relatively fixed on several types. A small number of road samples can also get robust classification results.

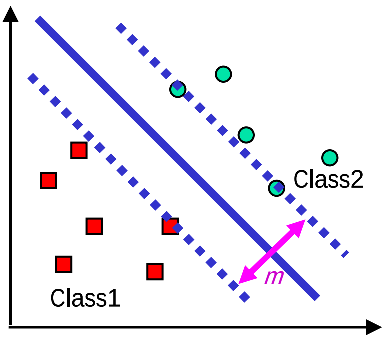

Figure 3.SVM classifier

We distinguish the road surface from buildings, waters and trees. For the large area shadows in the urban imagery, we also make dark shadow pixels as a specific class. In this step, most of the road pixels are extracted, with some disturbed noises.

3.2 Road Orientation Estimation

In order to extract road information exactly from classified road pixels, we need to estimate the road orientation of the road network. The reason why we do this is that in an urban road network, there are usually two main road orientations, which are perpendicular approximately generally. For those road sections with different orientations, they often connected with other straight road sections at intersections.

Most of buildings and other objects are constructed along the road. For estimation of the road orientation, we make statistics on edge direction and calculate two main road orientations from the edge direction histogram (Figure 4).

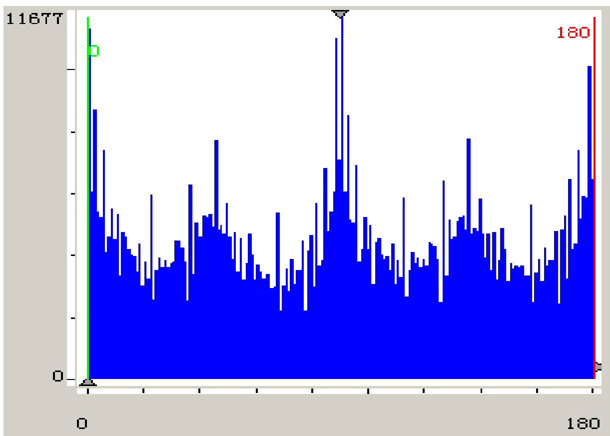

Figure 4. Edge direction histogram

We use Prewitt template to get the direction of each edge pixel, then calculate the number of pixel every π /8 by their directions. In this step, two main road orientations are estimated.

3.3 Directional Filter

Road sections are interconnected and meet at intersections, which are the main nodes of road networks. We got the primary road pixels after SVM classification and estimated road network orientation on the above procession. In this step we try to filter the non-road pixels from SVM-classified results. By the estimated road orientation, we can do the directional filter to the classified pixels.

Along two road orientation, we make filters. In this paper, we just calculate the mean numbers of the pixels on a template along two road orientation. The size of the template is decided by the minimum width and length of road sections. Generally, we make an assumption that the road is wider than four widths of cars and longer than the street block.

After processing, an image contain the main road information along the road orientation is produced.

3.4 Primary Nodes Extraction

Road intersections indicate the topology connections of different road sections. In the last step precession, we get an image contain the main road information along two directions. In this step, we try to extract road intersections by mathematical morphology operations.

The image is processed by a skeleton operation firstly. There are maybe some faults on road skeleton, mainly the interruption of a road and disconnection of intersected roads. Some operations based on blob analysis are done secondly. Finally, the intersections of the skeleton are extracted as primary road intersections in road networks.

After the above four-stage procession, the main road nodes of road network are extracted. This is the first step of our data upgrading framework. Some verification and matching processes need to be done in the next steps.

4. RESULTS

The following experiments test the approach described in this paper. We had access to pan-sharpened RGB IKONOS orthophotos with a resolution of 1 m per pixel. The research area of the images is located in a built-up area in Beijing, China. It is a part of typical road networks in Beijing. Figure 5.is the result of primary road nodes.

Figure 5. Primary road nodes

We have seen that main road intersections are extracted. There are also some faults need further procession. Due to the incomplete extraction of road skeleton, some intersections are not fully intersected. The position of the road intersection is not considered in the procession. A thought for solving this problem may be the consideration of context information, which can provide additional information about the road. In our former work (Ma, 2007), we can extract some physical barriers in the center of the road, which indicate an existence of real road and then a centreline of the road.

5. CONCLUSIONS

This paper presents a process for extracting road network nodes for upgrading fundamental GIS databases from high resolution satellite imagery in urban city, which is the first step of our work.

We develop a four-stage approach. In the first stage, we make image classification based on Support Vector Machine. In second stage, two main road orientations are estimated based on statistic of edge direction histogram. Then the directional filter is adopted for the classified road pixels. Finally, by some mathematical morphology operation, intersections of road networks are extracted, which are the primary nodes of road network. The test results show the applicability of the proposed method.

This paper presents the first step of our work focused on extracting road nodes. Our next research includes matching of the extracted road nodes with the vector data in fundamental databases. We will also investigate road boundary extraction and road centreline extraction in order to get accurate position of the extracted road.

ACKNOWLEDGEMENTS

This research is supported by the National Science Foundation of China (NSFC) under grant No.40620130438 and 40501062.

REFERENCES

Baltsavias, E.P., 2004. Object extraction and revision by image analysis using existing geodata and knowledge: current status and steps towards operational systems. *ISPRS Journal of Photogrammetry & Remote Sensing*, 58(3-4), pp. 129– 151.

Barsi, A., Heipke, C., Willrich, F., 2002. Junction Extraction by Artificial Neural Network System – JEANS. In*: International Archives of the Photogrammetry and Spatial Information Sciences*, Vol. 34, Part 3B, pp. 18-21.

Gautama, S., Goeman, W., D'Haeyer, J., 2004. Robust detection of road junctions in VHR images using an improved ridge detector. In: *International Archives of the Photogrammetry and Spatial Information Sciences*, Vol. XXXV, Part B3, Istanbul, pp. 815-819

Koutaki, G., Uchimura, K., 2004. Automatic road extraction based on cross detection in suburb, *SPIE*, V. 5 5299-36.

Ma, L., Grote, A., Heipke, C., etc., 2007. Physical Barrier Detection for Updating of Navigation Databases from High Resolution Satellite Imagery. In: *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Urumchi, Vol. XXXVI, Part 4/W54, pp.147-151.

Mena, J.B., 2003. State of the art on automatic road extraction for GIS update: a novel classification. *Pattern Recognition Letters*, 24 (16), pp. 3037–3058.

Price, K., 2000. Urban Street Grid Description and Verification. In: *Proc. of 5th IEEE Workshop on Applications of Computer Vision*, pp. 148–154.

Quackenbush, L. J., 2004. A Review of Techniques for Extracting Linear Features from Imagery. *Photogrammetric Engineering & Remote Sensing*, 70(12), pp: 1383–1392.

Ravanbakhsh, M., Heipke, C., Pakzad, K., 2007. Road junction extraction from high resolution aerial images. In: *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 36 (3/W49B), Munich, Germany, September 19-21, pp. 131-137.

Vapnik, V., 1995. *The Nature of Statistical Learning Theory*. Springer-Verlag, New York.