Multi-resolution and multi-spectral image fusion for urban object extraction

Yun Zhang and Ruisheng Wang

Department of Geodesy and Geomatics Engineering
University of New Brunswick
15 Dineen Dr., Fredericton, New Brunswick, CANADA E3B 5A3
YunZhang@UNB.ca; <Ruisheng Wang> i2z51@unb.ca

XXth ISPRS Congress

KEYWORDS: Digital, Urban, Object, Multispectral, Fusion, Classification, Extraction

ABSTRACT:

A new approach for object extraction from high-resolution satellite images is presented in this paper. The new approach integrates image fusion, multi-spectral classification, feature extraction and feature segmentation into the object extraction of high-resolution satellite images. Both spectral information from multispectral (MS) images and spatial information from panchromatic (Pan) images are utilized for the extraction to improve accuracies. This paper mainly concentrates on road extraction from QuickBird MS and Pan images using the proposed approach. Experiments of road extraction with QuichBird MS and Pan images demonstrate that the proposed approach is effective. The completeness and correctness of road network extraction reaches 0.95, significantly higher than those of other existing road extraction methods.

1. INTRODUCTION

The latest high-resolution satellites, such as IKONOS, QuickBird and OrbView, all simultaneously collect multi-spectral (MS) images at a lower resolution (4m or 2.8m) and panchromatic (Pan) images at a higher resolution (1m or 0.7m). In the multi-spectral images, most urban objects can be visually recognized according to the colour difference, but they cannot be clearly delineated due to the lack of spatial resolution. In the panchromatic images, however, the shape of most individual objects can be clearly identified, but many of them cannot be classified due to the lack of spectral information.

To extract useful information from available high-resolution images, including airborne and spaceborne imagery, different automatic and semi-automatic approaches have been developed. To date, automatic techniques for information extraction from imagery can be divided into two main categories: (1) multi-spectral classification techniques to classify objects from multi-spectral images, and (2) grey value and feature based techniques to extract objects from panchromatic images.

Multi-spectral classification techniques are efficient for classifying homogeneous objects. But they are inefficient for the classification of urban objects when high-resolution images are used, because many urban objects are not homogeneous in colour and different objects may appear in similar or same colour, such as asphalt paved roofs and roads. Further, the classification results usually are coarse due to the lower resolution of the multispectral images.

On the other hand, grey value and feature based techniques have been successful in extraction of objects from some simple panchromatic scenes. But they are still very limited in the extraction of urban objects due to the complexity of urban scenes and due to the lack of spectral information. In urban areas different objects may appear in similar grey values and have similar shapes, such as building roofs and small parking lots, so that they can be hardly differentiated automatically according to the grey values and shapes.

In this paper, we present a new approach to better extract urban objects, which utilizes both spectral information from multi-spectral images and spatial information from panchromatic images. Different from existing techniques, this new approach effectively integrates techniques of image fusion, multi-spectral classification, and feature extraction into the extraction process. New image fusion and edge-aided classification algorithms and software have been developed. The concept of the new approach can be used for urban road network extraction, building extraction, and other object extractions. Here we mainly concentrate on road extraction using QuickBird multispectral and panchromatic images. The road extraction results demonstrated that this new approach is significantly superiors to the conventional multi-spectral classification, panchromatic image based feature extraction, and other existing multi-spectral and panchromatic image integrated classifications.

2. THE PROPOSED APPROACH

Figure 1 illustrates the general process of the proposed approach. To overcome the shortcoming of classification of low-resolution MS images, the MS and Pan QuickBird images are first fused into a pan-sharpened MS image. An unsupervised classification is then applied to the pan-sharpened image to obtain a classified road image. And an edge detection approach is applied to the Pan image to obtain an edge image. In the edge-aided segmentation, the binary edge image from the Pan image is employed to segment the classified road image from the pan-sharpened image. Then, a shape-based segmentation and a segments filtering algorithm are employed to remove non-road objects.
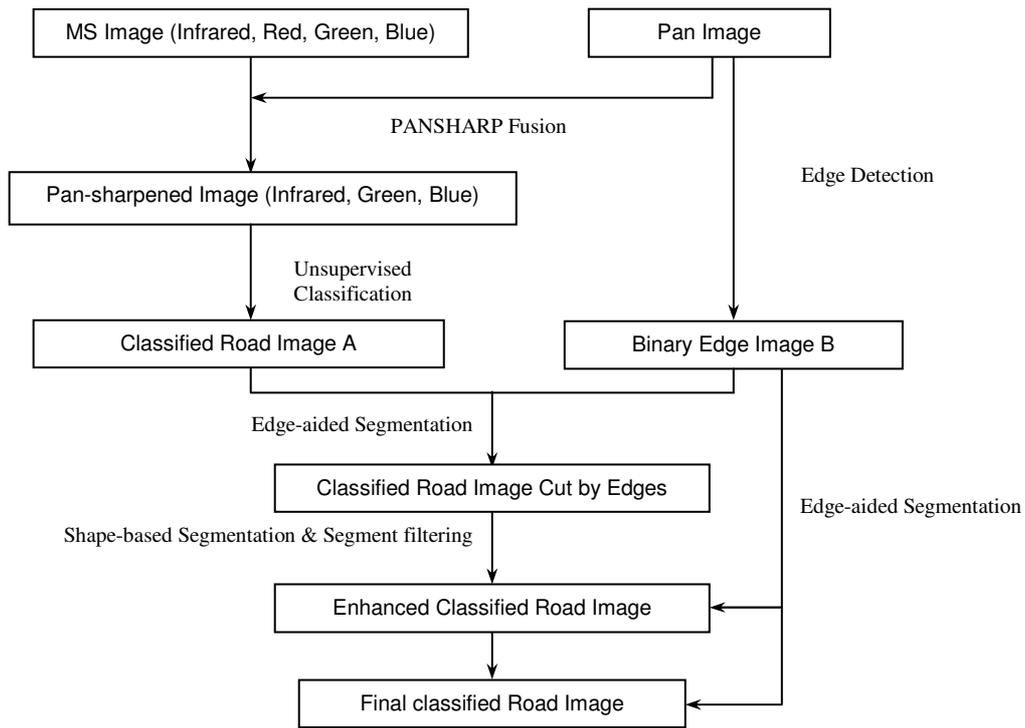
Figure 1. General process of the proposed image fusion, classification and future extraction integrated approach

The whole edge-aided classification process can be iterated to deal with complex road classification results. The individual processes of the proposed approach are described in the following sections.

2.1 Pan-Sharpening

Pan-sharpening is a technique that produces a high-resolution MS image by combining a low-resolution MS image with a high-resolution Pan image. The pan-sharpening technique used in this study is the PANSHARP module (Zhang, 2002) of PCI Geomatica. The algorithm achieves a maximal spatial detail increasing and a minimal color distortion (Zhang 2002). After the fusion, a pan-sharpened QuickBird image is obtained with a 0.61m resolution and 4 MS bands (NIR/R/G/B). Figure 2 shows a sub-scene of the original QuickBird Pan, MS and the pan-sharpened images.

(a)

(b)

(c)

Figure 2. Image fusion of QuickBird images for object extraction. (a) Original Pan image; (b) Original MS image; (c) Pan-sharpened image.

2.2 Classification

To extract road networks according to their spectral information and to get an acceptable result, the original QuickBird MS image and the pan-sharpened MS image were classified in this study using multispectral classification. Comparisons showed that the classification results from pan-sharpened MS images are significantly better than those from original MS images. The reason for this improvement is that the pan-sharpened image has

higher resolution, and the spectral information is well reserved from the original MS image. Therefore, the pan-sharpened image was chosen for the road classification.

Since an unsupervised clustering method is usually better suited for classifying heterogeneous classes in high resolution satellite images than a supervised classification (Jensen et al. 1994, Csatho and Schenk 1998, Zhang 2001), the unsupervised fuzzy K mean clustering method was used to classify the QuickBird images in this study.

Figure 3a shows the clustering result from the pan-sharpened QuickBird image in an urban area. Figure 3b is the classified binary road image from the clustering result (Figure 3a). It is clear that almost all the road networks are correctly extracted. However, the rate of misclassification is high. For example, there are small family driveways connected to road networks, and many house roofs are classified into the road networks. These make it impossible to obtain an accurate road network without further processing.

(a)

(b)

Figure 3. The unsupervised road classification of pan-sharpened QuickBird MS image. (a) A close-up of the clustering result in an urban area. (b) The classified road image after elimination of speckles.

2.3 Edge Detection

Sobel, Robert and Canny detectors were compared in this study. Robert edge detector can easily achieve a clear and proper edge image from a QuickBird Pan image (Figure 4a and 3b). However, some detailed edges in indistinct edge areas cannot be detected. The Canny edge detection algorithm (Canny, 1986) needs to adjust two thresholds and a standard deviation of Gaussian smooth mask to yield a proper result. But, edges in blurred areas can be clearly delineated. In this study, therefore, a combination of Robert and Canny detectors is employed.

(a)

(b)

Figure 4. Detection of road edges from original Pan image. (a) The original QuickBird Pan image. (b) The inverse of binary edge image from Robert edge detector.

2.4 Edge-Aided Classification

An edge-aided classification approach was developed to extract accurate road networks from a classified road image with the help of the edge information from the corresponding Pan image. The edge-aided classification consists of three main processes: edge-aided segmentation, shape-based segmentation, and segments filtering.

Edge-Aided Segmentation. As shown in Figure 3b, the road network classified from the pan-sharpened image contains many non-road objects either connecting to or isolating from the road network. Currently, most existing road extraction methods (e.g., Doucette et al. 2001, Zhang et al. 1999) experience difficulties to deal with such problems. In this study, therefore, we utilize the edges from the corresponding Pan image to separate the non-road objects from the road network. After performing the edge-aided segmentation, those objects connected to road networks are disconnected from the road networks. This can be clearly seen by comparing Figure 3b and Figure 5.
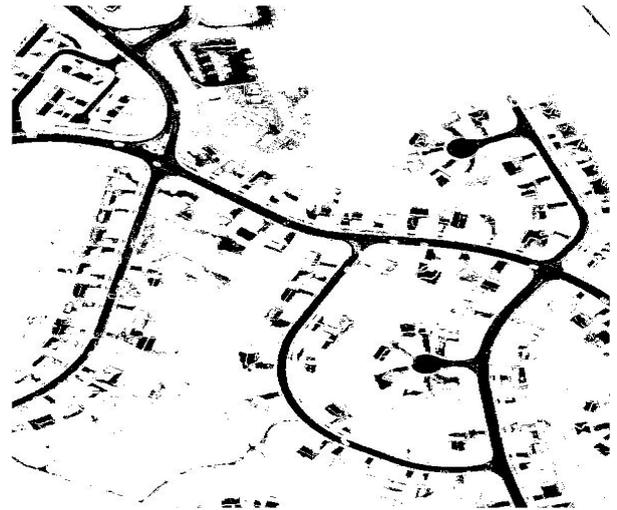
Figure 5. Road networks after edge-aided segmentation.

Shape-based Segmentation. A fast component labelling algorithm is applied to the road image after disconnecting noise, e.g. drive ways and house roofs, from the classified road network. Individual objects, including road networks and noise, are labelled first. They are then segmented according to their size (number of pixels) and shape information (e.g., compactness), resulting in final road networks to be extracted (Figure 6). An iterative process of edge-aided segmentation, shape-based segmentation, segments filtering, and mathematic morphological operations may be needed to deal with complex cases.
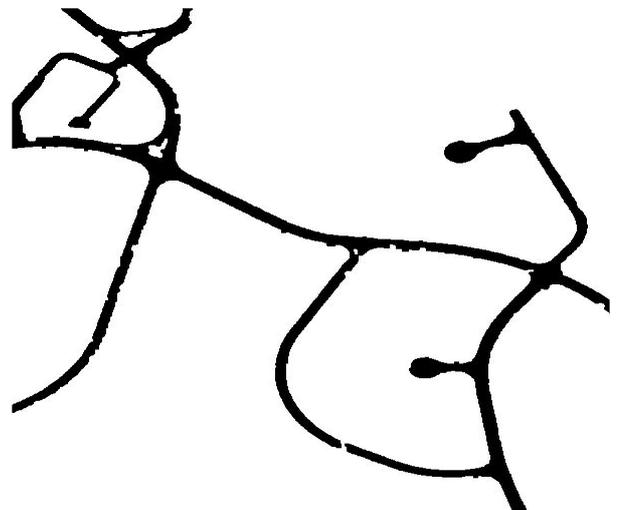
Figure 6. Road network extracted after edge-aided classification process.

Segments Filtering. To deal with big parking lots and buildings which are misclassified as road networks, a directional texture detector is developed to distinguish different types of objects according to their textures in different directions. The directional texture detector measures the pixel grey value variance along the central lines in each of four directions of an operation window. If all the variances in four directions are smaller than a certain value, it can be concluded that the object within this window is homogeneous. Therefore, this object can be considered as a non-road object and can be removed. Figure 7 shows the input image and the processed result. The classified road network (Figure 7a) is the input. The result of the segment filtering is shown in Figure 7b. After segments filtering and edge-aided segmentation, the final road network is extracted (Figure 7c).

(c)
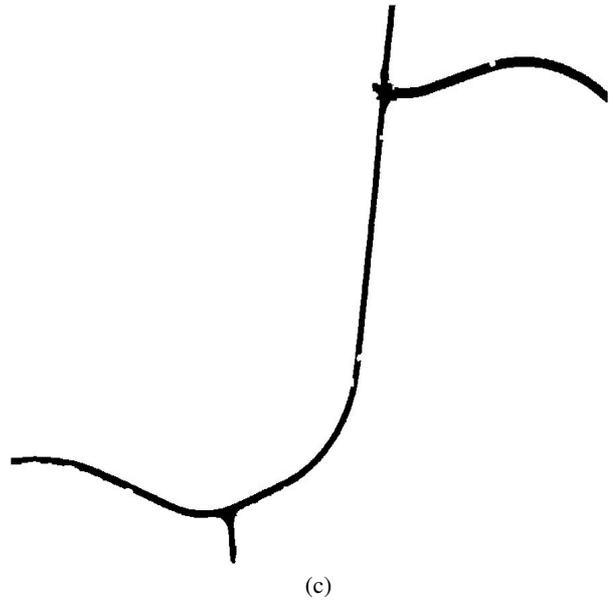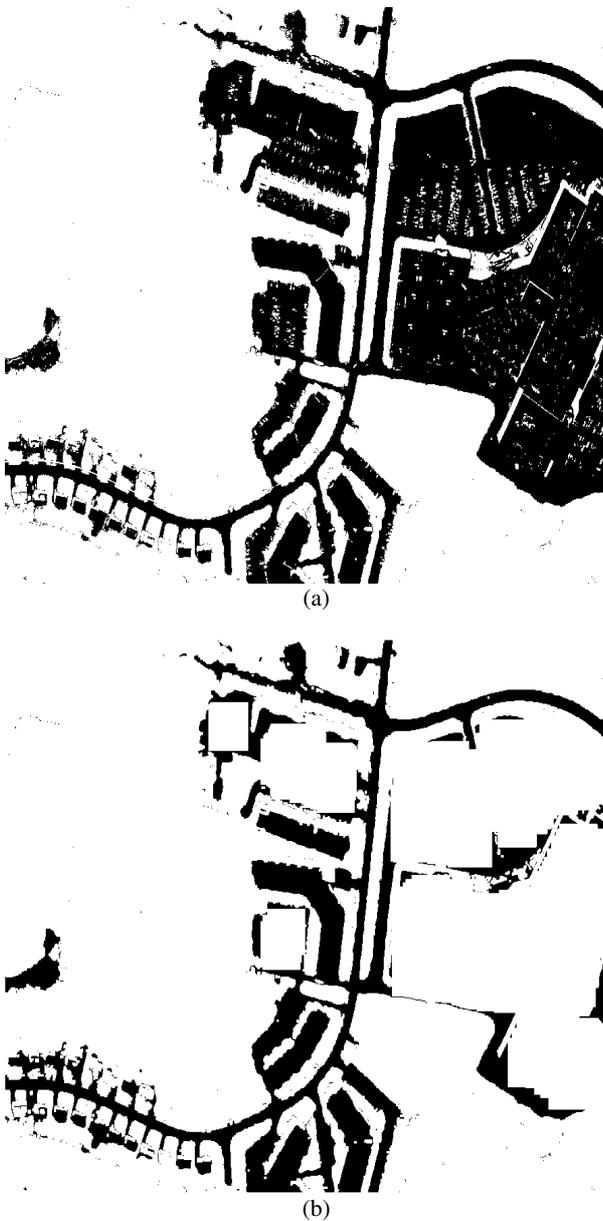
Figure 7. Directional texture detection and segment filtering. (a) The classified road network from the pan-sharpened image. (b) The classified road network after directional texture detection and segment filtering. (c) The extracted road network.

3. TEST DATA AND RESULTS

The images used in this study are QuickBird MS and Pan images taken in August 2002. The study area is Fredericton, NB, Canada. An example of the pan-sharpened image in the area is shown in Figure 8a with 1500×750 pixels.

The classified road network (Figure 8b) is a mixture of roads, buildings, and grounds with many driveways connecting to the road network. They are difficult to remove using existing techniques. However, the proposed edge-aided classification demonstrates the ability to handle these problems. Figure 8c shows the final road network extracted using the proposed method. Almost all roads in the network are successfully extracted. Only two small parts of roads in the bottom left and upper right parts of the image are missing, due to insufficient road width.

(a)

(b)

(a)

(b)

(c)
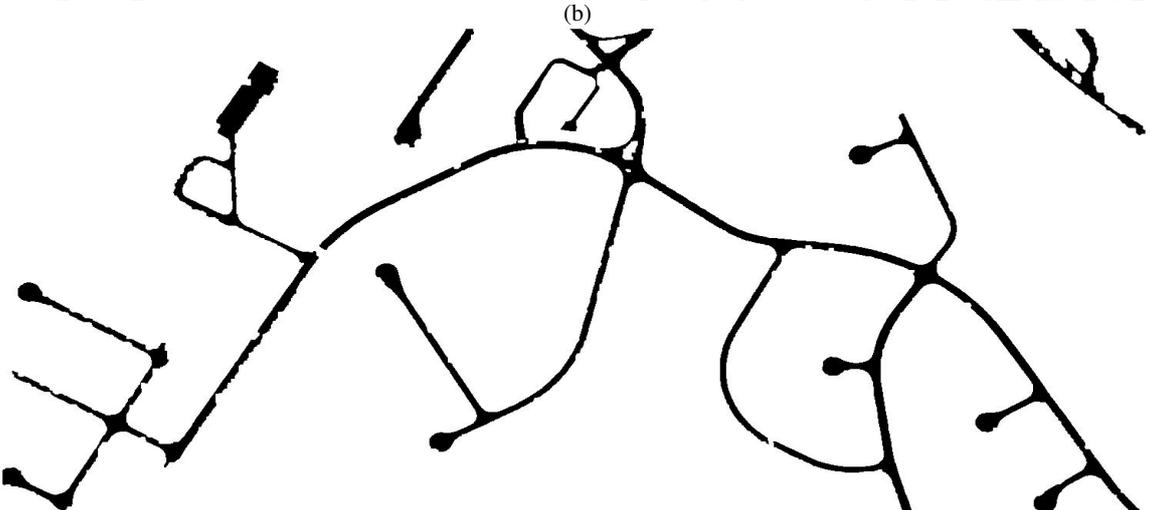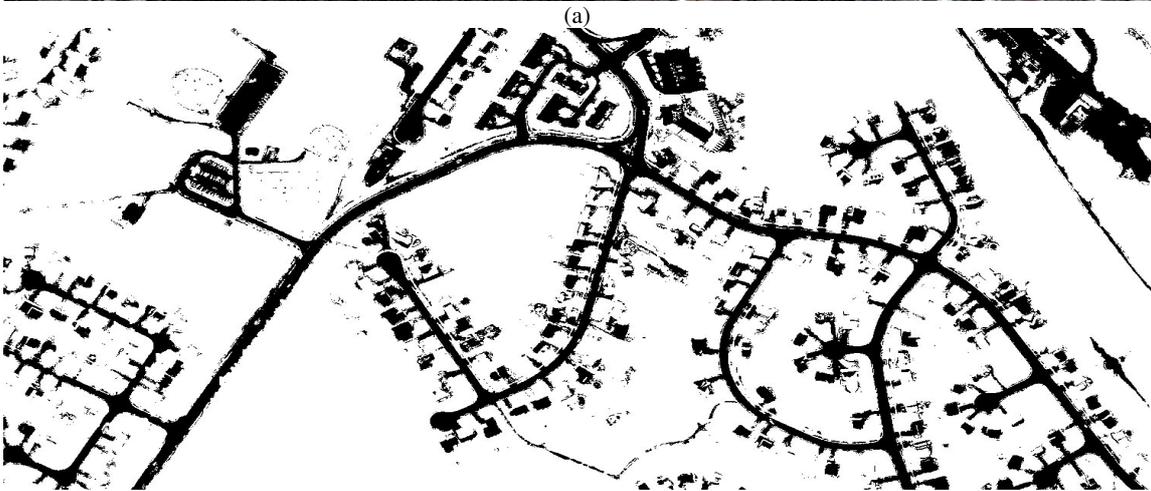
Figure 8. Road network extraction in the first test area. (a) Original pan-sharpened QuickBird image in urban area of Fredericton, Canada. (b) Classified road networks from Figure a. (c) Extracted road networks from the classified image using edge-aided post-classification.

4. ACCURACY ASSESSMENTS

Road completeness and correctness (Heipke et al., 1997) are used to assess the accuracy of the road extraction. The completeness is the ratio of correctly extracted road length (length matched between the extracted and reference data) to the total road length from the reference image. The highest value is 1. The correctness is the ratio of correctly extracted road length to the total length of the extracted road network. The optimal value is also 1. In this study, the completeness value reaches 0.94, and the corresponding correctness value is 0.98.

The results demonstrate that the proposed method achieves significantly higher accuracy than those of Pan based feature extraction (e.g. Hinz et al., 2001), multi-spectral classification (e.g. Shackelford et al., 2003), and MS and Pan integrated classification (e.g. Granzow, 2001).

5. CONCLUSION

A new approach for object extraction from high-resolution satellite images has been developed which effectively integrates image fusion, multi-spectral classification, feature extraction and feature segmentation into the object extraction process. Both spectral information from MS images and spatial information from Pan images are utilized for the extraction to improve the extraction accuracy. Experiments in road extraction from QuichBird MS and Pan images demonstrate that the proposed approach is effective. The completeness and correctness of road network extraction reaches 0.95, significantly higher than those of other existing road extraction methods.

6. ACKNOWLEDGEMENTS

REFERENCES

Canny, J.F., 1986. A Computational Approach to Edge Detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 8(6):679-698.

Csatho B.M., and Schenk, A. F., 1998. Multi-sensor Data Fusion for Automatic Scene Interpretation, *International Archives of Photogrammetry and Remote Sensing,* XXXII (7), pp. 336-341, Budapest.

Doucette, P., Agouris, P., Stefanidis, A., Musavi, M., 2001. Self-organised Clustering for Road Extraction in Classified Imagery. *ISPRS Journal of Photogrammetry &. Remote Sensing* 55, 347–358.

Granzow, Ed., 2001, Automatic Feature Recognition and Extraction from Remote Sensing Imagery. *National Consortia on Remote Sensing in Transportation. U.S Department of Transportation*.

Heipke, C., Mayer, H., Wiedemann, C., and Jamet, O., 1997. Evaluation of Automatic Road Extraction, *International Archives of Photogrammetry and Remote Sensing,* Vol. 32, No.3, pp.47-56.

Hinz, S., Baumgartner, A., Mayer, H., Wiedemann, C., Ebner, H., 2001. Road Extraction Focussing on Urban Areas. *Automatic extraction of Man-Made Objects from Aerial and Space Images (III)* (E.P. Baltsavias, A. Gruen, L.V.Gool, editors), *A.* A. Balkema Publishers, Lisse, pp. 255-266.

Jensen, J.R., Cowen, D.C., Halls, J., Narumalani, S., Schmidt, N., Davis, B.A., and Burgess, B., 1994. Improved Urban Infrastructure Mapping and Forecasting for BellSouth Using Remote Sensing and GIS Technology, *Photogrammetric Engineering & Remote Sensing*, 60:339-346

Zhang, C., and Baltsavias, E.P., 1996. Road Network Detection by Mathematical Morphology. *Proceeding of ISPRS Workshop: 3D Geospatial Data Production: Meeting Application Requirement.* 7-9. April. Paris. France. Pp.185-200.

Zhang, Y., 2002. A New Automatic Approach for Effectively Fusing Landsat 7 images and IKONOS Images. *IEEE/IGARSS'02*, Toronto, Canada, June 24-28, 2002.