http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 13 (11): 1903-1907, 2014
ISSN 1812-5638 / DOI: 10.3923/itj.2014.1903.1907

Building Footprints Extraction Methods Based on Marker-controlled Watershed Segmentation and Local Radon Transformation

[1]Lili Yan and [2]Peixian Li
[1]School of Environment Science and Spatial Informatics,
China University of Mining and Technology, Xuzhou 221116, China
[2]College of Geoscience and Surveying Engineering,
China University of Mining and Technology, Beijing 100083, China

Abstract: Building footprints extraction is an important part of buildings detection. This study presented two methods to extract building footprints. Firstly, the marker-controlled watershed segmentation method can obtain the closed building footprints. It can make full use of the grads information, building information by itself and background information from Synthetic Aperture Radar (SAR) image. Then, the local Radon transformation method can extract the location and direction of buildings. It can obtain the building footprints by combining and fitting the line segments. The airborne polarimetric SAR (PolSAR) image was acquired in the experiment. The experiment results show that the two methods have better advantages in building footprints extraction and can extract building footprints observably and perfectly.

Key words: Building footprints, PolSAR, marker-controlled watershed segmentation, local radon transformation

INTRODUCTION

In urban applications for PolSAR images, building footprints extraction is very important for detecting buildings. Because of the shadow and layer over effects on the buildings in SAR image, the building outlines in SAR image will be very different from the actual geometry structure of the building. According to the imaging characteristics of the buildings in the SAR image, the outline of buildings can be grouped by the vertical structure of the polygon (L-shaped, rectangular, etc.). Currently, image information (including panchromatic, multispectral information) combined with remote sensing image processing and analysis, machine vision, artificial intelligence and other achieving of new methods are mainly used for buildings footprints semi-auto or automatic recognition and extraction. A method (Baatz and Schape, 1999, 2000) combining multi-scale image segmentation with decision tree classification was proposed to extract buildings footprints from high resolution remote sensing images. This method uses the spectrum, texture and context information and gets a perfect result in optical images. In 2003, Extraction and Classification of Homogenous Objects (ECHO) method was used to process the IKONOS image classification and Hough transformation was used to extract the dominant direction of the line of buildings (Lee *et al.*, 2003). For the "H" type building, a new model was proposed and then a method based on the new model and clustering approach for buildings footprints extraction was used (Croitoru and Doytsher, 2003). This model and method provided a new thinking for the next study. A new approach was studied to automatically extract rectangle buildings from aerial urban images (Tao and Tian, 2003). This method merges edge detection into outlines extraction and the results have good robustness and precision. In previous studies, these methods were proposed and used only in optical images. However for the special imaging characteristics of SAR images, they are not very fit for SAR images. For the study, the buildings outlines are extracted based on the detected buildings area from PolSAR image. Two methods for building outlines extraction were studied. One is based on marker-controlled watershed segmentation algorithm to extract building footprints. This extraction method based on segmentation algorithm utilizes the gradient information, the building itself and the background information of the detected buildings area and it can effectively extract the closed outlines of the buildings. The other is based on local Radon transformation algorithm to extract building footprints. The extraction method based on local Radon transformation algorithm can extract the position and orientation of the buildings

Corresponding Author: Lili Yan, School of Environment Science and Spatial Informatics,
China University of Mining and Technology, Xuzhou 221116, China

outlines. Then, the col-line segments were combined based on the visual interpretation method and the outlines of buildings were fit. This method can quickly and accurately extract the outline of the buildings and vector data. The objective of the study is to extract the buildings footprints from SAR image effectively.

BUILDING FOOTPRINTS EXTRACTION METHOD BASED ON MARKER-CONTROLLED WATERSHED SEGMENTATION ALGORITHM

The principle of the watershed segmentation: Watershed segmentation method is a segmentation method based on the topological theory of mathematical morphology. Watershed calculation process is an iterative annotation process. The classical watershed method was presented by Vincent and Soille (1991). There are two steps in the watershed calculation algorithm. One is a sorting process and the other is a submerging process. First of all, sort each pixel from low to high on the gray level. Then in the submerging process from low to high, each local minimum value at the h order height effect range is judged and marked by using the first-in, first-out (FIFO) structure.

Watershed transformation obtains the water collection basin image of the input image. The boundary point between the water collection basins is the watershed. Obviously, the watershed denotes the maximum point of the input image. Therefore, in order to get the edge of the image information, the gradient image is usually used as the input image:

$$\begin{aligned} g(x,y) &= \mathrm{grad}(f(x,y)) \\ &= \{[f(x,y)-f(x-1,y)]^2 \\ &+ [f(x,y)-f(x,y-1)]^2\}^{1/2} \end{aligned} \quad (1)$$

In Eq. 1, f(x, y) denotes the original image and {•} denotes the gradient operation.

The watershed algorithm has a good response for the weak edge. The phenomenon of over-segmentation occurs when the image noise and the grayscale of the object surface change. Meanwhile, the watershed algorithm has a good response for the slight edge, which assures the closed and continuous edge. In addition, the closed water collection basins obtained by the watershed algorithm makes it possible for the image regional feature analysis.

In order to reduce the over-segmentation for the watershed algorithm, the gradient function is usually modified. The simple method is that the gradient image is processed by the threshold method. It can eliminate the over-segmentation due to the slight grayscale changes. It can be showed by:

$$g(x, y) = \max(\mathrm{grad}(f(x, y)), g^{\theta}) \quad (2)$$

where, g^{θ} means the threshold value.

Building footprints extraction based on marker-controlled watershed segmentation algorithm: The watershed segmentation algorithm has the advantages of extracting the continuous and closed boundary of the object effectively. Building footprints extraction method based on marker-controlled watershed segmentation algorithm is presented. The specific steps are given as follows:

- **Step 1:** The grayscale image of the buildings area detection result is input firstly
- **Step 2:** The gradient magnitude of the grayscale image is considered as segmentation function for SAR images. Then a better segmentation result can be obtained by marking the foreground objects and the background objects
- **Step 3:** The foreground objects are marked by using the mathematical morphology methods. These methods are "opening-by-reconstruction" and "closing-by-reconstruction"
- **Step 4:** The background markers are calculated by the threshold segmentation, the Euclidean distance calculation and the watershed transformation
- **Step 5:** Finally, the watershed transformation for SAR image is implemented based on the segmentation function

Figure 1 and 2 are the different alignments buildings footprints extraction results based on the marker-controlled watershed segmentation algorithm. The results show that the parallel and oriented buildings footprints extraction results based on the marker-controlled watershed segmentation algorithm are closed and continuous but there are some false and missing extraction.

BUILDING FOOTPRINTS EXTRACTION METHOD BASED ON LOCAL RADON TRANSFORMATION

The principle of the Radon transformation: The basic idea of the Radon transformation is integral operation of a function in the specified path (Gong, 2008). Radon transformation can be divided into linear and nonlinear Radon transformation according to different integral path. When the integral path is linear, it is called a linear Radon transformation. If the integral path is nonlinear, it is called

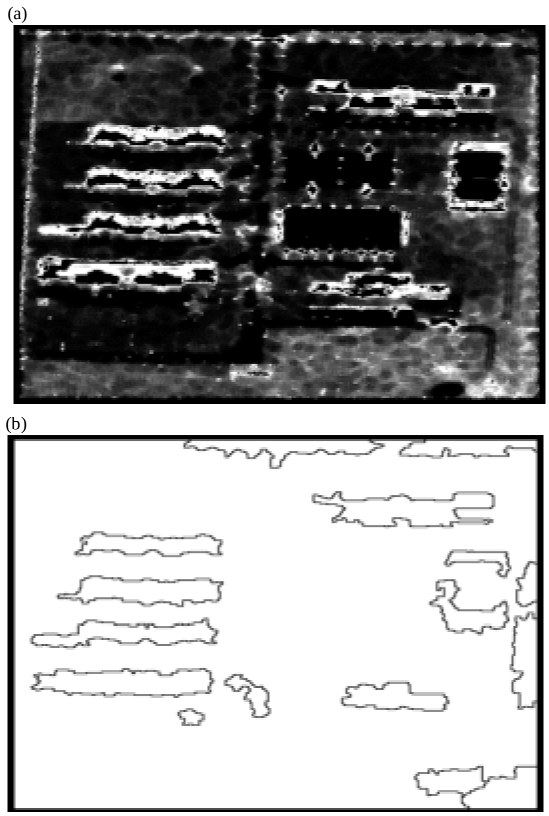

Fig. 1(a-b): Parallel building extraction results based on marker-controlled watershed segmentation algorithm, (a) Input parallel buildings and (b) Parallel building footprints

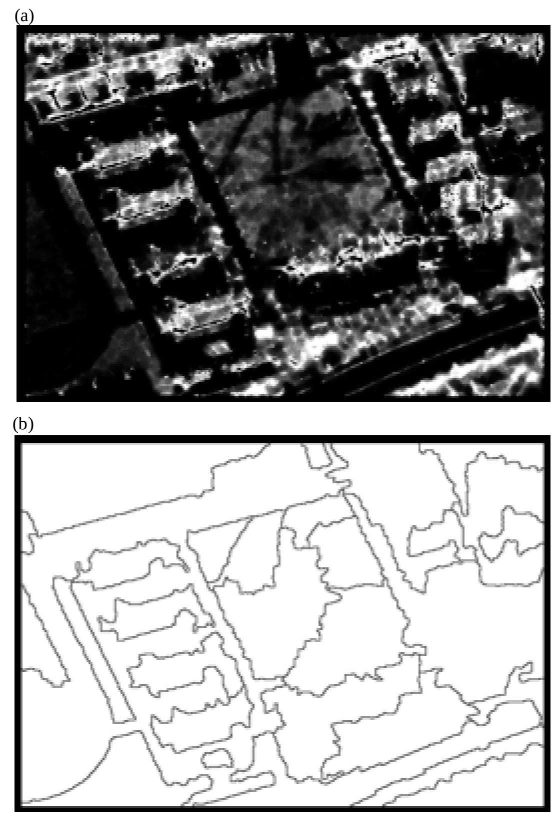

Fig. 2(a-b): Oriented building extraction results based on the marker-controlled watershed segmentation algorithm, (a) Input oriented buildings and (b) Oriented building footprints

non-linear Radon transformation or the generalized Radon transformation. These two kinds of transformation can be represented with unified formula. Radon transformation provides a unified mathematical basis for tomography imaging technology (Niu *et al*., 2001). Since the 1970s, Radon transformation achieved rapid development in its theory and application.

Radon transformation of the image is a transformation method to calculate the image projection at a given angle ray direction. The projection of the image is the linear integral of the image at a certain direction, which means cumulative sum for digital images. It is given by:

$$\begin{aligned} R(f(x,y)) &= \iint_{y\,x} f(x,y)\delta(r - x\cos\theta - y\sin\theta)dxdy \\ &= R(r) \end{aligned} \tag{3}$$

where, r is the distance of a the projection straight line from the starting point to the ending point, expressed as $r = x\cos\theta + y\sin\theta$; θ is the projection direction; the series of the integral of the type of the different projection direction forms the projection $R_\theta(r)$. A set of all the projections $\{R_\theta(r), \theta \in [0, \pi]\}$ is called Radon transformation. In Fig. 3, Radon transformation of the image can firstly divide one pixel into four sub-pixels.

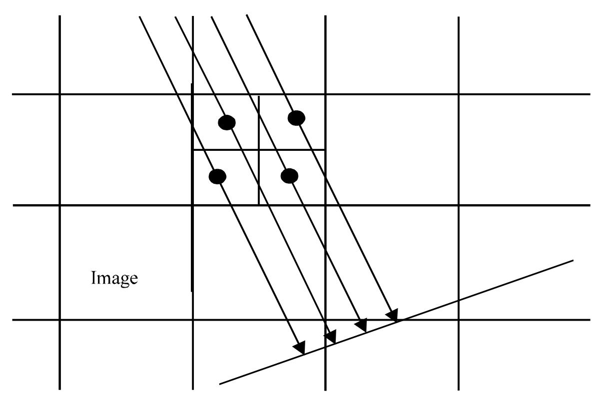

Fig. 3: The pixel projection sketch map of image Radon transformation

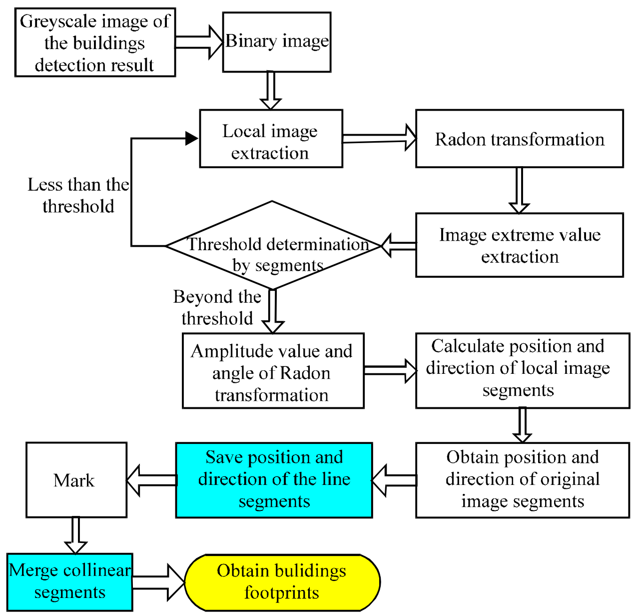

Fig. 4: Flowchart of buildings footprints extraction based on local Radon transformation

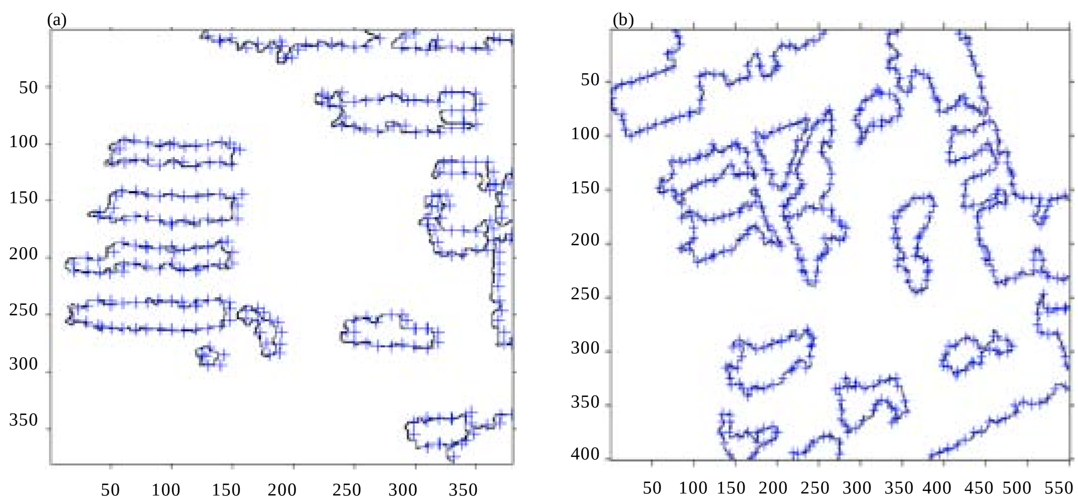

Fig. 5(a-b): Different alignments buildings footprints extraction results based on local Radon transformation, (a) Parallel buildings and (b) Oriented buildings footprints

Then calculate the sum of all the pixels values along the projection direction. Each projection line is calculated in accordance with the nearest sub-pixel value. The image can be observed from any angle by calculating the projection within the set $\{R_\theta(r), \theta\in[0, \pi]\}$ (Guo *et al*., 2012).

Building footprints extraction method based on local Radon transformation: The local Radon transformation algorithm can quickly extract the location and direction of the line segment. The process procedure of buildings footprints extraction based on local Radon transformation is presented by using the binary image of the buildings detection result and the buildings information. Figure 4 shows the flowchart of buildings footprints extraction based on local Radon transformation.

Figure 5a and b show the building footprints extraction results based on local Radon transformation for different alignments buildings. The input image of Fig. 5a is the parallel buildings detection result image shown in Fig. 1a. The input image of Fig. 5b is the oriented buildings detection result image shown in Fig. 2a. The extraction results shown in Fig. 5a and b indicate that the building footprints extracted by local Radon transformation are integral and continuous. It also has some false and missing extraction. Compared with Fig. 1b and 2b, parallel building footprints extraction results based on two methods are almost the same but oriented buildings extraction results are a little different. Therefore, the two methods both have their own advantages.

ANALYSIS OF THE RESULTS

The marker-controlled watershed algorithm can extract local characteristics of images. Building footprints extraction methods for SAR image based on marker-controlled watershed algorithm can overcome the misclassification ratio of global threshold segmentation algorithm and improve the robustness of building footprints extraction. In addition, the algorithm can effectively solve the over-segmentation problem and improve the extraction accuracy.

The Radon transformation algorithm can effectively detect the locations and orientations of building footprints, but it cannot determine the initial position and length of the lines. The local Radon transformation algorithm detects local images in small area and sets a threshold for local Radon transformation image to judge existing lines. This algorithm can effectively mark the border location of buildings in small areas. The threshold criterion can decrease false peak's influences and effectively improve the efficiency of building footprints extraction.

CONCLUSION

- Building footprints extraction method based on marker-controlled watershed segmentation algorithm has the advantages of extracting continuous and closed boundary of the object. The gradient information of buildings detection results and the information between building itself and the background are exploited. For different alignments buildings, the marker-controlled watershed segmentation algorithm procedure is given and the building footprints extraction results are accurate and effective
- Building footprints extraction method based on local Radon transformation can quickly extract the orientation and position of the line segment. The binary image of buildings detection results is used as the input image. For different alignments buildings, the local Radon transformation algorithm procedure is given and the algorithm can get a reasonable building footprints extraction results
- Marker-controlled watershed algorithm and local Radon algorithm can extract different alignments buildings footprints from SAR image. More in-depth study needs to be done on how to effectively extract buildings by synthesizing orientation and polarization scattering characteristics of buildings in more accurate extraction precision

ACKNOWLEDGMENT

The authors would like to thank CETC 38 and Chinese Academy of Surveying and Mapping (CASM) for providing the Chinese domestic X-band airborne PolSAR data. This work was supported by the Postgraduate Scientific Innovation Research Program of Jiangsu Higher Education Institutions under Grant CXZZ11_0300.

REFERENCES

Baatz, M. and A. Schape, 1999. Object-oriented and multi-scale image analysis in semantic networks. Proceedings of the 2nd International Symposium on: Operationalization of Remote Sensing, August 16-20, 1999, Enschede ITC, pp: 1-7.

Baatz, M. and A. Schape, 2000. Multiresolution segmentation: An optimization approach for high quality multi-scale image segmentation. Angewandte Geographische Inform. Sverarbeitung, 12: 12-23.

Croitoru, A. and Y. Doytsher, 2003. Monocular right-angle building hypothesis generation in regularized urban areas by pose clustering. Photogrammetric Eng. Remote Sensing, 69: 151-169.

Gong, X., 2008. High resolution radon transform and application. Ph.D. Thesis, Jilin University, Jilin, China.

Guo, L., L. Ma and S. Ye, 2012. Remote sensing image extraction of residential areas based on radon and tree-structured wavelet transformation. Geomat. Spatial Inform. Technol., 35: 150-153.

Lee, D.S., J. Shan and J.S. Bethel, 2003. Class-guided building extraction from IKONOS Photogrammetric Eng. Remote Sensing, 69: 143-150.

Niu, B., C. Sun and Z. Zhang, 2001. Polynomial radon transform. Chin. J. Geophy., 44: 263-271.

Tao, W.B. and Y. Tian, 2003. The technique for automated rectangle building extraction from aerial images. J. Astronaut., 24: 341-347.

Vincent, L. and P. Soille, 1991. Watersheds in digital spaces: An efficient algorithm based on immersion simulations. IEEE Trans. Pattern Anal. Mach. Intell., 13: 583-598.