Urban building extraction from high-resolution satellite panchromatic image using clustering and edge detection

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ABSTRACT

For decades, large-scale aerial photos have been employed to extract building for mapping application. With the successively launching of high-resolution commercial satellites (e. g. IKONOS and QuickBird), high-resolution satellite imagery has been shown to be a cost-effective alternative to aerial photography in many applications. Drawing on the traditional building extraction approach, this paper proposes an algorithm to extract urban building from high-resolution panchromatic QuickBird image using clustering and edge detection. In the first step, an unsupervised clustering by histogram peak selection is used to split the image into a number of classes. And the shadows of building are extracted from the lowest gray class. In the second step, the shadows are used as one of the evidences to verify the presence of buildings. Thus the candidate building objects are extracted from the clustering classes except for the shadow class. Finally, to refine building boundary and further exclude some false building objects, the Canny operator is applied to detect edge of the candidate building objects in the PAN image. From the Hough transform of the detected edges, the main lines, which compose the polyhedral description of the building, can be found. The building extraction results are compared with manually delineated results. The comparison illustrates the efficiency of the proposed algorithm.

Key Word: High resolution satellite image, Building detection, Clustering, Edge detection

1. INTRODUCTION

Over the years, automatic and semiautomatic extraction of cartographic features from aerial and spatial images has become a subject of intensive research. Of the many cartographic features to be detected, buildings are perhaps the most salient due to their number and complexity. With the successively launching of high-resolution satellites, high-resolution satellite images can be used for the extraction of buildings for mapping application. D. Lee *et al* [1] addresses building extraction from Ikonos image in urban area. Their approach uses the classification results of Ikonos multispectral images to provide proximate location and shape for candidate building objects. Building fine extraction is then carried out in the corresponding panchromatic image through segmentation and squaring. T. Knudsen and B.P. Olsen present an automated method for building detection based primarily on the spectral characteristics of building roof.

The task of automatic building detection is difficult for many reasons. Building can be rather complex structures with many architectural details. They may be surrounded by disturbing objects. The contrast between the roof and ground may be low, which causes the difficulty of segmentation. The versatile roof materials have very different spectral characteristics. Due to all the difficulties, there have been many methods proposed to solve the problem of building extraction and description in the past. A method to detect buildings and construct 3-D shape description of buildings from a monocular aerial image with a general view is described in [3]. Mayer [4] presents a comprehensive survey on the techniques used for image-based building extraction.

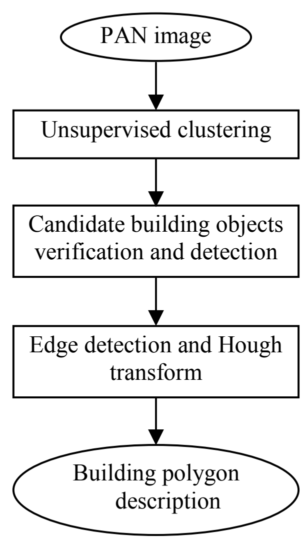

Fig.1. Flow chart of the proposed algorithm

In this paper, an automatic algorithm for urban building extraction from high-resolution satellite panchromatic image is proposed. Fig.1 shows the flow chart of the proposed algorithm. Through the unsupervised clustering, the shadow in the image is separated as one class and the building objects may lie in the clustering result of all other classes. The shadow and its direction are used as one main evident to verify the presence of building object. By this way the candidate building objects are detected from the clustering results. To refine the building boundary, for every detected candidate building object, Canny edge detection followed by Hough transform is used to construct the polygon description of building objects.

2. UNSUPERVISED CLUSTERING AND SHADOW DETECTION

The objective of clustering is to segment the building objects from their background and find out the shadow class. Because building roof material in urban area are highly diverse, to handle this, all pixels including building pixels are split up into small groups using an unsupervised clustering by histogram peak selection. Spectral diversity of ground objects in urban area makes the histogram of PAN image appear multiple peaks. So the unsupervised clustering results usually include more than two classes.

In histogram peak clustering, the local peaks are detected from the histogram, similar to histogram segmentation. The class borders are located in the local low peaks. Thus we get the initial clusters. To overcome over-segment or under-segment to building objects, A splitting and merging procedure is applied the initial clusters. For the class the maximum distance in which is too small, it is merged to the closest class. And for the class the maximum distance in which is too large, it can be further split into two or more classes. The splitting and merging procedure is repeated until appropriate clustering result comes out.

In urban area, the shadows of ground objects always lie in the image. In PAN image, shadows and water places look dark and take the lowest gray. By this fact, in the clustering result we take the class with lowest gray as the shadow class that can be used to verify the presence of building in the next section.

3. CANDIDATE BUILDING VERIFICATION AND DETECTION

The building verification process tries to establish correspondence between the building and its shadow cast. Because few building roof look as dark as the shadow, we consider that no building object lies in the shadow class. Through building verification, candidate building objects can be detected from every class except for the shadow class.

Given the sun angle of high resolution satellite, we know which side of a roof will cast shadow. Here the side is referred as the shadow side. The shadow is cast along the direction of illumination. Quickbird or Ikonos images are taken at about 10:30 AM by local time. The shadow of the building cast to its west side. Because relative high contrast between the roof and the shadow, straight line always appears on the shadow side. For the segmented object from the clustering results, the shadow side is determined first based on the sun angle. If it is the real shadow side of buildings, most of the pixels on this side should be close to the nearest shadow pixel (the distance is set less than 3). The pixel on the shadow side close to the nearest shadow pixel is referred as effective shadow side pixel. Beside the shadow evident, the size of bounding box of the segmented object can be used to verify the presence of building. From above analysis, the verification evidences for candidate building consist of the following components: (1) the longest side of bounding box of the segmented object is less than 500m and the shortest one is larger than 10m; (2) the area of segmented object is larger than $300m^2$; (3) the percentage of the number effective shadow side pixels and the total shadow side pixels large than 30%. And the shadow side must be straight line. The first evident can exclude some road objects and the second one can remove noisy small objects such as old small house which are not considered.

There are many difficulties in establishing correspondence between shadow and building. The shadow intensity can not be uniformly dark. Building sides are usually surrounded by a variety of objects such as trees. The shadow may be occluded by nearby building.

4. EDGE DETECTION AND HOUGH TRANSFORM

Edge detection and Hough transform are used to refine and construct the building delineation result for the candidate building objects detected in the forgoing section. Building roof usually has straight edges. So the Canny operator is used to detect the edge of the building objects. The extent of the candidate building object is used to define the rectangle working windows for edge detection. To avoid long line missing in under-segmentation situation, the working windows is set a bit large than the bounding box of segmented object. Due to noise and occlusion, the detected edges are usually fragment and thus not formed close boundary for the building.

To construct the polygon delineation for buildings, Hough transform is applied to the detected edges of the candidate building. From the Hough transform result, the straight line boundary can be found. The pixels on the found line, which is far from the nearest pixel in the candidate building, are removed as outlier. The found lines construct the polygon delineation for buildings. The straight line finding procedure is as follows:

(1) Find the dominate line.
(2) Find all the parallel lines of the dominate line.

(3) Find all the vertical lines of the dominate line.
(4) If the above lines can construct a polygon region, which overlaid on more than 40% area of the corresponding candidate building object, the polygon is referred as the effective delineation for the building. If the found lines can construct an effective polygon delineation, the polygon is extracted and the finding procedure for this building is terminated.
(5) Find another long line which forms an acute angle larger than 30 degrees with any found lines. Find all the parallel lines of the long line.
(6) If the found lines construct an effective polygon, extract the polygon and terminate the finding procedure for this building.
(7) If less than two long lines are determined and another long line can be found, go to (5).

5. EXPERIMENTAL RESULTS

The data used to test the proposed algorithm are Quickbird PAN image of Beijing city taken in 2002. Fig.2 shows the results of several examples on small windows. The manual delineation is also shown as comparison. Note that even the building boundary is noisy, our algorithm still successful locates the correct building boundary. However, in some case the extracted building is over-delineation because of over-segmentation and the some building is lost because of under-segmentation.

6. CONCLUSION REMARK AND FUTURE WORK

We have proposed an algorithm to extract building from a single PAN image of high resolution satellite in urban area. With shadow evidences, building objects can be separated successively from road objects that usually have similar gray with buildings. But the performance of extraction relies on the clustering results. The building may be lost in under-segmentation. And the extracted polygon may be over-delineated in the over-segmentation.

There is still much room for improvement with respect to increase the extraction rate and the refine delineation of building. There is also lots of additional information that can be incorporated into the analysis. In future work, to increase the extraction rate, the multispectral images can be used in extraction process. The texture measure may be taken into account. To further refine the delineation, tracing of the boundary can be consider after line finding to the Hough transform.

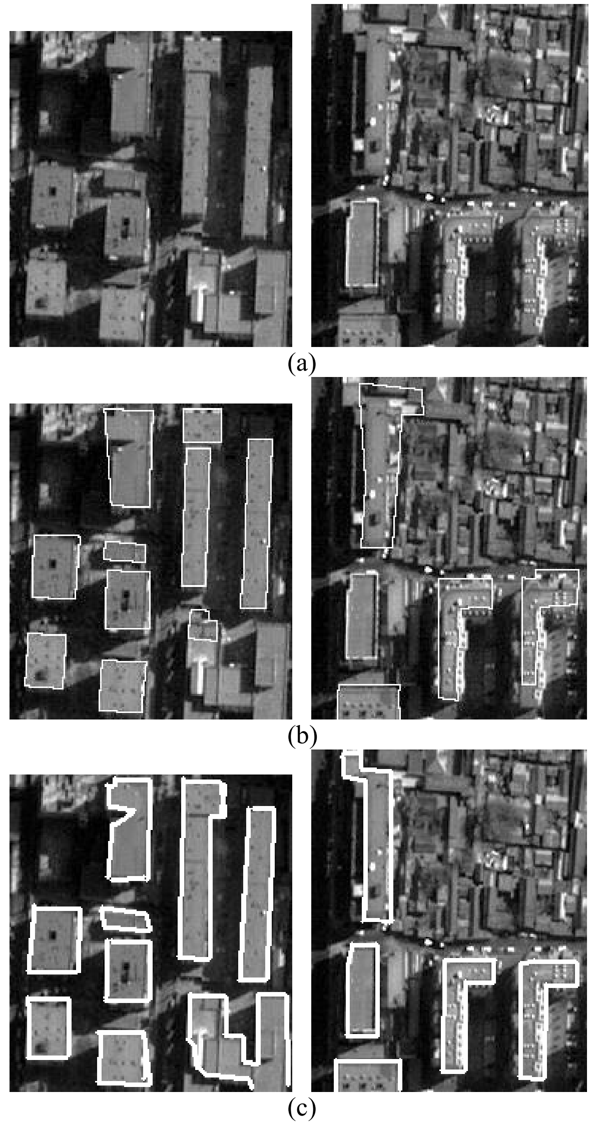

Fig.2. (a) PAN images, (b) extracted buildings by our algorithm, (c) manual delineation of buildings.

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