BUILDING EXTRACTION USING LIDAR DATA AND VERY HIGH RESOLUTION IMAGE OVER COMPLEX URBAN AREA

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ABSTRACT

This paper proposed a novel urban building extraction method to address the problems with shadow and spectral confusion using LiDAR data and very high resolution (VHR) imagery. The buildings were first extracted using height from LiDAR data and normalized difference vegetation index (NDVI) from VHR image. A refinement step was then adopted to reduce the errors caused by shadow and spectral similarity between the buildings with color roofs and vegetated roofs and the trees. A post processing step was finally conducted to further improve the result. The proposed method was quantitatively evaluated and compared with existing method using airborne LiDAR data and Quickbird image. The results indicated that the proposed method significantly outperformed the existing method. The proposed method is applicable for building extraction using VHR image and LiDAR data over complex urban areas with tall buildings and buildings with color roofs or vegetated roofs.

***Index Terms*—**building extraction, LiDAR, VHR image, shadow

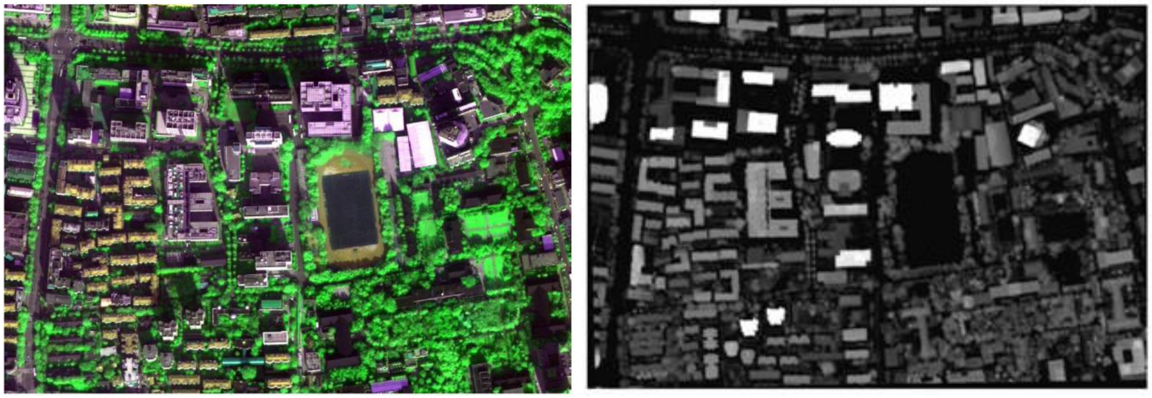
1. INTRODUCTION

Urban building information is important for many urban applications. The increasing availability of very high resolution (VHR) images from satellites like IKONOS, Quickbird, GeoEye-1 and Worldview-2 provides great opportunity for extracting buildings from these images. Airborne LiDAR data provide complementary information for building extraction at fine scale. Although a lot of work has done in the past decade on urban building extraction from both VHR imagery and LiDAR data, most existing studies focus on the development of new algorithms and methods, and evaluate these algorithms/methods using images from relatively homogeneous areas. However, due to different factors such as occlusion, shadow,spectral similarity and many others, building extraction in complex urban areasusing VHR images and LiDAR details still a challenging task.In this study, we propose a novel method of building extraction in a complex urban area using combined LiDAR data and VHR imagery.

2. METHODS

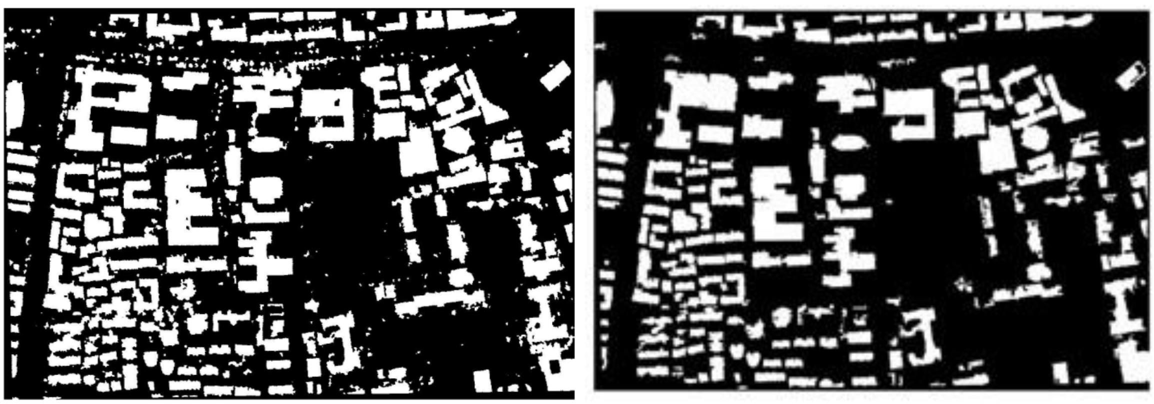
The proposed method mainly addresses the problems with shadow and spectral similarity common in VHR image. The method can be summarized as follows.Based on height information from LiDAR data (i.e. normalized Digital Surface Model (nDSM) from original cloud data) and NDVI (normalized difference vegetation index) from VHR image, initial results of building extraction was first produced. A refinement step was presented to extract buildings in the shadow areas and buildings with color roofs and vegetated roofs. Finally, a post-processing method was adopted to further improve the result obtained in the previous steps. The proposed building extraction method is conducted on object level. So, image segmentation was first conducted.

2.1.Image Segmentation



(a) (b)

Figure.1 Quickbird image (a) and nDSM image (b) of the study area



(a) (b)

Figure. 2 Building extraction results from different methods: (a) using nDSM and NDVI thresholding directly; (b) by the proposed method.

A multilevel hierarchical segmentation method proposed in[1] was adopted in this study. However, this is not a general requirement. Any other multilevel hierarchical segmentation method can also be used. The LiDAR data (i.e. nDSM data) and VHR image were separately segmented.The segmentation results of LiDAR data were used as the base of building extraction, while thesegmentation results from VHR image were used to extract shadow and vegetation.

2.2.Initial Building Extraction

After image segmentation, average values of height and NDVI for each object (segment) were separately calculated. A height threshold was setto separate ground objects and non-ground objects (including trees and buildings), whilea NDVI threshold was set to distinguish between vegetation and non-vegetation. Then initial buildingswereidentified as the segments withthe heightshigher than the specified threshold (i.e. non-ground objects) and the NDVI valueslower than the specified threshold (i.e. non-vegetation).

2.3.Refinement

The initial building extraction result produced in the previous step contains some non-building objects, i.e. trees in shadow areas which show low NDVI values. In order to removethe trees in shadow areas from the initial result, shadow areas were first extracted from the VHR image using the histogram thresholding method [2]. Those objects in shadow areas with DNVI values higher than the threshold values (i.e. trees)were removed from the building extraction result produced in the previous step.

Another problem with the initial building extraction results is that buildings with color roofs and vegetated

Table 1 Accuracy of building extraction using different methods (all in percent)

Methods adopted	OA	Kappa	Accuracy of target class (building)	
			PA	UA
1	91.21	78.10	90.00	79.01
2	92.71	80.71	83.45	87.83

1, using nDSM and NDVI thresholding directly; 2, by the proposed method.OA, overall accuracy; PA, producer's accuracy; UA, user's accuracy.

roofs were wrongly classified as trees due to spectral similarity. Arefinement method was presented to detect these buildings with green roofs and vegetated roofs.Given that these buildings and trees show different spectral variations, image texture was used to separate them. Image texture measured using variogram was extracted from nDSM data and VHR image (panchromatic band)respectively. Buildings with color roofs and vegetated roofs were separated from the trees by thresholding the nDSM texture and panchromatic texture separately and then were combined.

2.4.Post-processing

A post-processing method is proposed to further improve the result obtained in previous steps. The post-processing method includes two steps. Since buildings are usually of a certain size, a size threshold was first set to remove objects with size less than the threshold from the extracted buildings. The errors caused by mis-registration (such as some very thin objects) were reduced by a morphological method, called morphological reconstruction by erosion, where initial building extraction result and dilated initial result areconsidered as mask image and marker image, respectively. Moreover, edges of extracted buildings became regular and straight after morphological reconstruction.

2.5.Result evaluation

Evaluation of building extraction results is a very important step. However, there are no uniform evaluation criteria. In this study, the extracted buildings are quantitatively compared with reference data. The reference buildings are generated using manual interpretation of nDSM data with support of VHR image. Three categories of evaluation indices were adopted: pixel-based, object-based and spatial distribution [3].

3. DATA AND STUDY EREA

The LiDAR data set used in this study was acquired over Nanjing urban area. A pan-sharpened Quickbird image of the area, was also used in the experiment. The normalized DSM (nDSM) was first generated. The obtained nDSM was then co-registered with pan-sharpened Quickbird image. A subset of 1364 × 936pixels was finally used in the study (Figure 1). The image subset covers a portion of the dense urban area.

4. RESULTS AND DISCUSSION

Table 1 shows results of building extraction using different methods. From the table, the proposed method produced more accurate resultscompared with the existing method, in terms of overall accuracy and kappa coefficient. Moreover, the producer's accuracy and user's accuracy are more balanced. Form Fig. 2, it is easily found that using height and NDVI thresholding directly many trees in shadow areas were wrongly identified as buildings (Fig. 2(a)). However, using the proposed method, these trees were removed. Furthermore, edges of the extracted buildings produced by the proposed method are more straight and smooth (Fig.2(b)). An analysis of error distribution in the area show that the errors in the result produced by the proposed method are mainly from several factors, such as mis-registration, occlusion of buildings and trees, errors in image segmentation, threshold setting and errors inherent in LiDAR data. This may provide some clues to future research.

5. CONCLUSION

This paper proposed an automatic building detection method using LiDAR data and VHR imagery of complex urban area, where shadow cast by tall buildings and spectral confusion between green-roof buildings and trees made building extraction difficult. The experimental results showed that the proposed method effectively reduced the errors caused by these factors and produced higher accuracy than the existingmethod. Moreover, the analysis of errors in building extraction was also performed.

6. REFERENCES

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