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Fusion of Lidar and Imagery for Reliable Building Extraction

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Abstract

We propose a new building detection and description algorithm for lidar data and photogrammetric imagery using directional histograms, splitting and merging segments, and line segments matching. Our algorithm consists of three steps. In the first step, we extract initial building regions from lidar data. Here, we apply a modified local maxima technique coupled with directional histograms and the entropies of these histograms. In the second step, given the color segmentation results from the photogrammetric imagery, we extract coarse building boundaries based on the lidar results with region segmentation and merging from aerial imagery. In the third step, we extract precise building boundaries based on the coarse building boundaries using line segments matching and perceptual grouping. Experimental results on multisensor data demonstrate that the proposed algorithm produces accurate and reliable results.

Introduction

In recent years, the increasing need for accurate three-dimensional (3D) data of urban areas, and their continuous update has led to research efforts that aim to develop automatic or at least semiautomatic tools for the acquisition of such data. To satisfy the new demands, more automated methods that produce accurate geo-information are required to keep costs within reasonable bounds. With its high pulse frequencies, light detection and ranging (lidar) is a very valuable data source for the production of geo-information. For this reason, lidar plays an important role in both the automation of building detection and the creation of 3D topographical databases.

Early researchers generally used three kinds of methods to detect and reconstruct buildings from lidar data and photogrammetry. The first technique is to use only lidar data, because the photogrammetry of the region that corresponds to the region of the lidar data maybe impossible to obtain. There have been several attempts to detect building regions from lidar data. The task has been solved by classifying the lidar points according to whether they belong to bare-earth, buildings, or other object classes. Morphological opening filters are used to determine a Digital Terrain Model (DTM) that can be extracted by subtracting object points from the Digital Surface Model (DSM). By applying height thresholds to the normalized DSM, an initial building region is obtained. This initial classification must be improved to delete vegetation regions. In Brunn and Weidner (1997), this was accomplished by a framework for combining various cues in a Bayesian network. In Rottensteiner and Briese (2002), an algorithm for building detection that relied on DTM generation by hierarchic robust linear prediction (Briese *et al.*, 2002) was presented. The DTM and DSM grids in Rottensteiner and Briese (2002) were used for further classification.

The second type of method is to use 2D or 3D information from photogrammetric imagery. Early researchers tried to extract feature-ground separation, but it is hard to separate building boundaries from other distracting lines, such as road boundaries, by using only perceptual information such as parallel lines and right-angled corners. Therefore, other information is used for building extraction. The most notable is the depth information from stereo by multiple images (Sun *et al.*, 2005). Kim and Nevatia (2004) proposed a method that automatically constructs the description of complex buildings from multiple images. The main difficulty in utilizing stereo information is that although range data can be generated from stereo analysis, its quality is not good enough to generate building hypotheses directly, since the roofs of many buildings lack sufficient texture for stereo processing. In addition, nearby trees of similar height also make the use of such range data difficult.

The third type of methods uses both the lidar data and photogrammetric imagery. Since lidar and photogrammetric imagery each has unique advantages and disadvantages for reconstructing building surfaces, advantages of one method can compensate for disadvantages of the other method making it natural to combine the two methods. More specifically, intensity and height information in lidar data can be used with texture and boundary information in photogrammetric imagery to improve accuracy. Shenk and Csatho (2002) proposed feature-based fusion of lidar data and digital aerial images to obtain a better surface description than could be achieved by using only one of these data sources. Habib *et al.* (2005) proposed a method based on the registration of photogrammetric imagery and lidar data using linear features. Sohn and Dowman (2003) focus on an exploitation of synergy of Ikonos imagery combined with a lidar DEM. Specifically, individual buildings are localized with rectangle polygon by a hierarchical segmentation of lidar DEM and Ikonos multi-spectral information. However, this method has building extraction errors, such as intrusion/extrusion of building shape. The Rottensteiner *et al.* (2004) method consists of building detection step, roof plane detection step, and the determination of roof boundaries step. Building detection is based on the Dempster-Shafer theory for data fusion. In roof plane detection, the results of

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Photogrammetric Engineering & Remote Sensing
Vol. 74, No. 2, February 2008, pp. 000–000.

0099-1112/08/7402–0000/$3.00/0