Urban Building Mapping using LiDAR and Relief-Corrected Colour-Infrared Aerial Images

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Abstract - The integration of high spatial resolution airborne LiDAR and colour-infrared ortho-images provides excellent data for the automatic mapping of buildings in urban areas. However, there is still uncorrected relief displacement in the commonly available orthorectified aerial images. This can produce errors in building footprint extraction when combining the LiDAR images with the ortho-images. This paper describes a newly developed relief displacement correction method to correct for the leaning effect of the buildings and an object-based classification method to map buildings in urban areas. Using these methods, the building mapping accuracy is improved.

Keywords:

Urban, LiDAR, building extraction, high resolution orthoimages, Mapping

1. INTRODUCTION

Measurements of urban buildings, such as building footprints, heights, and structural types, provide important information for urban planning, natural disaster risk and impact evaluation, and urban climate and environmental prediction. The traditional way for extracting buildings is the conventional field survey and manual interpretation of aerial photos including on-screen digitizing and editing. Although this may have great accuracy, it requires excessive manual work and high cost. In recent decades, numerous methods have been proposed by scientists for extracting targets from remote sensing images without involving excessive manual and field work (Blaschke, 2010). Various data sources have been used to extract building footprints, such as from high resolution remotely sensed images (Ahmadi et al., 2010; Aldred and Wang, 2011) and the Light Detection And Ranging (LiDAR) data (Vu et al., 2009).

The combination of high spatial resolution aerial images and LiDAR can provide an excellent data source for the automatic mapping of buildings. However, on the commonly available orthorectified aerial images, there is still uncorrected relief displacement. This is because conventional orthorectification methods are based on a digital terrain model (DTM) – an elevation model that describes the terrain surface when buildings and trees are removed. Although the orthorectification removes the topographic effects, it cannot remove all the relief displacement of tall objects (such as buildings and trees). This creates significant positional errors since the rooftops of the buildings are displaced away from their footprints. Very few methods have been developed to correct for these errors (Zhou and Kelmelis, 2007; Lehrbass and Wang, 2010).

The objective of this study is to apply a newly developed method to correct for the leaning effect of the buildings on the orthorectified Colour Infrared (CIR) aerial images, combine the corrected CIR images with the LiDAR data, then use object-based classification to map buildings.

2. METHODOLOGY

The study area is part of London, Ontario, Canada, including the University of Western Ontario (UWO). It includes many different types of buildings, such as tall institutional buildings on the UWO campus and a diverse mixture of residential houses. The study area also includes natural areas, developed parks, rivers, and bridges. The site was selected because of its complexity and its diversity of land cover types.

There are two main stages of the proposed method: (1) Correction of the CIR orthoimages for Building relief displacement removal; (2) Object-based building footprint extraction by combining the relief-corrected CIR images and the LiDAR data.

2.1 Building relief Displacement Correction

In order to map urban tree cover, Lehrbass and Wang (2010) proposed a new method for correcting the cross-track relief displacement in an already orthorectified optical image using LiDAR data. This method is applied in this study to correct for the relief displacement of tall buildings.

In the DTM orthorectified colour-infrared (CIR) images, tall buildings are misaligned due to relief displacement. This causes the top of a building to be displaced from the building footprint; the taller a building is and the further it is from the image's principal point, the more it appears to lean away from the principal point radially. By measuring the relief displacement at rooftop control points, a linear regression can be performed to estimate the location of the flight line. This estimated flight line can be used with the control points to calculate an apparent flying height. Using these estimated parameters with the LiDAR derived Normalized Digital Surface Model (NDSM), the cross-track relief displacement can be predicted for all points in the orthoimage. With this method, the tall objects can be aligned between the LiDAR and the CIR images (Lehrbass and Wang, 2010).

2.2 Building Extraction

A new procedure is proposed for building extraction using the object-based classification method from the relief-corrected CIR images and the LiDAR derived NDSM (Figure 1).

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The first step is to perform an image segmentation and to remove water areas. This can be done using the LiDAR derived Point Density Model (PDM). When the LiDAR point cloud data are interpolated into a raster NDSM, the values for water bodies can be wrong due to poor reflection of LiDAR signals from water's surface. There are usually no LiDAR returns for those areas. Therefore, the water areas can be identified where the PDM is close to zero.

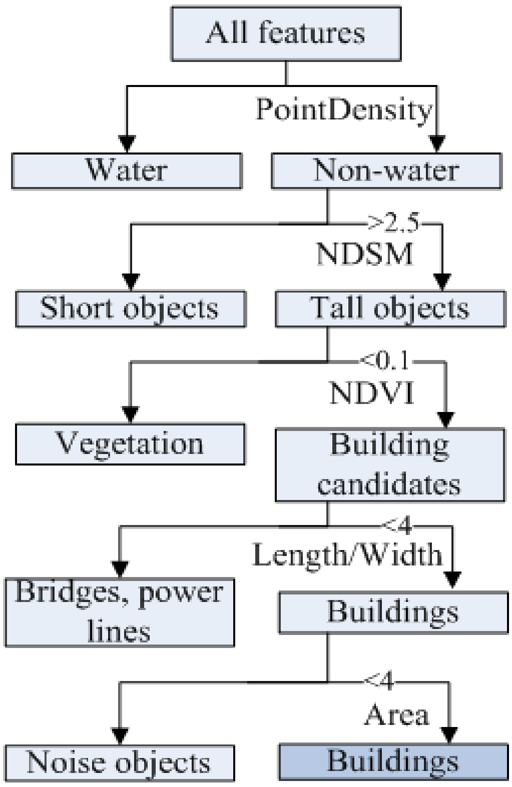

Figure 1. Proposed procedure of building extraction from LiDAR data and the relief-corrected Colour Infrared imagery

In the second step, an image segmentation is performed on the non-water area using the NDSM. A threshold is applied to separate ground objects from tall objects. We assume that a building should have a height at least 2.5 meters. Optical images contain spectral information but no height information. Roads and buildings usually have similar spectral reflectance values in all wavelength bands. This leads to difficulty to differentiate them using only optical images. An NDSM provides a vital parameter to distinguish buildings from roads and other ground objects by using the height information.

The third step is to distinguish man-made objects from vegetation within the tall object class. Optical images provide useful information to achieve this task. The Normalized Difference Vegetation Index (NDVI) is calculated. From our experiment, most of the buildings have an NDVI value less than 0.1, so we use "NDVI<0.1" as the threshold to eliminate vegetation from man-made objects.

The tall object class from the third step contains mainly buildings. However, it also contains power lines, higher roads and bridges which have a height greater than 2.5 meters, such as bridges over rivers and overpass roads. When we observe these features carefully, they all appear as linear features or skinny objects. Building objects in general have a length to width ratio less than 4. Since there are still some long shaped buildings, we also need to preserve the long buildings when determining the rule to delete the skinny non-building objects. Therefore the rules are defined as follows. If an object has a length to width ratio greater than 10, it will be deleted; if a building has a length to width ratio between 4 and 10, and it has an area less than 50 square meters, then it will also be deleted.

After removing the skinny objects from building candidates, post-processing is performed to generate a refined map of building footprints. There are still some small sparse vegetation objects, high street lamps, construction debris, as well as noise objects left as building candidate objects. Therefore, the next step is to remove very small objects. We assume that buildings should have at least a size of 2 meters by 2 meters, so objects smaller than this are removed. The boundaries of the buildings are then smoothed to avoid too many acute corners.

3. RESULTS

The above described procedure was applied to the CIR images and the LiDAR data for the study area. Figure 2 shows a sub-image of the result of building extraction. It can be seen from Figure 2 that most buildings have been well detected.

In order to evaluate the accuracy of the building extraction, 500 random reference sample points were generated. All these points were evaluated via visual interpretation based on all available reference maps and images. The validation points are shown on Figure 2 as belong to building (red cross) or non-building (yellow cross).

For this small test area, the object-based classification using the LiDAR data with the uncorrected CIR image produced an overall accuracy of 98.2% for the two classes (Building and Non-Building), with a Kappa coefficient of 0.918. For the same method applied to the LiDAR data combined with the CIR image after relief displacement correction, an improved result was achieved: an overall accuracy of 99.2% and a Kappa coefficient of 0.965.

Figure 2. The extracted building boundaries and validation points. The background is the original colour infrared image.

4. CONCLUSION

In this paper, we have presented a building extraction approach based on relief displacement corrected aerial imagery and LiDAR. After tall object relief correction, the buildings are better-matched positionally between the corrected CIR images and the LiDAR. In the proposed method, height information from LiDAR is used to differentiate ground objects and tall objects. The CIR imagery is used to distinguish vegetation and buildings according to their different NDVI values. Extra information has been used to generate a refined result, such as the length to width ratio and the area of objects. The validation results show that the proposed method achieved high accuracy for building extraction, while the one based on corrected images performed better in the building edge areas.

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