SYNERGY BETWEEN LiDAR AND IMAGE DATA IN CONTEXT OF BUILDING EXTRACTION

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ABSTRACT:

This paper compares the paradigms of LiDAR and aerophotogrammetry in the context of building extraction and briefly discusses a photogrammetric strategy for refining building roof polyhedrons previously extracted from LiDAR data. In general, empirical and theoretical studies have confirmed that LiDAR methodologies are more suitable in extracting planar roof faces and ridges of the roof, whereas the aerophotogrammetry are more suitable in extracting building roof outlines. In order to exemplify how to explore these properties, it is presented a photogrammetric method for refining 3D building roof contours extracted from airborne LiDAR data. Examples of application are provided for this refining approach.

1. INTRODUCTION

Building extraction methods are very important in the context of spatial data capture and updating for GIS applications. These methods may be classified into three categories according to the kind of input data, i.e.: methods using LiDAR data (e.g., Wei, 2008; Galvanin and Dal Poz, 2012), using photogrammetric data (e.g., Müller and Zaum, 2005; Sırmaçek and Ünsalan, 2011), and combining LiDAR and photogrammetric data (e.g., Kim and Habib, 2009; Cheng et al., 2011).

Specifically, building extraction methods combining LiDAR and image data aim at taking advantage from the synergy between both data sources. Building roof boundaries are potentially well defined in image data than in LiDAR data. The opposite occurs when the goal is the reconstruction of surfaces with homogeneous texture, like the planar surface of roof faces. The main motivation of this paper is the possibility of refining the contours of the LiDAR derived building polyhedron by using their well-defined planar roof faces and the corresponding well-defined building roof contour extracted from only one high-resolution aerial image. This paper is organized as follows. Section 2 briefly reviews the main aspects of the synergy between LiDAR and image data in context of building extraction methods. Section 3 presents an approach for refining building polyhedrons previously extracted from LiDAR data using a line-based photogrammetric model, along with some experimental results. Finally, the paper is finalized in Section 4 presenting some conclusions.

2. SYNERGY BETWEEN LIDAR AND IMAGE DATA IN CONTEXT OF BUILDING EXTRACTION

Building extraction using LiDAR data or image data shows advantages and disadvantages (Kaartinen et al., 2005.). In order to reconstruct polyhedral-like buildings it is necessary to basically extract from the data (image and/or LiDAR) planar roof faces and rectilinear building boundaries. The extraction of planar roof is more reliable and accurate when accomplished from LiDAR data. This is usually true because roofs are usually homogeneous in optical images and, as a result, it is very difficult to extract dense positional information along them using photogrammetric techniques. Moreover, the opposite takes place when using LiDAR-based techniques. In addition, roof plane orientation is better when using LiDAR data than using photogrammetric data. Since LiDAR roof face planes are well-defined, roof ridgelines derived by intersection of these planes are well-defined as well. Concerning the extraction of building boundary, the use of photogrammetric data is advantageous because positional information along break lines is dense in photogrammetric images and usually poor in LiDAR data. As a result, if one wants to accurately extract building boundaries, photogrammetric data should be used in order to accurately detect and delineate edges related to building boundaries. In general, fine details, like edges, corners etc., should be extracted with the help of photogrammetric images. Finally, photogrammetric images are also necessary to attribute accurate and complete semantic meaning to a whole building or to parts of a building.

In general, due to above properties hybrid approaches combining LiDAR and photogrammetric data can potentially deliver results with better accuracy, reliability, and completeness than ones obtained using either LiDAR or photogrammetric data.

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3. BUILDING REFINEMENT APPROACH

3.1 Line-based method

The proposed method for refining the LiDAR-derived building polyhedron is based on two main steps. First, straight lines representing the sides of a selected building roof contour are extracted from the image and projected onto corresponding LiDAR derived building polyhedron faces by using a line-based photogrammetric model. Figure 1 shows the geometric principle of the proposed method for projecting image-space straight lines onto corresponding building polyhedron faces. For instance, let´s consider the polyhedron edge $\overline{\mathbf{A'B'}}$ (dashed line in Figure 1) to show how to photogrammetrically refine it. Suppose that the image-space straight-line segment $\overline{ab}$ corresponds to the polyhedron edge $\overline{\mathbf{A'B'}}$. As such, the segment $\overline{ab}$ defines one of the sides of the building representing the polyhedron in the image. Moreover, their endpoints or parameters can be measured in the image, manually or by an appropriate algorithm. The projection of the line segment $\overline{ab}$ onto the corresponding building polyhedron face (resulting in the 3D straight-line $\overline{\mathbf{AB}}$) is based on the intersection between two planes (Figure 1), as follows:

- Plane defined by the perspective center (**PC**) and the line segment $\overline{ab}$;
- Plane containing the polyhedron points **A'**, **B'**, **C**, and **D**.

As shown in Figure 1, the intersection of both planes generates the straight line **r** containing the unknown points **A** and **B**.

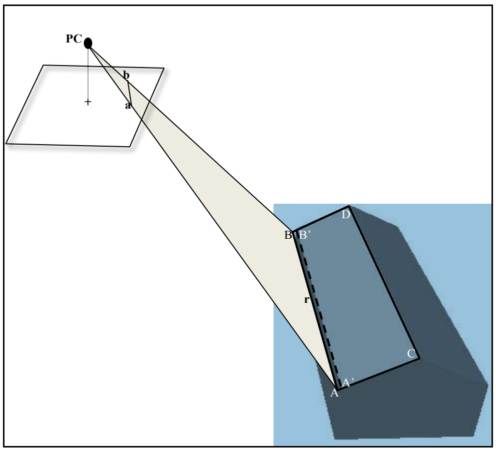

Fig. 1 – Princípio do modelo fotogramétrico para projeção de retas.

Finally, in the second step the refined contour of the polyhedron is determined by connecting every pair of adjacent projected lines, resulting in a new set of contour vertices.

3.2 Example

The example presented below is based on one hip-like roof (Fig. 2) selected in a high-resolution aerial image (GSD~ 0.2 meters). The corresponding polyhedral model was extracted from a low-density (about 2 pts./m^2) LiDAR point cloud. A reference polyhedron model was also manually extracted through stereo photogrammetric intersection.

In order to preliminarily check the feasibility of the refining method the discrepancies (i.e., the Euclidian distance between corresponding vertices) between the LiDAR derived and reference building roof contours and between the refined and reference building roof contours are computed. These discrepancies show that the refining method allows a clear improvement in the geometric quality of the LiDAR derived building roof contour. Moreover, the Root Mean Square Error (RMSE) shows that the refined building roof contour is significantly (almost twice) more accurate than the LiDAR derived building roof contour.

Fig. 2 - Test building roof

4. CONCLUSIONS

This paper presented an overview of advantages and disadvantages of LiDAR and aerophotogrammetry paradigms in the context of building extraction and briefly presented a photogrammetric strategy to take advantage of the synergy between both data sources. The example of application confirmed that the proposed photogrammetric strategy was useful in improving the accuracy of the boundary of the LiDAR- derived building polihedron.

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