ABSTRACT

Kim, KyoHyouk. Ph.D., Purdue University, May 2011. 3D Building Reconstruction from Airborne Laser Scanning Data. Major Professor: Jie Shan

Buildings are commonly acknowledged as the most prominent objects in the generation of a 3D virtual model of our environment. Determining their exact locations, spatial extents, patterns, or detailed geometric structures is often required in a range of applications, such as urban modeling, city planning, or virtual reality. Land surveying and photogrammetry have been the conventional approaches for this purpose; however, both are very labor-intensive and time-consuming processes. Since the late 1990's, new data sources, such as high-resolution images and airborne laser scanning datasets, became available that required the development of more advanced algorithms. These new approaches continue to be studied as new sensor technology with higher resolution and accuracy are developed. Chief among the current day technology is Light Detection And Ranging (LiDAR), which has been successfully used for this field of study over the past two decades.

LiDAR is an active remote sensing system with the integration of three state-of-the-art technologies (lasers, a global positioning system (GPS), and an inertial navigation system (INS)). LiDAR uses an onboard laser scanner to provide the source of energy and is a promising solution to topographic mapping. Compared with conventional surveying and photogrammetry-based approaches, LiDAR systems allow for determining the 3D position of the footprint of a laser beam as it hits an object with a high degree of accuracy in a short period of time. LiDAR provides data for high-resolution digital elevation models (DEMs), digital surface models (DSMs), and detailed 3D building models. However, the use of LiDAR data also imposes several new challenges, most of which emanate from the characteristics of LiDAR data (i.e., discrete and irregular patterns of measurements) and the huge size of the data. Furthermore, fully automatic 3D building reconstruction has not been achieved yet because of the significant heterogeneity in appearance and complexity of buildings, which therefore still requires a human operator.

The main objective of this study is to reconstruct 3D building models from airborne laser scanning data. While most existing approaches show promising results toward automatic generation of 3D building models, a number of issues remain to be addressed.

In the context of LiDAR filtering, most of the existing filtering algorithms require a priori knowledge about the study areas, which is denoted as input parameters to the given algorithm. These parameters often vary depending on the terrain characteristics. Therefore, it is critical to determine the optimal set of parameters to obtain the most promising results. However,

determining those parameters is not always straightforward and often requires many trial-and-error processes. It is even more difficult when the terrain characteristics over the study area are not uniform. In the context of the extraction process, segmented roof planes are mostly fragmented, which often leads to confusion in determining the neighbourhood relations among complex roof segments. Furthermore, the number of roof planes that exist in the given building is a critical input parameter in some clustering algorithms, which leads to an additional processing step. Locating height discontinuities (also called step edges) exclusively from the segmented LiDAR points is also difficult and often requires additional information or constraints.

To resolve these issues, in this thesis, we introduce novel approaches to LiDAR filtering, segmentation of the point cloud, and 3D reconstruction. First, we propose a novel filtering algorithm to separate the ground and non-ground LiDAR points. The main effort is devoted to simplifying and overcoming the shortcomings of the existing morphological filtering algorithms. Compared to the existing methods, the proposed approach is less dependent on parameters such as the slope of the terrain and the window size, which enables the proposed method to be applied to varying terrains with minimal parameter changes. Second, we propose a new methodology for the segmentation of point clouds. We formulate the region-based segmentation under the framework of level set theory. Unlike other segmentation approaches, the segmented roof planes are always connected without gaps or empty regions in this approach, which helps sustain the same topologic relations of the given building roof form, thereby defining the roof structures and supporting the 3D roof reconstruction. We then propose the complete framework for an automatic 3D building reconstruction from airborne laser scanning data and aim to achieve 3D building models between LOD1 and LOD2 complexity, depending on the average point density of the input data we use. Finally, the applicability, efficiency, and robustness of the proposed approach are demonstrated with different sample data sets.