Potential and idiosyncrasy of Object-based image analysis for airborne Lidar-based building detection

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Abstract: Today, a plethora of approaches exists that can be used for the task of object extraction from LiDAR data (point and/or derived raster information). The majority of approaches deal with the extraction of artificial objects or distinct natural objects (e.g. single trees). Local height variations or number of signal returns are often input to extraction processes. If only relying on pixel-based concepts, results of such analyses may provide sufficient detection accuracy but they may also generate various misclassified objects since they lack object-based view. In the presented paper, we developed an Object-Based Image Analysis (OBIA) approach for building extraction starting from LiDAR point data only. We hypothesize that an OBIA approach could performs better than a pixel-based approach as it resembles the way in which humans perceive reality. The developed method consists of a set of rules applied to continuously re-shaped (based on pre-classifications) candidate objects. The results of the proposed approach have been compared to buildings which were manually identified from a Digital Surface Model (DSM). Primary results show completeness value of 97.80% and correctness of 80.5%.
Keywords: Remote Sensing, Geography, LiDAR, Image processing and analysis.

1. Introduction

Today, LiDAR data became one of the new data sets which could be collected for vast areas in a short time frame. The collected data contains a lot of valuable information but in order to give it contextual value, the data needs to be analyzed and transformed into meaningful form. In order to do this, many scientist developed their own approaches for data extraction from LiDAR point clouds. The majority of approaches deal with the extraction of artificial objects or distinct natural objects such as single trees (Aparecida dos Santos Galvanin, 2012; Haala and Brenner, 1999; Nardinocchi and Scaioni, 2001; Saeedi, Samadzadegan, and El-Sheimy, 2009; Wang and Schenk, 2000; Yao, Krzystek and Heurich, 2012; Zhao, You and Huang, 2011). As already proved by Lang and Blaschke (2003), artificial objects can be often more easily extracted from the available data because the spectrum of natural objects usually exceeds that of artificial objects in number and complexity of the genesis. A widely used method in extraction workflows from LiDAR data is basic local neighborhood calculations applied to point clouds or their 2D/2.5D derivatives with an addition of a basic classifier. Furthermore, local height variations or number of signal returns are often input to extraction processes. By including this information, further accuracy improvement is expected. For example, an isolated coniferous tree can be wrongly interpreted as a building based on its height difference compared to the surroundings. Likewise, a transparent roof consisting of glass may get misclassified as vegetation based on the multiple returns it could generate. To avoid these occurrences, we developed an Object-Based Image Analysis (OBIA)

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approach to extract buildings from LiDAR point data. OBIA has gained an increasing importance in the classification of the remotely sensed data (Blaschke, 2010). It relies on the segmentation of the underlying data and the classification of the resulting image objects into the desired classes, in which object-generation and classification can be coupled in a cyclic manner (cf. Lang, 2008). Only view studies are available which focus on the direct integration of OBIA and the LiDAR point cloud itself (Höfle and Hollhaus, 2010; Tiede et al. 2012).

2. Test data set and developed methodology

Our data set represents the area of Biberach and der Riss in Germany. The data was recorded with the Trimble Harrier 68i system. The point cloud consists of multiple returns with recorded intensity and a density of 4.8 points per square meters. The flight was conducted at the height of 600 m above ground with a swath width of 693 m. The recorded data were pre-processed and corrected in terms of horizontal and absolute height shifts in relation to the reference data that was collected (GCPs and buildings' polygons). Strips have been corrected in terms of roll, pitch and heading and vertically aligned to each other.

The procedure begins with the generation of a Digital Surface Model (DSM) derived from the last pulse data. Based on the generated DSM, a slope layer is derived and segmented to extract initial buildings outlines. In order to separate ground from elevated objects, we calculate the height difference between the objects and their imminent surrounding defined by a narrow buffer zone based on neighboring pixels (not objects, avoiding errors through generalized object mean values). Elevated objects are removed from the DSM through pixel re-growing process and a digital terrain model (DTM) is generated. The created DTM is subtracted from the last pulse DSM resulting in a normalized digital surface model (nDSM). The object delineation process repeats as described before, but now the newly generated elevated segments are undergoing a cyclic series of classifiers and rules in order to re-shape initial objects and to delineate and extract single building objects. Within this process, we make use of object-specific properties like for example geometric features (area, ratio between circumference and area, shape index, rectangular fit), topological relationships (neighborhood/containment using pre-classifications) and height property linking directly to the underlying LiDAR point data (point data statistics per object). The described procedure is realized through Cognition Network Language (CNL), a modular programming language in the eCognition software package (Trimble Geospatial, Munich, Germany). It allows the direct connection of *.las point files and derived objects in a knowledge framework.

The building classifications obtained using the object-based approach described above were compared to a reference data which was obtained by visually interpreting the DSM raster and marking each building with a point feature. A "point-in-polygon" metric was used in order to calculate thematic accuracy of the whole approach.

3. Results and discussion

The accuracy assessment of the building classifications results are depicted in Table 1. By visually inspecting DSM raster 820 building objects were identified. Our approach extracted 802 building-polygons in total (Figure 1). From 802 polygons, 642 (80.05%) were correctly extracted single buildings and represent correctly extracted forms. 63 polygons (7.86%) represented situations in which two or more buildings were enclosed by one polygon.

Reason for such occurrences are the closeness of some buildings which resulted in joining them during the extraction process. 97 (12.09%) polygons did not represent buildings and are considered as false positives.

Table 1. Accuracy measurement of obtained results

Description	Results
Total number of polygons extracted with the rule set	802
Total number of polygons extracted manually from the DSM	820
Amount of extracted polygons which represented single building	642
Amount of extracted polygons where buildings got merged into one	63
Correctly classified buildings	80.5%
Incorrect classification (false buildings or more buildings merged together)	19.95%
Connected building polygons (Two or more buildings merged together)	7.86%
Polygons that are not buildings but were identified as such	12.09%
Completeness (amount of candidate building polygons)	97.80%
Correctness (amount of candidate objects that ARE buildings)	80.05%

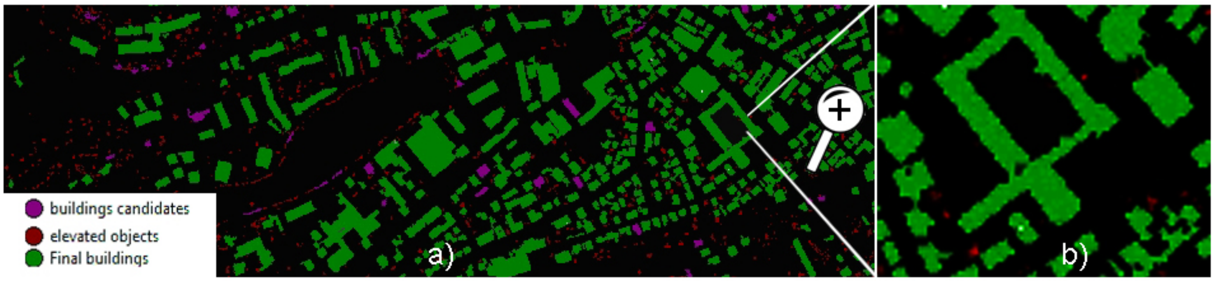

Figure 1. a) Successfully classified objects (green) and b) zoom into an area to provide closer look

4. Conclusion

The presented study showed the successful implementation of an object-based approach for the building extraction from LiDAR point data only. The method relies on sequences of segmentation and classification techniques implemented with use of CNL modular programming language. The method performed good in extracting complex-shaped building structures but in some cases failed to separate structures which are relatively close to each other or share the same wall. In the future work we plan to test the transferability of the proposed methodology to different study areas and different LiDAR data.

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