3D Building Change Detection on the basis of Airborne Laser Scanning Data

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Abstract

The paper presents the possibility to use airborne laser scanning (ALS) for building change detection. For the analysis data was gathered during two campaigns: 2003 and 2011. As research area we chose a test site covering 0.72 km², representing different kind of land cover classes: water, buildings, vegetation, bare-ground, and other artificial and temporary objects. The extraction and classification of the objects was performed in 3D in order to preserve all information contained in the data, i.e., the original point cloud. The first, results of our study present the advantages and new possibilities in buildings change detection in 3D, which were not possible in the analysis based on satellite and aerial images only.

Keywords: LiDAR, classification, building change detection.

1 Introduction

In the last decades the detection of land cover changes (LCC) has been investigated intensively [1]. The rational is the desire to acquire the knowledge on actual anthropogenic and natural changes which occur in the environment, to understand the reason for these processes, and eventually to predict the trajectories of change in the future [2, 3].

Studies focused on the change detection of buildings and generally on LCC can be based on different kind on data. The first studies in this field were based on the analysis of old historical topographic maps, used to reconstruct changes which occurred in the past [4, 5]. With the passage of time and the development of new technologies, exploiting aerial and satellite platforms, it was possible to verify the changes on a basis of images, more precisely photographs, representing the terrain with the vertical view. Many studies are concerned with algorithms for land cover classification on basis of these images and methods for evaluation of the results [6, 7, 8].

In the last decade airborne laser scanning (ALS) matured as a technology, and it is generally used for the measurement of the Earth surface. Laser scanning provides point clouds and is inherently 3D. Often, the 3D content of the data is ignored and the point cloud is transformed during early processing stage into surfaces. In the last years, however, a plenty of different applications directly in the point cloud appeared [9]. One of these applications is LCC detection. So far this have not been analysed intensively, possibly also due to the lack of suitable time series data.

The first studies in building change detection, based on digital surface models (DSMs) comparisons, have been proposed by Murakami et al. [10], and Vögtle and Steinle [11]. Another studies [12, 13] showed the potential of integration the information from aerial images and ALS data for detection of building change. The study presented changes in 3D environment on a basis of 3D Surface Separation Map (SSM) has been proposed by Xu et al. [14].

Our aim is to investigate, if a 3D approach has advantages in building change detection for urban planning, and if such 3D approach is feasible. Due to this fact we are not focused on verification and comparison of 2D buildings classification correctness with respect to aerial and satellite images.

In this research we analysed ALS data gathered over an eight year time interval.

2 Research area and data

As research site we selected the city of Bregenz located in relatively flat terrain at the foot of the hill, and with the access to a lake. The test site covers an area of 0.7225 km². The area represent a variety of land cover classes such as: water, buildings, vegetation (forest, fields), artificial objects, temporary objects (cars, boats, trains), and bare earth terrains.

The data was gathered during two laser scanning campaigns in October 2003, and in April 2011 respectively. The data sets represent X, Y, Z coordinates and information on the number of returns for the laser shot and the return number as well as information on the intensity (reflection strength) of the point (Tab. 1).

Table 1: The data specification.

Data collection time	October 2003	April 2011
Area	850*850m	850*850m
Number of points	6911894	7433618
Density of the data	10.05	10.55
Max number of returns	2	5
Intensity	5-255	0-65534

Source: Laser scanning campaigns reports.

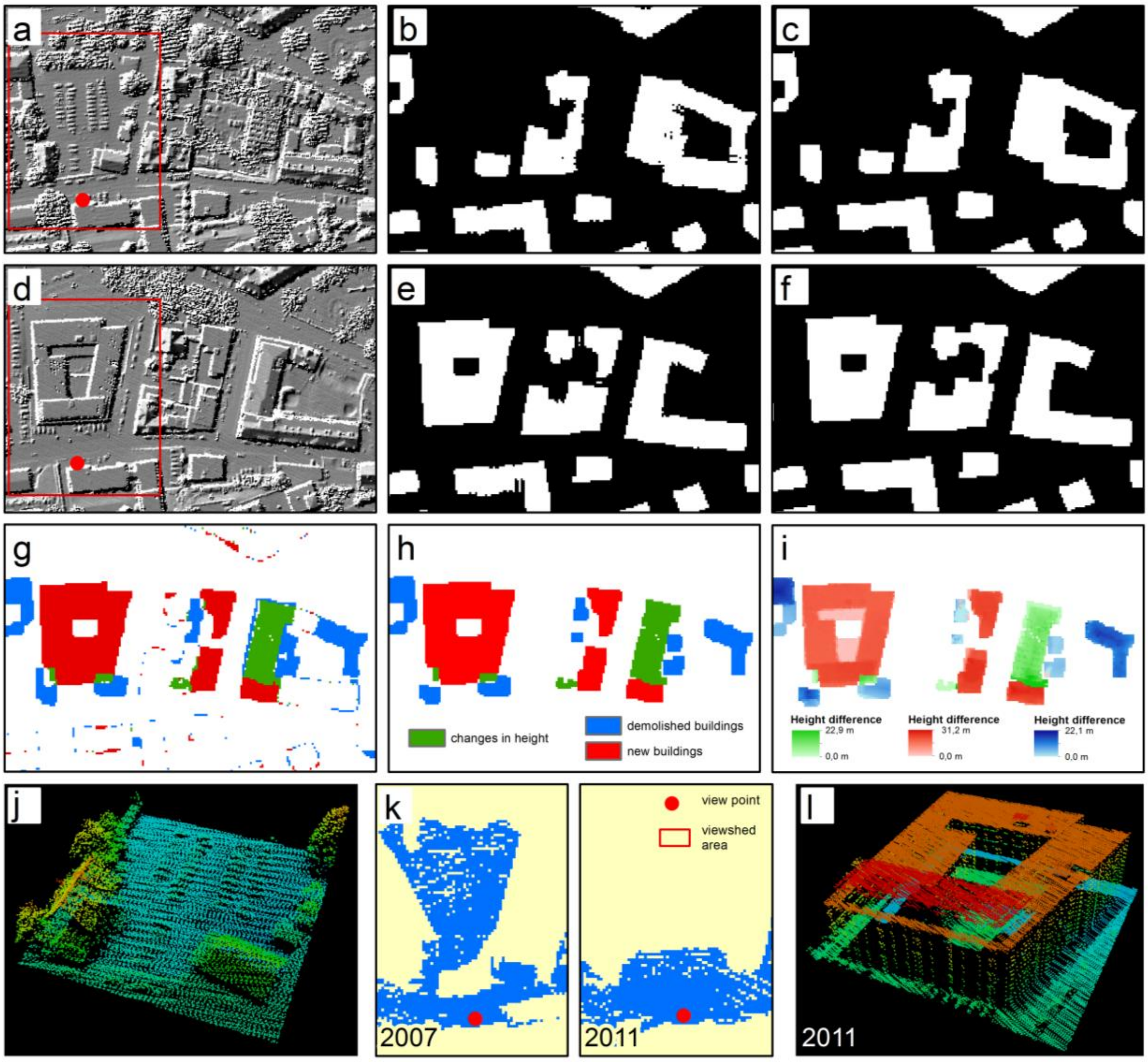
3 Applied methodology

For the data extraction and classification we applied our own automatic method based on the geometrical attributes of the data and the neighboring statistics of the extracted objects. The methodology is applied in the decision tree, on which the parameters and thresholds were selected on experience and are related to the properties of the objects. Features used were: planarity, echo ratio, normalized echo, normalized Z, and number of echoes. This was done using OPALS [15]. To preserve the information which represents the point cloud the classification has been applied in 3D. It means that as a final result we achieved the point cloud classified for ground, buildings and other data.

To assess the accuracy of the proposed method a qualitative comparison to reference data was performed. Reference data was generated by manual interpretation of the changes in the building structure for 0.31 km² area which represent similar terrain as research area in this study [16]. The quality of the classification method for the reference data is 87%, and is defined as the number of correctly classified points divided by total number of points. According to visual verification of the results we noticed that almost all the buildings were detected; however, not all the points have been correctly assigned as buildings. While the classification result is overall well a small number of classification errors were corrected manually in order to concentrate on the performance in buildings change detection.

From the classified data set we generated separately the raster digital surface model (DSM) (Fig. 1a; 1d), and digital elevation model (DEM) for both two time series data sets. From the buildings class we generated a binary map (1m pixel size) representing the building and the "not a building" classes (Fig. 1b; 1e); to remove salt and pepper noise from the images we applied morphological closing filter with kernel size equal to 1 meter (Fig. 1c; 1f).

Figure 1: Workflow



Source: Own study

The next step in our method was to extract a binary map representing building change by subtraction. The results are presented on Fig. 1g; red color represents new buildings, and blue color buildings which were demolished. To remove noise due to small errors in the alignment of the two datasets we again applied a morphological filter, this time the opening filter with 2 meter kernel size (Fig. 1.h). The kernel size in this step was bigger than in the previous step, to avoid errors which can occur, due to the X,Y coordinates shift between two data sets.

In the last step we subtract buildings height for the data sets of the two epochs and replaced them into the binary map representing new and demolished buildings. This step enabled to achieve height difference changes of the buildings (Fig. 1.i).

Additionally we evaluated changes of the view (Fig. 1.k – blue color represent visible area) that occurred in the areas marked using red rectangle in Fig. 1.a and 1.d. Smaller part of this area is also represented in Fig. 1.j – before building construction, and in Fig. 1.l - after construction of a large residential block. As a view point we selected the front of the residential block at ground level height, located in the southern part of the selected area.

4 Results

The achieved results show the usability of the ALS data for building change detection. According to our evaluation, in the area of 0.7225 km² we detect nineteen new buildings, from which eight were represented by residential buildings with a height taller than 15 meters. The analysis enables also to detect buildings which were demolished. After visual verification and comparison with the point cloud data we noticed that in our study area this phenomenon occurs for small buildings.

Due to the high accuracy of the data it was also possible to detect buildings in a renovation and buildings which shapes changes. The example is a building in Fig. 1.i. On the left side of the figure we see a changes in height in a part of new building. This change is caused by the fact that in this area in 2003 were two small, and low buildings. This buildings were demolished and on their place was built a new higher and bigger building. Different situation (not visible in the figure) we detected in eastern part of our test area where a new floor to the building was built.

The viewshed evaluated for one example building shows how, after the residential block construction, the view from selected point changed. As we see in Fig 1.k in 2011 year the northern part of the urban space is not visible.

5 Discussion and conclusions

The analysis shows the potential of the ALS data for buildings change detection. The height information contained in the data gives new possibilities in 3D change detection in time. This information can not be used on the basis of 2D satellite and aerial images. An additional dimension provides the analysis in 3D which can include expansion of build up areas in height. This information is usually used in urban planning to verify the influence of the new buildings for the sunlight reaching to the ground and also for the lighting of buildings. This is an important issue because it may result in smaller amount of light during the day inside the buildings. This can also have an effect on the temperature during sunny days, especially if newly constructed buildings on the northern hemisphere of the earth are located on the southern part of the analysed view point.

Furthermore the information about the topography relief contained in the data give us an important information regarding the topography barriers and corridors which can be determinant for further buildings changes in the future.

The results of our research provides an example of the usefulness of the ALS data for buildings change detection and new aspect – the third dimension of the data, which can be taken into consideration during the analysis.

6 References

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