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Low-Level Aerial Photogrammetry as a Source of Supplementary Data for ALS Measurements

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Abstract. The development of laser scanning technology ALS allows to make high-resolution measurements for large areas result-ing in significant reduction of costs. The main stakeholders at heights data received from the airborne laser scanning is mainly state administration. The state institutions appear among projects such as ISOK. Each point is classified in ac-cordance with the standard LAS 1.2, our research focuses on the class 6 – buildings. In the project ISOK, the buildings are not measured in whole (from every side). A typical way to measure the missing elements is to increase the coverage of the cross and additional raids which unfortunately increases the cost measurements. An alternative solution density point clouds ALS is the use of optical scanning and UAV. The article shows the process of density the point clouds coming from ALS using point cloud obtained through optical scanning. The methods that illustrate the process of compaction data format LAS using the following methods: point cloud having field coordinates in the system compatible with the system of clouds acquired with ALS, point cloud in the local system, point cloud in the local system without the scale. The file size, depending on the density of the point cloud was analyzed.

Keywords: UAV, ALS, compare point cloud, ISOK, optical scanning.

Conference topic: Technologies of geodesy and cadastre.

Introduction

Laser scanning technology is commonly used all over the world for the last decades. Through that time, the techniques of data acquisition by using red- light scanners develop into many forms. The one of the most popular methods is ALS (Airborne Laser Scanning). Based on the LiDAR data, a DTM could be created (Digital Terrain Model), with accuracy showed in Reutebuch *et al.* researches (Reutebuch *et al.* 2005: 283–288), where the analysis of the Canadian's forest was performed. In many European countries, administrations ordered to cover lands with digital models represented by points from ALS. The accuracy of the data was described in researches of Ahokas *et al.* (Ahokas *et al.* 2008: 267–270) on the example of Finland and Hejmanowska *et al.* (Hejmanowska, Warcho 2010: 13–24) on the example of Italy. Moreover, the airborne laser scanning is widely used in forest management (NÆSSET *et al.* 2004: 482–499; Holopainen *et al.* 2011: 29–32), measurements of the coastlines and cliff's monitoring with additional using of MLS and TLS (Janowski *et al.* 2013: 17–24; Bobkowska *et al.* 2017). For urbanized terrain, LiDAR technology provides the source of the spatial data needed to create 3D model of the whole city or singular building (Tse *et al.* 2008: 161–175).

Creating 3D model of the cities in addition to manual operations are time consuming and the results are depending on the operator skills. The requirements of the market develop a lot of algorithms which could help with automatize the modelling process. For example (Pingbo *et al.* 2010: 829–843) made the analysis of the algorithms fot TLS dataset. Based on that research there are three main processes: geometric modeling, object recognition and object relationship modeling. To compare, for the data, obtained using ALS technique, the (Rottensteiner, Briese 2002: 295–301) work is focused on automatic city modelling possibility. The methodology there described, emphasis on classification of the two point groups: one, belong to the building, and second, belong to the ground. It has to be mentioned that mostly in airborne laser scanning, points which belong to the building are located on the roofs. To generate model with high City GML standards, there is a need to condense the point cloud. In this paper, the authors are presenting the solution to integrate the point cloud, obtained from ALS with optical scanning. The main goal is to estimate the standard deviation between the integration of the point clouds, claim the usefulness of this process and select proper parameters of the point cloud extraction from optical scanning in the need of avoiding data redundancy and increase the size of the file on the hard drive. Similar research was performed by (Mikrut *et al.* 2014: 37–44). But in this case only one object was created using terrestrial photogrammetry techniques.

The object of this study is located in Gdansk, University of Technology campus and represented by Audytorium Novum building. The campus is placed in the urbanize terrain, belong to the administration boundries of Gdansk Wrzeszcz.

Airborne Laser Scanning data

Used data comes from the IT system of the Country's Protection Against Extreme Harazds (ISOK). Received point cloud was characterized with density not less than 12 pts/m^2. It has to be mentioned that data collected in the ISOK project is archivized and share by the Central Office of the Geodesy and Cartography documentation. All of the points, collected by using ALS were stored as .las files compatible with ASPRS standards (Maślanka 2016: 511–519). The file, which contains the object of interest comprehend over 5,5 milions of points on the surface of 29,88 ha. With the density on the level of 18.5 pts/m^2, the terrain is divided into classes and represented as follows: class 0 (never classified) – 6%, 2 (ground) – 17%, 3 (low vegetation) – 23%, 4 (medium Vegetation) – 3%, 5 (high vegetation) – 27%, 6 (building) – 24%, 7 (noise) – < 0.05%. The used .las file was come from Jun 28, 2011.

Photos as a source of point clouds

The data, which were used for compaction the existing point cloud, were obtained by photogrammetry techniques. The three types of the input data (point clouds) were assumed:

- type I – point cloud with geographical reference compatible with the cloud, which is compacted,
- type II – point cloud in the local coordinate system on a scale compatible with the cloud, which is compacted,
- type III – point cloud in a local coordinate system on a scale incompatible with the cloud, which is compacted.

In order to accuracy of the described data, the authors considered the circumstance where the point clouds reference should not exceed the assumptions, defined is ISOK project. All three types of the point clouds have been developed on the basis of the images obtained using the camera Panasonic DMC-GH4 and lens with a focal length of 12 mm from unmanned aerial vehicle (UAV). The use of drones for photogrammetry and remote sensing (Colomina, Molina 2014: 79–97; Nex, Remondino 2013: 1–15) is common. The camera has been calibrated. 315 photos were performed and used throughout the project. The process of developing photos a semi-automatic. Used software environment, which is based on the methods of digital photogrammetry allowed to obtain a point cloud. Technical data about the camera and the project and the type I of clouds are presented in Table 1, Tables 2 and 3.

Table 1. Camera information

Camera Model	DMC-GH4
Resolution	4608 × 2592
Focal Length	12 mm
Pixel Size	3.78 × 3.78 μm

Table 2. Project information

Number of images	315
Flying altitude	25.5 m
Ground resolution	7.66 mm/pix
Coverage area	759 m²
Number of points (all)	~49 mln
Number of points (taken for preliminary analysis)	~18 mln
Reprojection error	0.514 pix

Table 3. Control points RMSE

Count	5
X error (cm)	2.10
Y error (cm)	0.77
Z error (cm)	0.75
XY error (cm)	2.24
Total (cm)	2.36
Image (pix)	0.62

For preliminary analysis, a dense cloud of points were analysed. Moreover, for further research (analysis of file size), datasets which were charakterized by the less density were taken into account. The information about the project for point clouds is containing information about its geographical location (type I). In comparison, another type of point cloud was developed by the use of the same photos. In the case of type II where the same control points were used in different coordinate system (the local system). Type III was initially developed without any georeferencing and scale. Only in a second step, the scale has been given based on a length between the two characteristic points.

Comparison of fitting point clouds

For the purposes of the analysis, described in this paper, dense clouds, including over number points were used. This was necessary because of the algorithms used for comparison of the two point clouds. In this case, the base point cloud was the cloud developed from the photos, while the compared cloud was a cloud from the ISOK project. Detailed description of the analysis was divided into three data types of clouds, due to a different approach in each case. Currently, such a comparison of the point clouds were used in many fields. Not only to estimate the accuracy of the fitting process but also in engineering, for example, differences between base models and cloud of points obtained from the basis of measurement of the product produced were compared. Such a comparison is also used in biometrics (Bobkowska *et al.* 2016a: 15–21; Bobkowska *et al.* 2016b: 767–774).

Type I – point cloud with geographical reference compatible with the cloud, which is compacted

In case of this study, the comparison between point cloud, received in ISOK project and georeferenced point cloud from the UAV was made. For this tool based on the determination of the distance between the point of the comparator with reference model (in this case the cloud type I) was used. It was assumed that the reference cloud is sufficiently dense, that it is unnecessary to use the local modeling. The comparison result is shown in Figure 1.

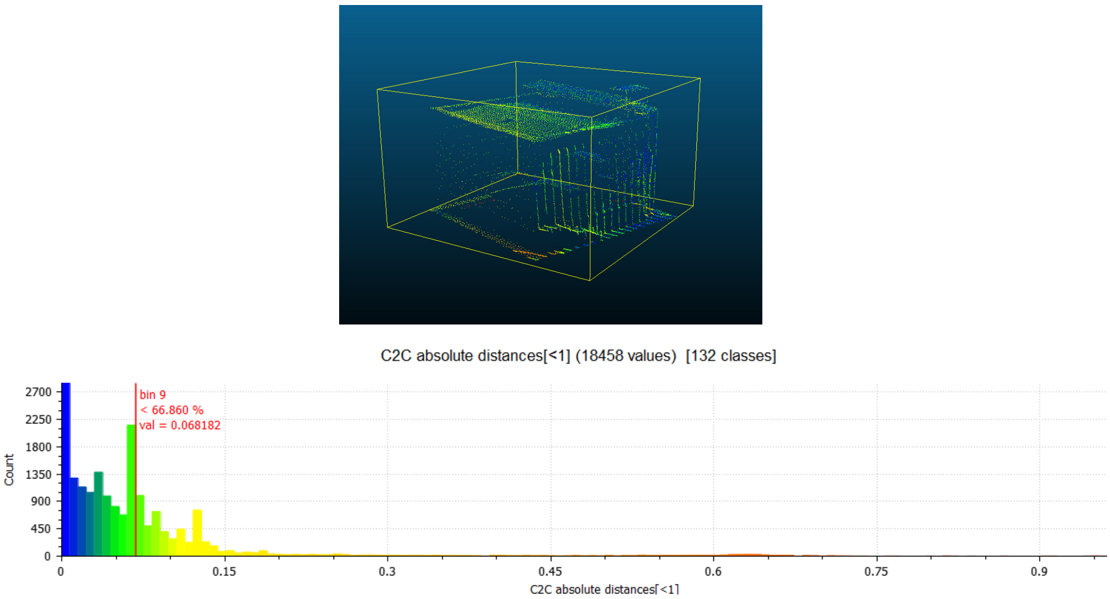

Fig. 1. Compare type I and ISOK point cloud

Type II – point cloud in the local coordinate system on a scale compatible with the cloud, which is compacted

In this case, the aligmnment between point clouds was made. To achieve this tasks are ready tool based on the algorithm of ICP (Iterative Closest Point) has been used. This allowed for the transformation of the local coordinate system to the cloud geodetic coordinate system. The next step was the comparison that has been made in the same way as in the case of type I of point cloud. The effect is shown in Figure 2.

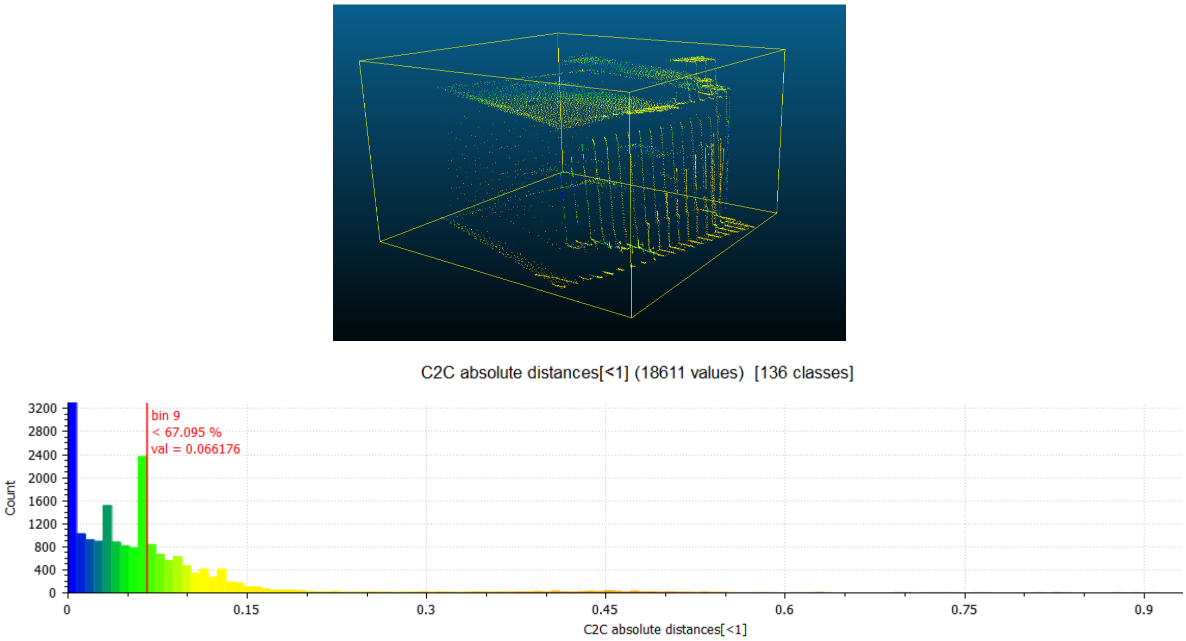

Fig. 2. Compare type II and ISOK point cloud

Type III – a cloud of points in a local coordinate system on a scale incompatible with the cloud, which is compacted.

III type of point cloud did not contain georeferencing, initially also did not include the scale in according to the coordinate system with the point cloud from the ISOK project. There have been scaling point clouds based on the known length of the section between the two points. After scaling, fitting the point cloud to a cloud with ISOK was made, as in the case of type II. Then a comparison was made as in the case the clouds of type I and II. The result was shown in Figure 3.

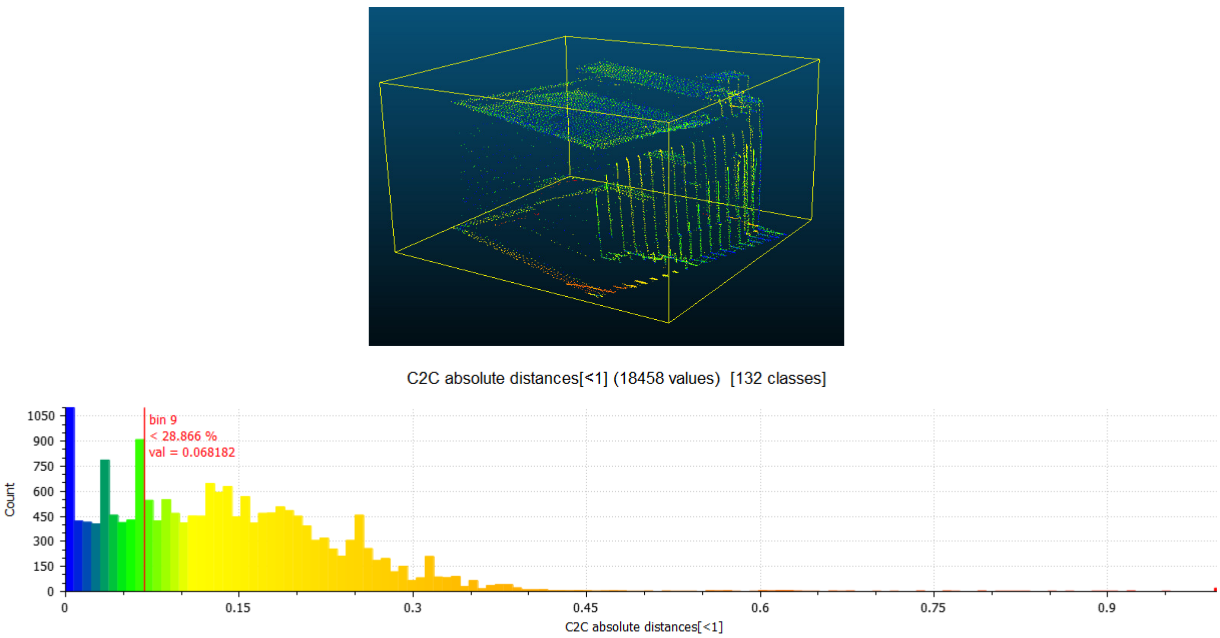

Fig. 3. Compare type III and ISOK point cloud

The fact is that the area around the elaboration of the building has changed since the overflight as a part of the ISOK project until such time as the needs of this work. What affected the comparison of point clouds to each other.

Large discrepancies resulted from eg. Constructed building in the neighborhood and underground parking. Despite differences in the ground, for adjustment II and III type of cloud was successful. However, after assessing the histograms, it is noticeable that most of the points of point cloud type III) deviates by 10 cm. Whereas assessing histograms of type I and II it can be said, that a better result obtained by comparing the type II. However, during project, it should be taken into consideration whether an area has changed or remained.

Data integration

To avoid the situation of data redundancy, only the points which are representing the object of interest were chosen. In this part of the analysis, the cloud of Geographical reference (type I) was taken into account. Next, from the point cloud, obtained from UAV, the points belonging to the roof were removed. To integrate the UAV and ALS data, georeference of this data was used and the point clouds were merged on the .las file level. It is very important to assign default value (zero) for UAV data to attributes like: return number, number of returns, scan direction flag, edge of flight line or scan angle rank, because the information about the attributes is not registred by this photogrammetry technique. The visual effect of this operations were presented in the Figure 4.

In comparison between ALS and UAV point cloud, the second one is denser than the first. In case, when the main assumption is to dense the ALS point cloud, it is neccessery to match the density of each point cloud. In Table 4 the authors represented parametres, which characterize merge data. The analysis was focus on the one building, where one dataset of ALS data (received from CODGiK) contains 200 buildings.

Table 4. Merged point clouds parametres

Point Cloud	Density [pts/m^2]	Number of points	LAS FILES WEIGHT [KB]
ALS	ALS = 18.5	14 896	495
ALS + UAV 30 cm	UAV = 11.1	30 528	1014
ALS + UAV 20 cm	UAV = 25.0	49 016	1628
ALS + UAV 10 cm	UAV = 100.0	134 797	4510
ALS + UAV 5 cm	UAV = 400.0	405 073	13 450

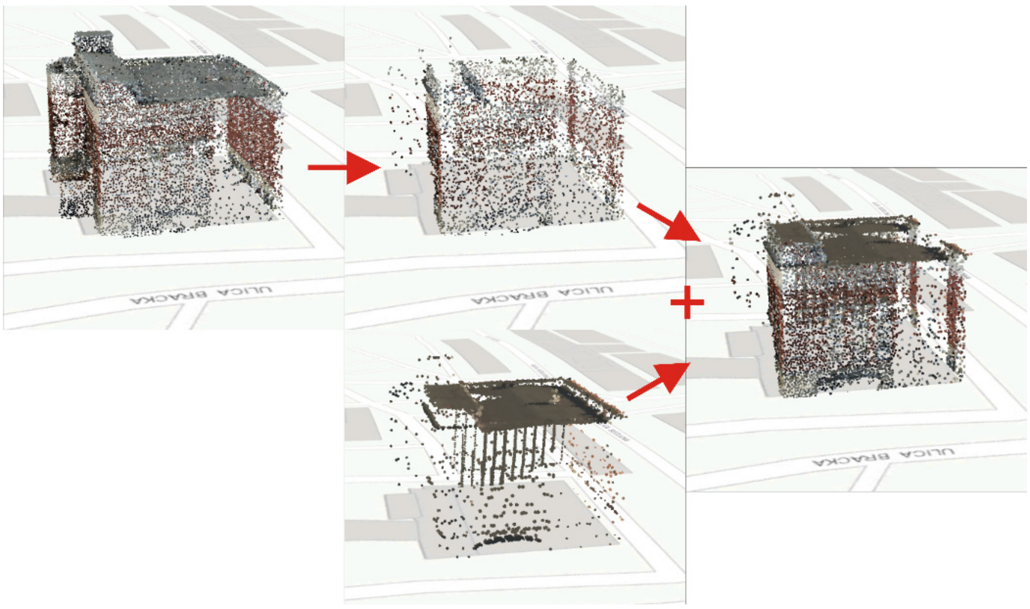

Fig. 4. ALS and UAV data integration

Conclusions

In the recent years, remote sensing technologies have become a subject of research for many scientists and are being increasingly used in administration and industry (Hejmanowska *et al.* 2015: 6549–6558). The research presented in the article show the supplement method for ALS point cloud, on the example of the building. Low-level aerial photogrammetry seems to be the optimal method due to the process of development and to subsequently fit the two clouds. For the present example, the obtained results indicate that the cloud of points used for the density need not be with the geographical reference. This saves time. In order to thicken the clouds for analysis, which do not require high accuracy, cloud developed without the use of of control points (where the scale is conferred by exclusively by rescaling based on one section) can be used. In this case, the awareness of errors and imperfections of this type of cloud is needed. The use of unmanned airborne platforms allows to obtain images of the entire building (all external walls and roof). Points measured on the roof are important during the process of fitting the clouds, when the area around the building was changed. While data integration an important element which should be noted is the density of the points ALS, the authors suggest that wprowadznie cloud of points obtained on the basis of images with a density greater than 20cm – about 25 points / m2 is not suitable.

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