LiDAR and image point clouds as a source of 3D information for a smart city – the case study for trees in Jordan Park in Kraków, Poland

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Abstract

Nowadays, 3D point clouds and image point clouds collected by advanced technologies could be a source of information about greenery in smart city (e.g. height, DBH and crown width of the trees). They give the opportunity to perform precise remote measurements of objects in space, using e.g. the TerraScan software. In our work, TLS (2019), UAV (2019) and ALS (2017) 3D point clouds were used to measure height and crown width of 16 trees and then compare the results. Comparing to TLS, UAV and ALS understate the height on average per tree (0.40 m from UAV, 0.16 m from ALS) and crown width on average per tree (0.54 form UAV and ALS). The standard deviation for height ranged from 0.48 m for UAV to 0.39 m for ALS. For crown width it ranged from 0.44 m for UAV and 0.52 m for ALS. According to the results, UAV and ALS can be alternatives for less time and budget consuming than TLS. But it is important to highlight that ALS is also time-consuming and expensive because we need to normalize 3D point clouds from IPC even to use data from UAV.

Keywords: LiDAR TLS, ALS, image matching UAV, smart city

INTRODUCTION

One of the cornerstones of smart city concept is the use of innovative and intelligent solutions for the city's management, which include modern technologies like terrestrial laser scanning (TLS), airborne laser scanning (ALS) and digital photogrammetry (eg SfM). The use of these technologies for the urban forest management has been increasing mainly due to 3D point clouds data in inventory and monitoring processes of city green infrastructure.

Around the world, the application of these technologies has shown complementary purposes of use in urban tree inventories, tree height and DBH (diameter at breast height) estimations, trunk location, urban forest dynamics, crown volume and segmentation, LAI (leaf area index) estimation, pests and diseases evaluation, biodiversity and ecosystem services evaluation, like carbon storage estimations.

The aim of this research was to compare TLS (2019), UAV (2019) and ALS (2017) 3D point clouds used for urban forest monitoring and management process in Jordana Park in Krakow.

METHODS

During four days of measurement (23-26.09.2019) data set was obtained from 236 scanner stations, using a RIEGL VZ-400i terrestrial laser scanner, which was enough to cover the whole park (around 21.5 ha). For each scanner position, the nominal number of cloud points has been set to 90 million. In addition, five digital images (RGB) were taken for each scan using an external Nikon D810 digital camera calibrated with a scanner. The georeference to the PL-1992 (EPSG: 2180) and PL-KRON86-NH systems was made by fitting the TLS project into the signalized targets, measured using a GNSS receiver.

For the photogrammetric survey carried out in late September of 2019, we used a Yuneec Typhoon H520 UAV and RGB camera, with an E90 wide-angle of 20Mpix. The UAV flights were processed with 15 GCPs which were measured using Hi-TARGET v90 GNSS receiver. Two cross section missions were flown during which 437 images were captured. The photogrammetric dataset was processed using Agisoft Metashape Professional software. The first step of the process was the extraction of the external and internal parameters of the camera, aligning photos and building a sparse point cloud. We set a high key point density and high level of accuracy by matching images during the processing. Afterwards, GCPs were identified in the UAV photographs. The point cloud density reached was approximately 1368 pts/m^2. The data was exported to the PL-1992 system (EPSG: 2180).

All Poland is covered by ALS LiDAR point clouds, acquired between 2011-2018 in a national-wide project (ISOK, CAPAP by GUGiK). The point cloud (CS: PL-1992) density for the cities was set to minimum of 12/m^2 and fully classified (LAS specification; ASPRS) and colorized. For some cities like Kraków the second LiDAR ALS (CAPAP) campaign was performed in 2017 and 2018. We used ALS point clouds for Jordan Park acquired in early November of 2017.

By using the TerraScan (Terrasolid, MicroStation V8i) software, we measured 3D point clouds for the total height and width of 16 trees. Crown width measurements was taken in east-west and north-south directions to generate an average of crown width. From the 3D point clouds we selected 16 trees with no overlapped or touching crowns to get better measurements. All the measurements from ALS, TLS and UAV 3D point clouds were compared.

RESULTS

The average difference in total height between TLS and UAV was 0.73 m, and between TLS and ALS was 0.54 m. Although, the standard deviation was around 0.43 m (0.48 m from UAV and 0.39 m from ALS). The lower value between TLS and ALS is caused by measurements done from leaf-off season, in November. When compared to TLS, both UAV and TLS underestimated the total height of trees in 0.40 m (UAV) and 0.16 m (TLS) on average per tree (Table 1).

Table 1. Differences between TLS, UAV and ALS measures for total height of trees.

	TLS – UAV [m]	**TLS – ALS [m]**
Mean difference	0.72	0.54
Maximum	1.62	1.34
Minimum	0.02	0.01
Standard deviation	0.48	0.39
Difference between the sums of height	6.35	2.54
Average understate of height per tree	0.40	0.16

The differences between data collected in the same year (TLS and UAV from 2019) were higher than the differences between data collected in two different years (ALS from 2017, TLS from 2019), because of several reasons. During the period of two years trees were growing and consequently their total height and crown width changed, but TLS and ALS are more accurate than UAV 3D point cloud to catch those changes in the crown. This can have influenced the higher difference observed. Otherwise, the human factor is also relevant, because of the manual measurements on the 3D point clouds that can lead to some errors during the process. Of course, larger number of measured trees can give more reliable results.

The differences among crown width measurements from UAV, ALS and TLS were quite similar. The mean difference was around 0.64 m (0.68 m from UAV and 0.60 from ALS), standard deviation was approximately 0.50 m (0.44 m from UAV and 0.52 m from ALS). Compared to TLS, both UAV and ALS underestimated the crown width, exactly on the same value (0.54 m per tree).

Table 2. Differences between TLS, UAV and ALS measures for crown width of trees.

	TLS – UAV [m]	**TLS – ALS [m]**
Mean difference	0.68	0.60
Maximum	1.71	1.56
Minimum	0.14	0.02
Standard deviation	0.44	0.52
Difference between the sums of crown width	8.63	8.70
Average understate of crown width per tree	0.54	0.54

ALS 3D point cloud as well as UAV only slightly underestimated total height and crown width of trees when compared to the TLS method. Therefore, depending on the expectations, both methods could be used as an alternative instead of using TLS.

The TLS and UAV 3D cloud points were collected during the leaf-on period (when there are leaves on the deciduous trees) and gave precise results. In this sense, the leaf-on season was used to obtain high quality Digital Surface Model (DSM) from UAV images, while UAV images taken during the leaf-off season could potentially provide a suitable ground reference (DTM), but getting DSM models would be more difficult and less accurate.

The accuracy of ALS 3D point cloud is high, but their acquisition is like in TLS, expensive and time-consuming. Due to the TLS equipment limitations, the method can be applied only to small areas and cannot obtain 3D data at the regional scale. The combination of UAV and TLS equipment was well suited for the need of small and midsize tree farms. UAV technology can be useful for measuring the urban forest but there are challenges related to the drone approach.

UAV can be a lower-cost alternative for measuring the height of trees. However, without ALS data it is impossible to normalize 3D point clouds from Image Point Clouds (IPC) obtained by the UAV, because there are limitations to get information about the terrain profile.

Although there are some limitations for the UAV method, Ritter (2014) pointed out that with downward-facing UAVs it’s possible to assess the overall health of trees because it is possible to analyze the limb’s mortality from the air, what can be sometimes impossible from underneath the tree. This procedure can be interesting for the evaluation process of the urban forest in order to control problems with dead branches or tree mortality in a fast and low-cost way.

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