Comparison of UAV LIDAR and photogrammetry approaches for the survey of the Cultural Heritage in challenging conditions

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Abstract

The use of Unmanned Aerial Vehicle (UAV) for surveying allows to obtain satisfactory results with a lower risk for the operators. This instrument is suitable to carry on-board several sensors for the data acquisition. In the latest years, further to the success of Photogrammetry, also the Light Detection and Ranging (LiDAR) instrumentation has been conformed to be easily mounted on drones. This work is focused on the comparison of the UAV LiDAR and photogrammetry for the surveying of the Castle of Casalbagliano, part of the Italian Cultural Heritage. The two techniques have been compared on the basis of their point clouds. The parameters which have been taken into account are the overall geometry, the reconstruction of the vegetated areas, and the colour. The pros and cons of the two methods have been discussed, as well as their integration.

Keywords: UAV, LiDAR, Photogrammetry, Integration, Precision, Resolution, Cultural Heritage

INTRODUCTION

The increasing manageability and compactness of the new Light Detection and Ranging (LiDAR) instrumentation is changing the approach with respect to the opportunities of employment of this technology, expanding the fields of its applications. In facts, the possibility to use this sensor mounted on an Unmanned Aerial Vehicle (UAV) makes it more flexible, hence more suitable to work in a wide range of scenarios; thus, the limits of the traditional airborne LiDAR are compensated without changing approach, as proposed instead by Toschi et al. (2019).

The integration and the comparison of this technique with UAV Photogrammetry is a topic of interest, in order to deepen the specific properties of the two approaches and to improve their potential. The combination of these sensors has been employed in order to map and monitor the environment in urban and natural contexts (Balotă et al., 2019; Cao et al., 2019; Lin et al., 2019; Shaw et al., 2019).

In this paper, the use of the UAV LiDAR is tested and compared with UAV Photogrammetry for the survey of the Castle of Casalbagliano, an inaccessible building of the Italian Cultural Heritage. The same case study has been examined during a previous survey campaign, which date back to 2016. At that time, the building has been surveyed by means of several techniques, including UAV Photogrammetry, Terrestrial Laser Scanning (TLS), Total Station (TS) and Global Navigation Satellite System (GNSS), simulating an emergency situation. The so-obtained data have been deeply analysed in order to conceive an optimizated strategy for UAV photogrammetry in order to produce the outputs in the fastest and most effective way (Gagliolo et al., 2017 and 2018). The focus of this study concerned three parameters: the shooting geometry, the GCPs number and distribution, and the post-processing settings. The final result has been represented by a list of guidelines to be applied in an emergency scenario. In particular, it has been highlighted that the most significant parameter to consider for the optimization is the number of images, because their increase causes an exponential growth of the computational effort.

In this same perspective of optimization, the present work focuses on the achievement a similar result accounting on the UAV LiDAR technique.

Therefore, the aim is to evaluate the precision and the resolution reachable with LiDAR and Photogrammetry in such scenario, in which on the one hand a high level of detail is required, while on the other hand the safety conditions for the operators need to be guaranteed. The dissertation is organized according to the procedural workflow, which includes the survey campaign, the data post-processing and analysis.

SURVEY CAMPAIGN

The analysed case study is the Castle of Casalbagliano (Alessandria, Piedmont). The building has been surveyed in a single day on the 16th July 2019. The LiDAR survey has been performed with LiAir 50 mounted on the drone DJI M600 Pro, while the photogrammetric one with DJI Phantom 4 Pro, equipped with its own embedded camera. The specifications of the employed instrumentation are resumed in the tables below.

Table 1. LiAir 50 specifications.

LiAir 50 specifications	
Laser Sensor	Velodyne VLP-16
Range accuracy	±3 cm
Maximum range	100 m
Angular resolution	0.1°
Vertical FOV	-15° ~ +15°
Horizontal FOV	360°

Table 2. DJI Phantom 4 Pro camera specifications.

DJI Phantom 4 Pro camera specifications	
Sensor size (pix)	5472×3648
Sensor size (mm)	13.2×8.8
Pixel size (μm)	2.4
Focal length (mm)	8.8

A set of Ground Control Points (GCPs) coordinates has been collected by means of a GNSS receiver in NRTK mode. Ten targets, represented by cardboard and Acrylonitrile butadiene styrene (ABS) markers (*t* label in the picture below), have been positioned all around the building, as depicted in the figure below.

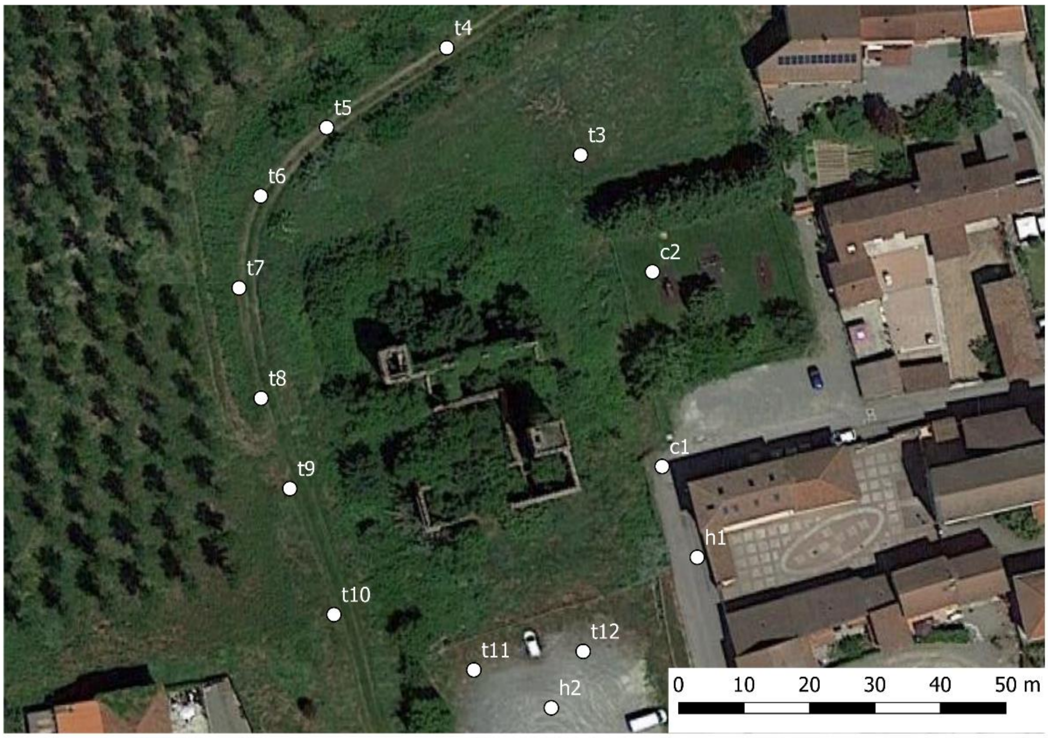

Fig. 1. GCPs arrangement.

Concerning photogrammetry, a single flight has been performed above the area in Fig. 1, using four different shooting geometries: nadiral (autopilot), 45° internal/external and frontal to acquire all the façades. The total amount of collected images is 198. The exposure of images has been set manually to compensate the shading and to focus on the details of interest.

The resulting GSD from the different geometric configurations varies within the range from 7 to 25 mm, resulting from a flight height of about 40 meters.

Concerning LiDAR, at a distance of 40 m, the angular resolution of 0.1° corresponds to a spatial resolution of about 7 cm.

DATA POST-PROCESSING AND ANALYSIS

Two point clouds have been produced starting from the images and the LiDAR acquisition respectively. The so-obtained products have been further analysed and compared by means of the open source software CloudCompare (2020).

The collected images have been processed by using the software Agisoft Photoscan© (2020). The photogrammetric point cloud has been reconstructed using both high quality parameters for the aerotriangulation and the dense cloud generation. Since the images have been processed at the original resolution, the spacing between points is in the order of the GSD. The result in terms of precision of the Bundle Block Adjustment, obtained using 5 GCPs and 5 CPs with an alternated distribution, is a Root Mean Square Error (RMSE) of 38 mm on the GCPs in the 3D space, while the average residual on CPs is 37 mm. These values are comparable with the expected precision of the GNSS NRTK positioning.

The LiDAR point cloud has been produced using LiAcquire proprietary Software, distributed by GreenValley International (2020) as well as the hardware LiAir 50. First of all the trajectory has been corrected using a PPK approach implemented in LiNAV module that combine GNSS raw data (both from base and rover) and IMU raw data. Then each image taken from the camera integrated in the LiAIR has been associated with the timestamps of the trajectory. The alignment has been performed using all the laser channels.

The point clouds obtained by the two different techniques have been compared accounting on the overall geometry, the reconstruction of the vegetated areas, and the colour. A preliminary filtering has been performed using the Noise and the Statistical Outlier Removal (SOR) filters, available in CloudCompare; the first one is a low pass filter which removes the points not fitted by a local plane, while the second rejects the points which are farther than the average distance plus ‘n’ times the standard deviation (n is chosen by the user). Furthermore, a manual cleaning of the point clouds has been achieved.

About the geometry, the point clouds have been compared analysing sections and samples located in the tower façades (Fig. 2).

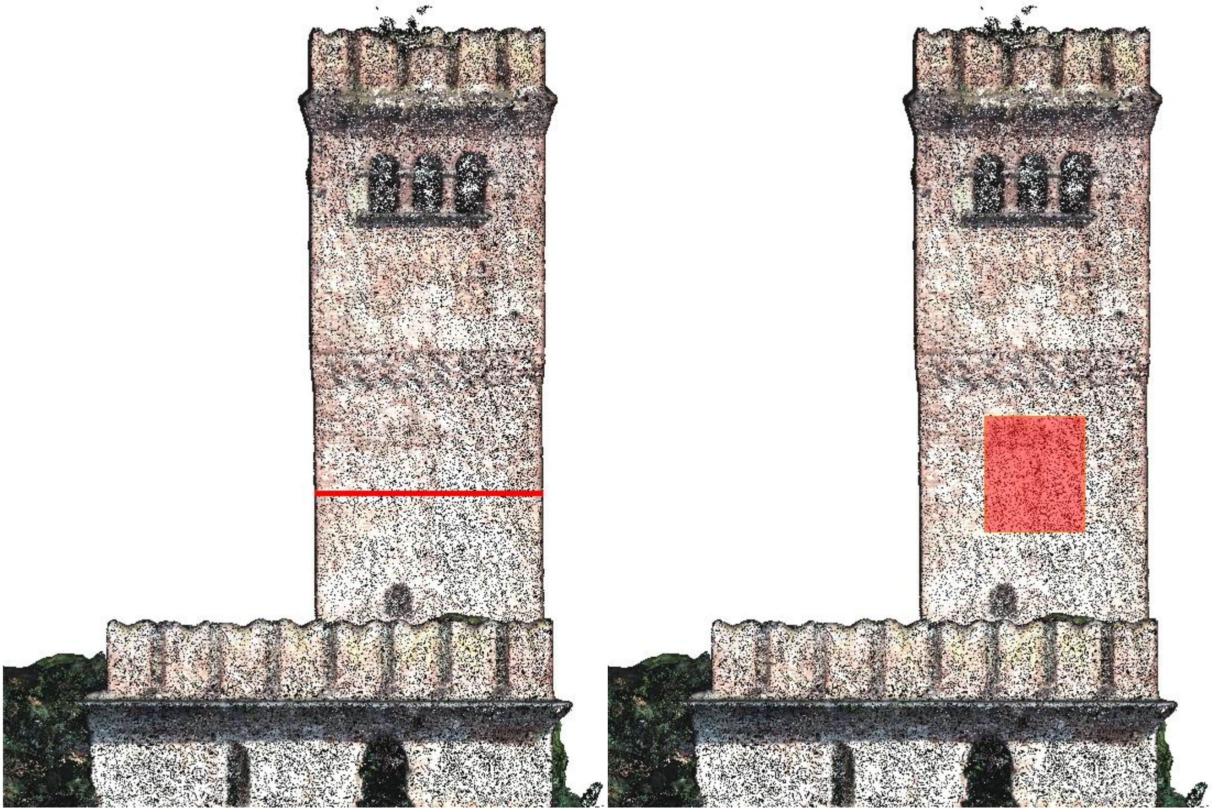

Fig. 2. On the left the location of the section of the tower, on the right the sample considered for statistics.

The relevant parameters considered are the point density and the noise, which result better in the photogrammetric point cloud, as it could be inferred by the Fig. 3; however, in both cases the spacing corresponds to a centimetric order of magnitude.

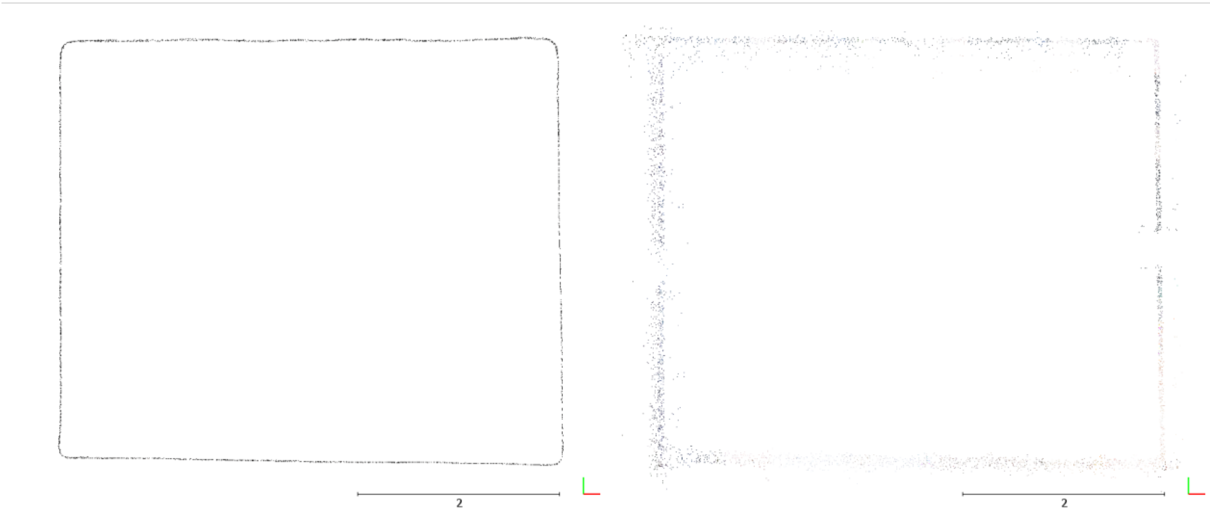

Fig. 3. On the left the section of the tower from the photogrammetric point cloud, on the right the one from LiDAR.

As expected, the LiDAR geometry is more accurate in the vegetated areas and there is a partial reconstruction of the internal façades, which are hidden in the darkness hence not perceivable in the pictures. Further analyses concerning geometry have been carried on using the command Rasterize to compute per cell statistic: the sample on the tower façade has been divided in 10×10 cm cells, which colour represent the population (values from 2 in blue to 36 in red, as depicted in Fig. 4).

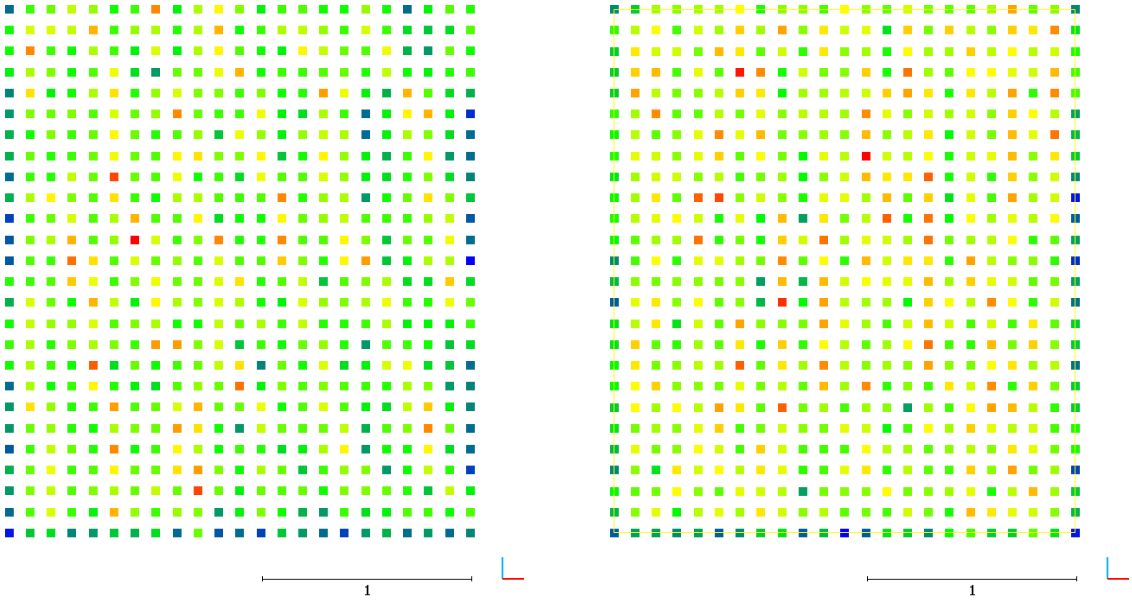

Fig. 4. Per cell population: on the left the output from photogrammetry, while on the right the one from LiDAR.

Concerning the radiometry, the LiDAR point cloud has been automatically coloured thanks to the embedded camera of the LiAir 50. However, since the shooting point of view is mainly nadiral, the so-obtained pictures are not satisfactory to obtain a realistic colouration of the point cloud. To compensate for this issue, the clouds could be integrated, interpolating the colour from the photogrammetric point cloud and attributing it to the LiDAR one.

From the performed analyses, it is possible to infer that at the state of the art UAV Photogrammetry is more advisable to be applied to survey a building in such scenario, accounting on the overall geometry and radiometry (Fig. 5). Nevertheless, UAV LiDAR allows a better reconstruction in complicated areas, e.g. vegetated or shadowed areas. Thus, both the techniques make a significant contribution considering an integrated approach.

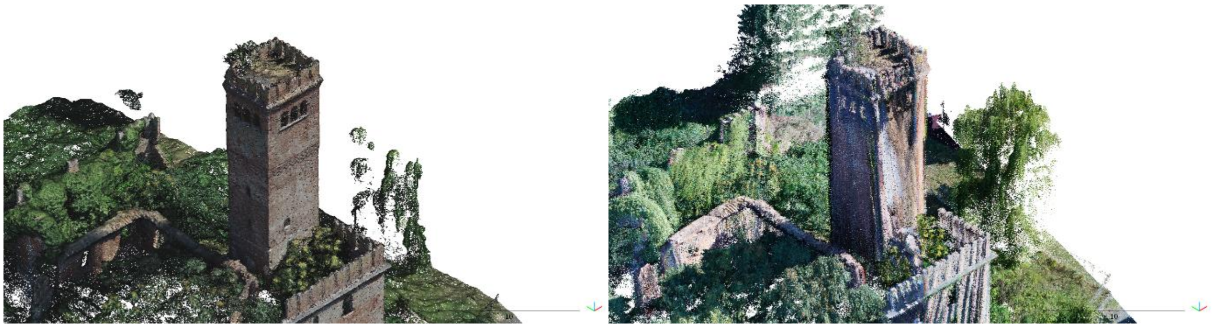

Fig. 5. Overview of the two analysed point clouds: on the left the photogrammetric one, while on the right the one from LiDAR.

The further developments will concern: on the one hand, the comparison of the product from the UAV photogrammetric surveys with the estimated precisions achieved by using a realistic planning method (Passoni et al., 2018); on the other hand, the quality of the result of the LiDAR acquisition with respect to the nature of the material which makes the acquired surface (Fagandini et al., 2017).

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