A COMPARITIVE STUDY OF LOW-COST UAV POINT CLOUDS WITH TERRESTRIAL LASER SCANNER POINT CLOUD OF A BUILDING

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Abstract

Recently, 3D models of a structure or landform have gained importance as datasets for many applications such as disaster management, heritage conservation, city modelling etc. The efficient generation of high-resolution 3D model is both a relevant research topic and an important issue for professional practice. Both Unmanned Aerial Vehicles (UAV) and Terrestrial Laser Scanners (TLS) are becoming important techniques for surveying and mapping. UAV technology, when used in aerial mode, and TLS on the ground seem complementary technologies. While aerial UAV images are ideally suited to model the top view of a landscape or a terrain, terrestrial scanners are able to take data from different angles in the front or back of an object. If these two datasets are merged together, an efficient 3D model can be created which can be used for various applications like structural deformation monitoring or landslide monitoring. This experimental work explores the possibility of merging both the datasets.

Keywords: 3D model, TLS, UAV, point cloud, RMSE, Low cost

BACKGROUND

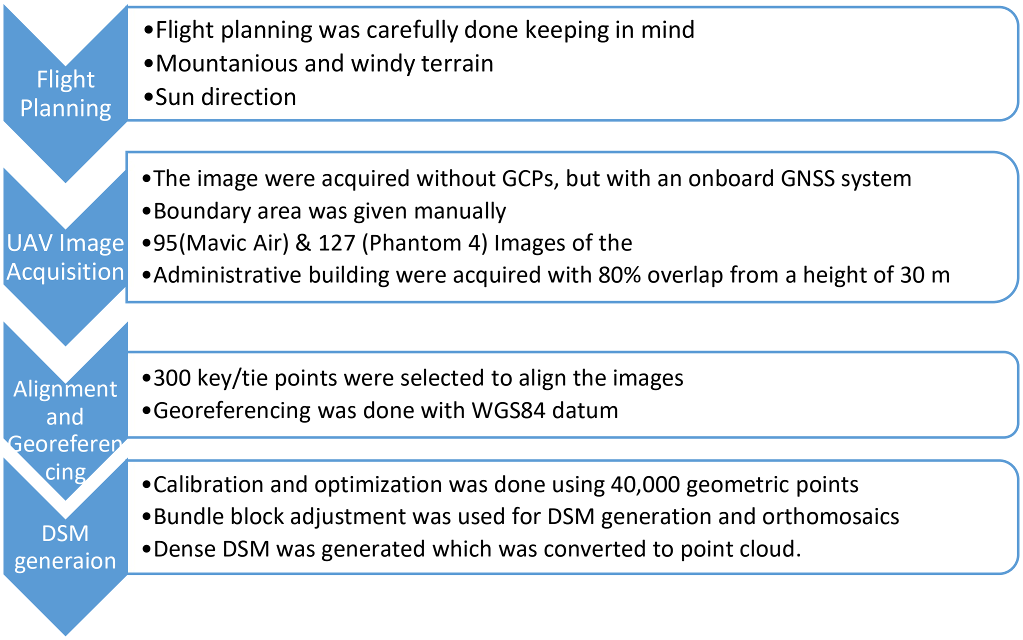
Both Unmanned Aerial Vehicles (UAV) and laser scanners are becoming important techniques for surveying and mapping in recent years. While laser scanners systems have put themselves as the strong contenders for highly automated generation of digital elevation and surface models, UAV's are emerging as a powerful tool for the same. Although, the accuracy of laser scanners is very high, but aerial laser scanners are ultra-expensive as compared to terrestrial ones. Laser range scanning is providing an efficient way to actively acquire accurate and dense 3D point clouds of object surfaces or environments but only in a particular way or direction. Also, UAV's due to their flexibility and ease of operability, are becoming popular in the field of surveying, and photogrammetry (Colomina and Molina, 2014) (Nex and Remondino, 2014). Point clouds can be generated with the help of these UAV's, which can be obtained in any view, by combining a large number of images obtained from them using structure from motion (sfm) technique (Turner et al., 2012) (Micheletti et al., 2015). Thus, it raises various questions about the comparative study of 2 low-cost unmanned aerial systems and laser scanner technologies. The research here compares data of 2 UAV's point cloud with laser scanner point cloud using RMSE tool, such that the point cloud with more accuracy could be merged with laser scanner point cloud.

METHODOLOGY

Data collection: Aerial imagery of the administrative building of our institute was collected in two phases with deploying two low-cost UAV's (Neitzel and Klonowski, 2011) i.e DJI Mavic Air and Phantom 4 Pro with 1/2.3" CMOS sensor and 1'' CMOS sensor camera affixed with a resolution of 12 MP and 20 MP respectively. In UAV photogrammetry, the leading concern is wind, which due to low weight of the drone can significantly change planned flight lines position. Also, the presence of sun can cause problems as it leads to the appearance of shadows on images. To avoid undesirable effects, the flights were performed during a cloudy and windless day. The whole process was planned to be conducted late in the evening, or early in the morning due to low crowds, which resulted in reducing the number of people and cars on the images.

Terrestrial images of the same area i.e. Administrative block were taken with the help of Leica Nova MS60 Multistation which is a robotic total station with laser scanning capabilities, which was used to survey administrative block. This system provides scan data acquisition with up to 2 mm accuracy. The TLS survey was conducted at the morning in order to eliminate any discrepancies caused by a changing scene or atmospheric conditions. The resulting cloud consisted of 16,894,095 points.

Data Processing: For comparison of the two UAV point clouds to the laser scanner point cloud, it was desirable to convert the images obtained from the two UAV's to point cloud. This was done using AgiSoft Photoscan and Pix4D software. The process followed is as under (Fig. 1):



- Flight planning was carefully done keeping in mind
- Mountanious and windy terrain
- Sun direction

- The image were acquired without GCPs, but with an onboard GNSS system
- Boundary area was given manually
- 95(Mavic Air) & 127 (Phantom 4) Images of the
- Administrative building were acquired with 80% overlap from a height of 30 m

- 300 key/tie points were selected to align the images
- Georeferencing was done with WGS84 datum

- Calibration and optimization was done using 40,000 geometric points
- Bundle block adjustment was used for DSM generation and orthomosaics
- Dense DSM was generated which was converted to point cloud.

Fig. 1. Processing steps for UAV point cloud generation**.**

Due to unavailability of a DGPS/RTK system, UAV data was taken without GCP's (Gindraux et. al, 2017) (Forlani et. al, 2018) (Nagendran et. al, 2018). Instead the point cloud obtained from the robotic total station was chosen as a reference to judge the accuracy of the two low-cost UAV point clouds. Distances and areas were calculated on the three-point clouds and RMSE were then calculated for each of UAV point cloud. Image scale taken was 1/8th of the ground distances for all the three-point clouds. While processing the data first time, after bundle block adjustment, error due to reprojection went up to 10 to 20 cm's for various points which was high. This was over come by again acquiring the UAV data in continuous mode rather than in" stop and go" mode. Though most images were taken orthogonally, some of the images were taken obliquely at an angle of 75˚.

Elkharachi (2017) states that in the mapping application, vertical accuracy is computed by vertical Root-Mean-Square-Error (RMSE). So, the mathematical relation mentioned below has been widely adopted since the late 1970s. This individual point differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power as given in equation (1) below:

$$RMSE = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n} e_{v_i}^{n}}$$

$$\mathrm{e}_{\mathrm{v}_i} = V_{r_i} - e_{m_i} \tag{1}$$

where,

RMSE= Root Mean Square Error,

v_{ri} = reference elevation at the point i,

e_{mi} =DEM elevation at the point i,

n = No. of ground check points

Data Analysis: The following DEM's (Fig. 2) were obtained with the help of Phantom 4 Pro, and Pix4D Mapper (UAV data processing software) along with the automated flight planning.

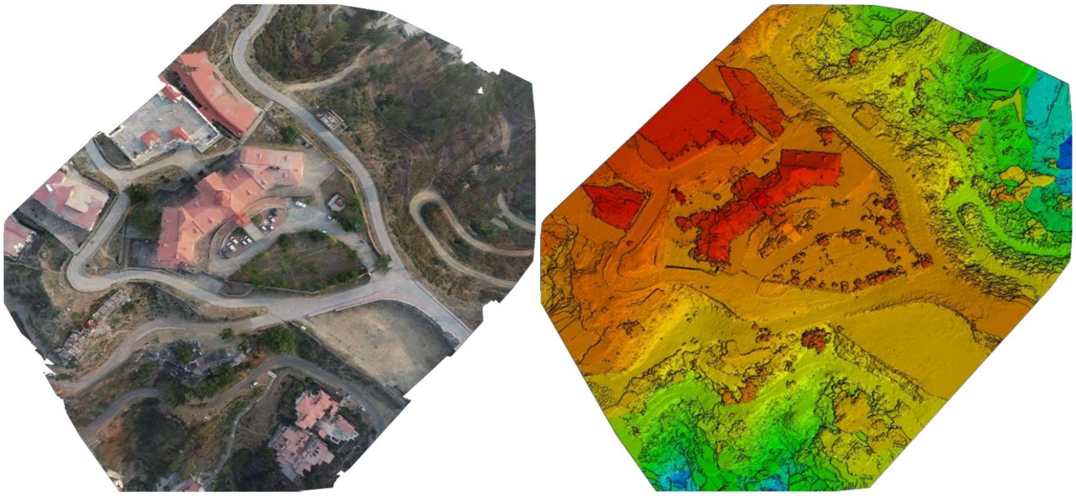


Fig. 2. Orthomosaic and the corresponding sparse Digital Surface Model (DSM).

After densification of the point cloud obtained by the two UAV's, each of them was compared to laser scanner point cloud using different quantitative parameters like distance, height etc. RMSE computations were used to compare the point clouds.

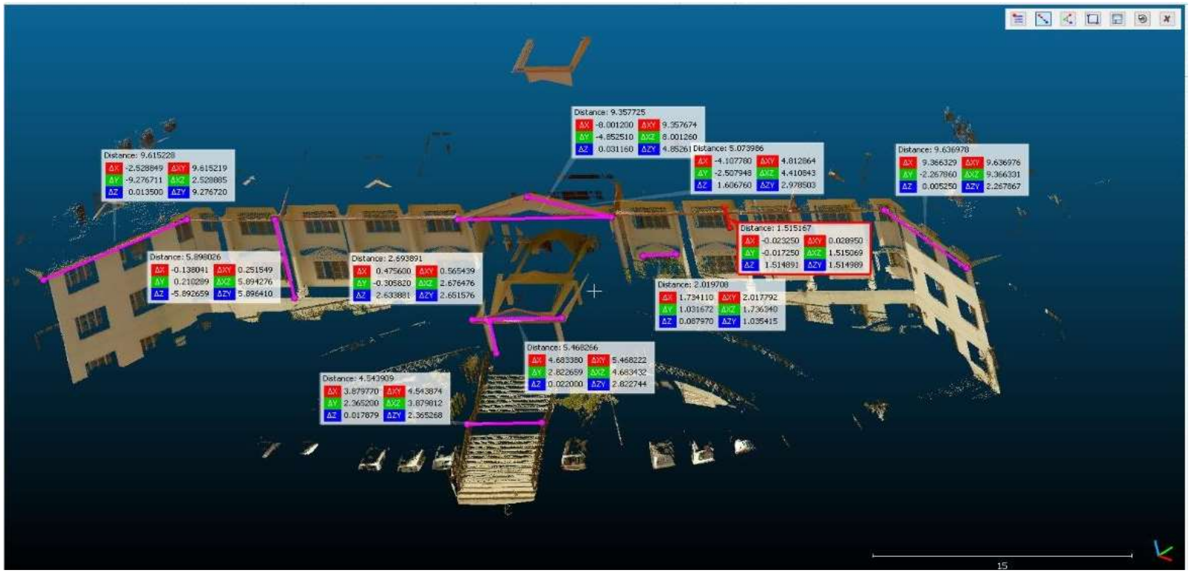


Fig. 3. Measurements on the TLS Point Cloud

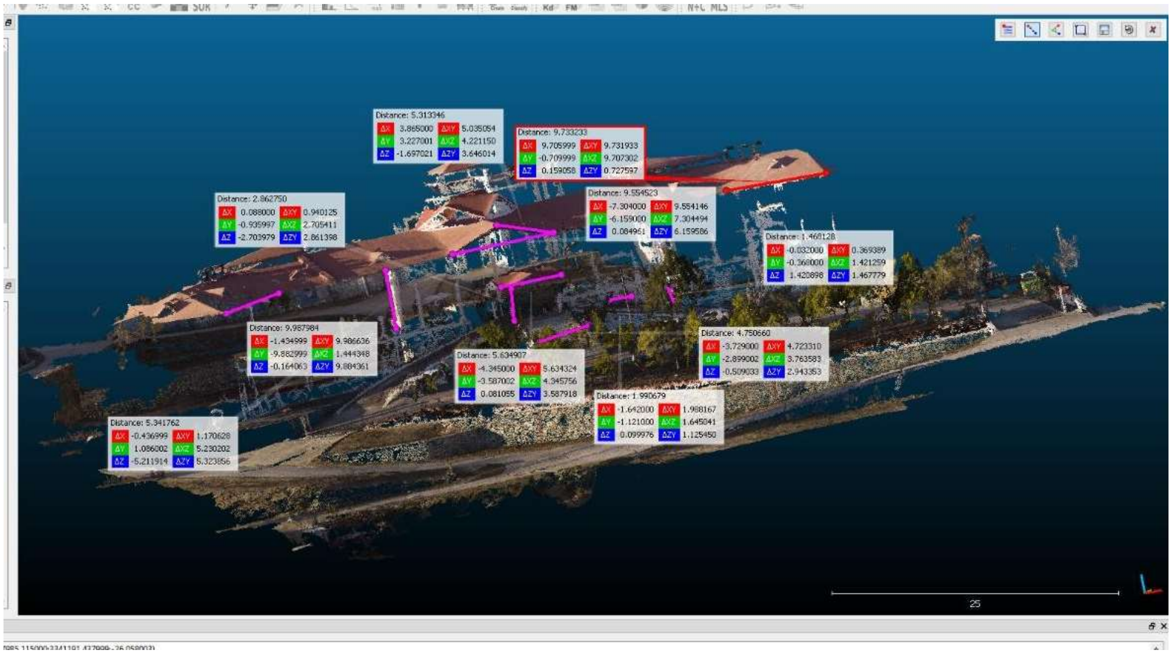


Fig. 4. Measurements on the DJI Mavic Air Point Cloud (1st UAV)

The Root Mean Square Error = 0.2475 m (Fig.6) was obtained for Mavic air point cloud with respect to laser scanner point cloud.

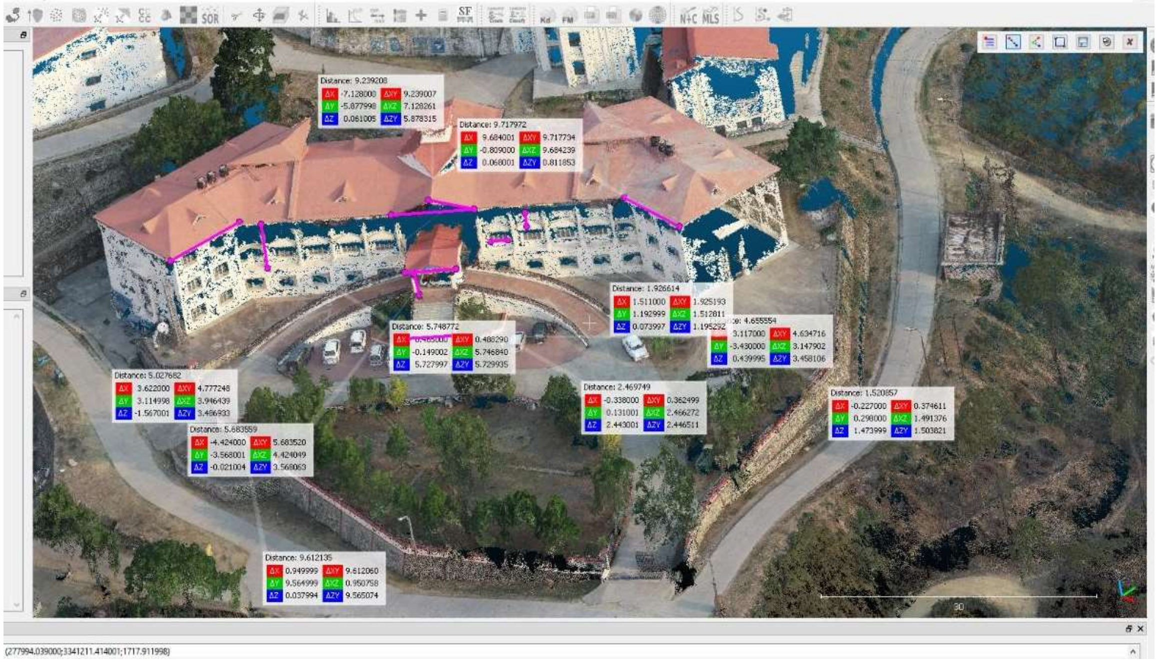


Fig. 5. Measurement of distances of the DJI Phantom 4 Pro Point Cloud (2nd UAV)

The Root Mean Square Error = 0.1251 m (Fig. 6) was obtained for Phantom 4 Pro point cloud with respect to laser scanner point cloud.

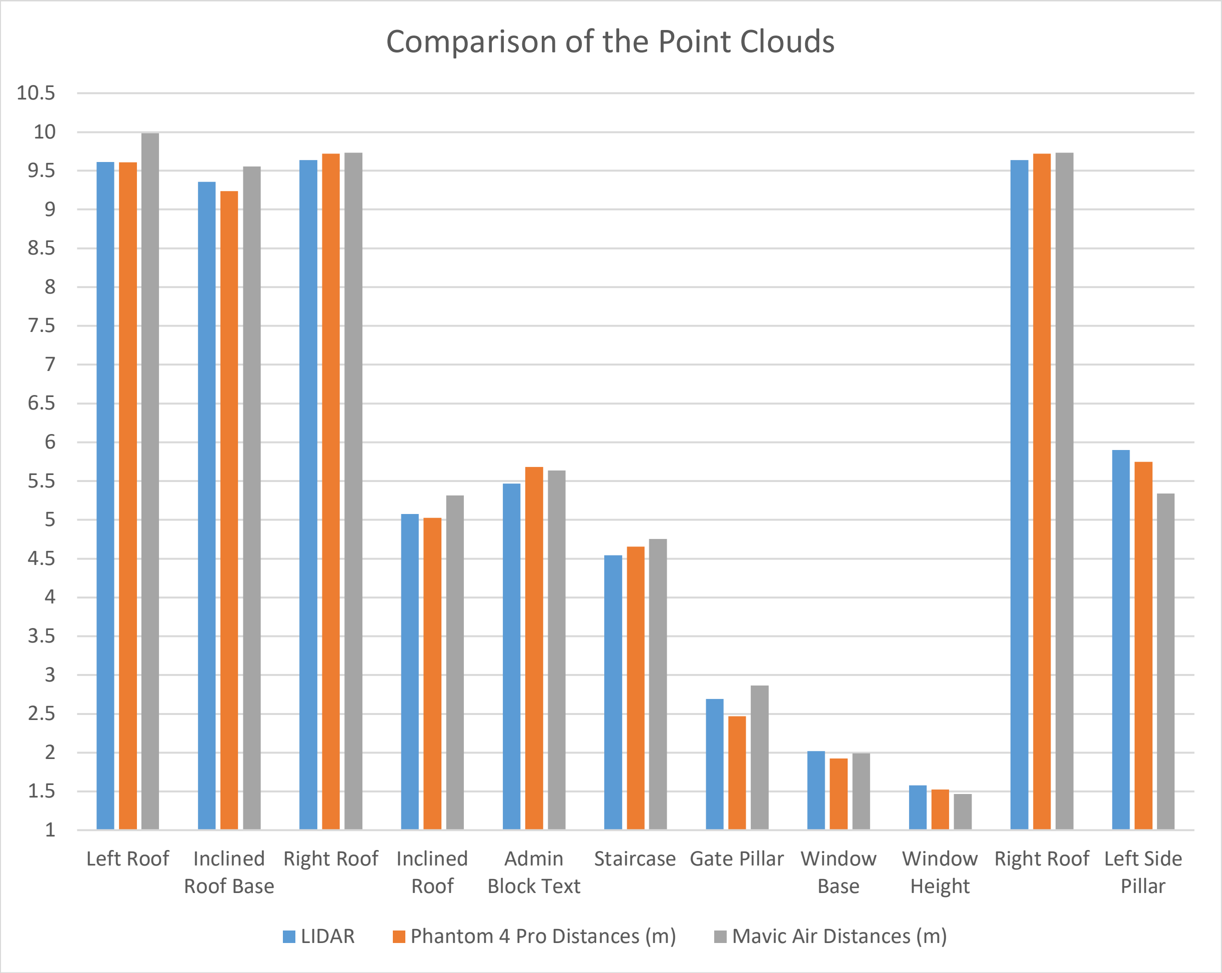


Fig. 6. Comparison of Phantom 4 Pro & DJI Mavic Air Vs Laser scanner measurements

RESULT

UAV technology in aerial mode, and TLS on the ground seem complementary technologies. while aerial UAV images are ideally suited to model the top view of a landscape or a terrain, terrestrial scanners are able to take data from different angles in the front or back of an object. Merging the two datasets together can create an efficient 3D model which can be used for various applications in civil engineering (Liu et al., 2014) like structural deformation monitoring, 3D city modelling, transpotation engineering for disaster management or for geomorphic studies like landslide monitoring.

Terrestrial Laser Scanner has limitation that it cannot capture top view of the structures or landforms though being highly accurate. This shortcoming can be overcome by using UAV derived point clouds and the merged cloud can resemble a complete 3D model. Therefore, the point cloud with least RMS error i.e. Phantom 4 Pro (2^{nd} UAV) cloud was merged with laser scanner point cloud to create complete 3D model of the administrative building. The Phantom 4 pro shows closeness to the laser scanner point cloud. The mean reprojection error for Phantom 4 came out to be 0.163 while that of Mavic air was 0.241. This means more correlation between the successive images leading to better 3D adjustments and thus resulting in a more accurate point cloud as compared to Mavic Air point cloud. Also, Phantom 4 pro weighs about 3 times more than Mavic Air resulting in more stable platform for collection of images.

Further work: The work can be further made accurate by using GCP's for georeferencing and acquiring more oblique photographs (Aicardi et. al, 2016). As the accuracy of DSM generated by UAV's increases for increase in GCP's, UAV point clouds could be easily merged with laser scanner point clouds for creating 3D model. The products obtained can be used a variety of applications like glacier and landslide monitoring, 3D city modelling and planning, traffic monitoring as these require more accurate DSM or DEM's.

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