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Digital Terrain Model (DTM) Extraction from Leaf-off UAV Images in a Dense Broadleaved Mixed Forest

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***Abstract* – The Digital Elevation Models (DEMs) are essential source of topographic information in many disciplines. The goal of this research was to exploit leaf-off UAV images as an alternative method for DTM development in a dense forest. In this regard, the low-altitude images acquired by a consumer-grade camera mounted on a drone was used for analysis. For DTM generation we used a photogrammetry-based workflow to produce and classify 3D point clouds. Based on ground 3D point clouds and interpolation technique a high resolution DTM was generated. The results indicated that, there is a strong relationship between the estimated (leaf-off UAV images) and measured (DGPS) Z values (R2 = 0.972 and RMSE = 1.47 m). We concluded that the VHR leaf-off UAV aerial imagery can be used for DTM extraction from dense forests.**

Keywords* – *digital elevation model, digital terrain model, UAV photogrammetry

1. INTRODUCTION

The Digital Elevation Models (DEMs) are essential source of topographic information in many disciplines, including surveying and 3D modelling. Digital terrain model (DTM), Digital surface model (DSM), and Canopy Height Model (CHM) are three common types of DEMs. Without taking into consideration the features on the ground surface, a DTM is utilized for bare ground elevation modeling [1]. The DSM, on the other hand, takes into account the elevation of things like buildings, trees, etc. In a CHM, the discrepancies between the DSM and DTM are represented by subtracting the DSM from the DTM. [2].We can create very high-resolution DTM, DSM, and orthomosaics from a series of overlapping 2D images using new 3D reconstruction techniques. [3, 4].

In forestry, DTM have been widely employed in various forest inventory applications such as logging routes identification, forest road detection, construction canopy height models, tree height and crown diameter measurements [5]. It is challenging to monitor and simulate DTM in areas with dense canopy cover because bare ground is frequently partially or completely hidden by the vegetation layer. Therefore, using LiDAR to penetrate forest canopies is the best technique to monitor bare ground and create DTM in dense forests [6]. In order to gather high-density point clouds and produce high-resolution digital elevation models, forestry applications have made extensive use of airborne laser scanning (ALS), often known as LiDAR (DEMs). For researchers, however, ALS has become exceedingly

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expensive, particularly if we require high-density data or high temporal frequency. Therefore, scientists are working to develop methods to produce high-accuracy DEMs. High spatial resolution 3D point clouds and DEMs can be produced by UAVs, which can reduce the cost of data collecting and processing time. As an alternative method for DTM production in a dense forest, we planned to use leaf-off UAV images in this work. Therefore the main of this study is:

- Evaluating the performance of high spatial resolution leaf-off UAV aerial images and 3D photogrammetry for DTM generation in a dense forest.

2. EXPERIMENT DESCRIPTION

We propose a methodology which includes a series of activities such as UAV image acquisition during leaf-fall period, point cloud classification, and DTM development. (Figure 1).

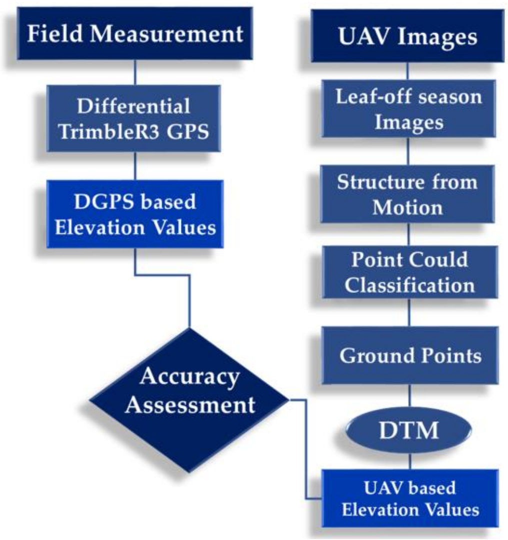

Fig. 1 Methodology overview

UAV platform and DTM construction

Analysis was performed using low-altitude images acquired by a drone equipped with a consumer-grade camera. It was a Survey 1 visible light camera with a 4032 x 3024 pixel detector, a 60 ° FOV, and a 4 mm focal length. Normally RGB images between 350 and 650 nm are captured using this camera. At 100 meters in elevation, the calculated theoretical ground surface distance (GSD) was 5 cm. An octocopter that had been built by the University of Tehran specifically for photogrammetry purposes was carrying the camera. Additionally, the UAV had GPS and an IMU to provide accurate georeferencing data. (Figure 2).

In order to produce DTM, the dense point cloud is automatically divided into two classes: ground points and the rest. The classification process involves two steps and depends on three factors: maximum angle, maximum distance, and cell size.

1. The point cloud is split into cells of varying sizes, and the lowest point (intended to be a ground point) in each cell is identified. Using the triangulation approach, the first approximation of the terrain model is generated from these lowest points.

2. In the second phase, a new point is introduced to the ground points from the previous step if it meets the following two conditions: 1) it is close to the terrain model; and 2) the angle between the terrain model and the line connecting this new point is smaller than a specific angle. Cell size should be specified in relation to the size of the greatest area within the image that lacks ground points, such as tree crowns or close forest. We analyzed multiple scenarios based on various values for the aforementioned factors, and the optimal mode was chosen. (Table 1).

Fig. 2 UAV platform

Table. 1 Underground water level variation in time (example)

Processing step	**Parameter name**	**Parameter value**
Aligning images	Accuracy	Highest
Optimization of image alignment	-	Default
Ground control point placement	-	Manual
Building dense points	Quality	High
Point cloud classification (leaf-off)	Cell size	10 m
	Max angle	30
	Max distance	1 m

DTM was generated through a TIN method using ‘Agisoft Metashape” standard workflow. For accuracy assessment, we used 97 Ground Control Points (GSP), which were recorded using differential Trimble R3 GPS and statistical analysis.

3. RESULTS AND SIGNIFICANCES

The resulted DTM and hillshade are represented in Fig. 3. The accuracy of generated DTM was analyzed by comparing with DGPS coordinate. In polarimetry accuracy, a sub meter ±0.261m and ±0.324 m was obtained for X and Y coordinates respectively. The results show a significant association between estimated (leaf-off UAV pictures) and measured (DGPS) Z values (R2 = 0.972 and RMSE = 1.47 m). (Figure 4).

We calculated the residuals of estimated values and MAE to see how close estimations are to measured values. (Figure 4). The MAE of Z coordinates was found to be 1.32 m.

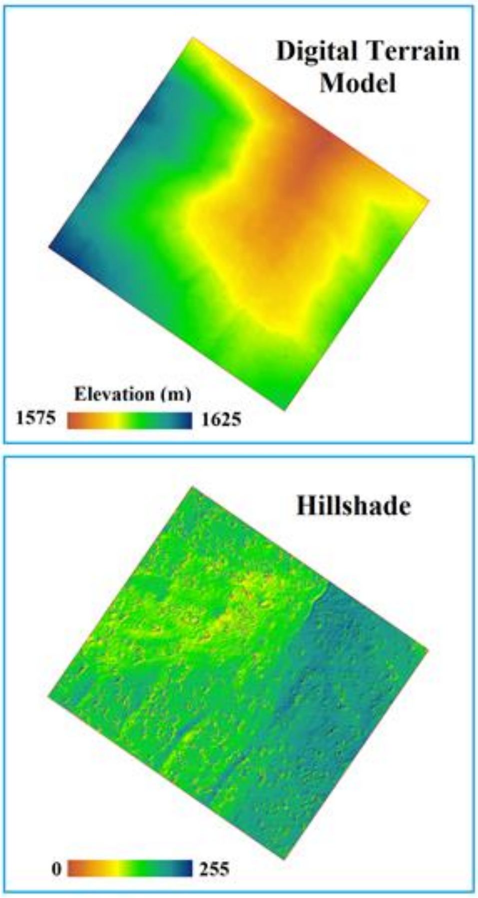

Fig. 3 DTM extracted from leaf off UAV aerial images

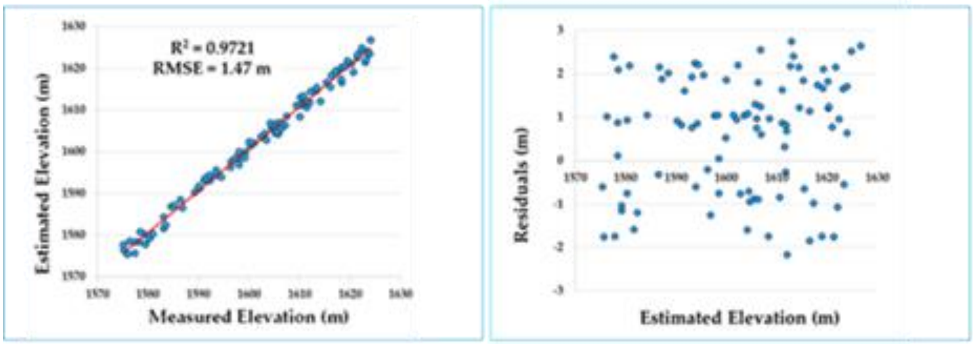

Fig. 4 Linear regression and residuals between estimated and measured parameters

4. CONCLUSIONS

Based on this study, the VHR leaf-off UAV aerial imagery can be used for DTM extraction from dense forests. The accuracy produced by the data is relevant for various applications with low cost expenditure and less expert manpower.

On the other hand, this low-cost approach may be associated with a lot of challenges in image processing. Image alignment is one of these challenges in natural forests. Because of repetitive patterns in natural forests, detecting such patterns, automatically or sometimes manually, is a challenging problem. Flight configuration, camera type, image processing options, weather conditions and filed structure are also the factors that can affect the results.

5. REFERENCES

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Note:

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