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Automated Measurement of Plant Height of Wheat Genotypes Using A DSM Derived From UAV Imagery

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Abstract: In this study, we have evaluated the use of UAV photogrammetry for monitoring of a wheat experiment under field condition, filtered DSM to derive the wheat plant heights, and compare the results with the field measurements. The images were acquired with use of low cost UAV Walkera QR350 and GoProHero3+ action camera in May 2015. Totally 477 images were acquired for quality assessment of the proposed method and a reference dataset was collected with terrestrial fieldwork. For comparison of field measurements with DSM-derived plant heights, the maximum calculated plant height in the plot was selected. The mean, median, and standard deviation were calculated as 4.66 cm, 3.75 cm., 13.78 cm. Regarding statistical t-test between the field measurements and plant heights from DSM, t-value was calculated as 1,82 and p-value was 0,071. Since t-value is larger than 0.50, the values between traditional method and our approach are highly correlated considering the fact that p-value confirms this result.

Keywords: UAV; DEM; precision agriculture; wheat experiment; plant height

1. Introduction

Turkey is a country with a good climate and ecological properties for agricultural production, and the agriculture occupies 24.6% workforce of the whole country[1] . Wheat production is important for Turkish economy and Turkey produced 17 million tons of wheat in 2016.

Traditionally, the monitoring of the wheat height is performed with field works under experiment conditions. The breeders and agronomists measure the height of the wheat genotypes with random selection in predefined interval distances. But it is time consuming and not accurate since it is not possible to measure all wheat genotypes tested in the field experiments. Thus, automated and accurate methods are needed.

High resolution imagery allows producing an accurate 3D model of any object including agricultural field experiments. UAV technology gives an opportunity to acquire imagery from above and then photogrammetric workflow can produce high resolution orthoimage and also a 3D model. UAV technology also allows repeating the process in predefined dates to monitor the growth of plant height of wheat genotypes periodically.

For monitoring of the wheat growth, the height of wheat is one of the important parameters. The monitoring of the height changes among different times will allow agronomist and breeders to determine the health and growth of the wheat experiments.

In the literature, crop surface models are created and used for measuring of the crop heights [2–4]. Bendig et al [3] created crop surface models of barleys with cm resolution, and they calculated a mean value for each harvest parcels to estimate the crop heights. They applied photogrammetric method with use of Agisoft Photoscan software package. Laser scanning data also were used with Tilly et al [4], they created crop surface models from the laser derived point clouds. Similarly to Bendig [3], Possoch et al [5] also generated CSM with using UAV-based crop surface model, and they used mean values of the subtracted surface model from DTM.

In agriculture, UAVs are also used for LAI and NDVI analysis to monitor the health of the crops, but without considering the height of the vegetation [6–8].

There are some researches regarding the tree height estimation. Considering the use of UAVs in forest inventory studies, Fritz et al. [9] detected the individual trees in an open area. They processed more than 1000 images which acquired at 55 m flying height. The used camera was a Panasonic G3 with 14-42 mm focal heights and 16.6-megapixel resolution. The image acquisition was performed in April before the leaf emergence. They generated orthoimages and point clouds, and compared them with ones generated with a terrestrial laser scanner. For processing of imagery, they used CMVS and PMVS-2 software packages to process data. The processing schema consisted of 6 steps, viz. data cleaning, SIFT feature extraction, image matching, classification, point cloud generation, including camera parameters for 3D modeling of the vegetation surface. They detected 73 trees. Their study compared laser-based and image-based point clouds and confirmed that the results from image data were superior to those from the laser scanner. Feng et al. [10] classified UAV-based images to detect urban vegetation.

In this study, we evaluated the use of UAV photogrammetry for monitoring of the wheat field experiments and compared the results with the field measurements.

2. Experiments

The study area is located in Dosemealti agriculture area near Antalya province. This region has a lot of wheat cultivation sites and also industrial organizations for the process of the agricultural products. Figure 1 shows the study area which contains 192 cultivation parcels in the wheat experiments where 52 of them were investigated.

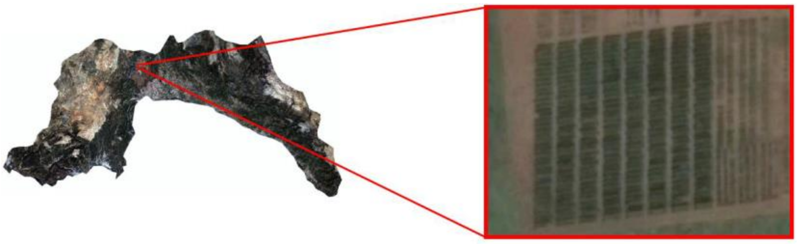

Figure 1. Experimental area.

The process starts with image acquisition with a low cost UAV. The UAV was very simple, operated in a manual mode in high windy conditions. Therefore, the flying height varied during the acquisition.

The images are pre-processed due to noise elimination and enhancement. Then, commercial software package, Agisoft Photoscan was used to create high resolution orthoimage and digital surface model. For measurement of the wheat plant heights, the digital surface model was filtered to derive the terrain model. Then, the terrain model was sub-structured from the surface model. Later on, for determination of the wheat plant heights for each parcel, the maximum elevation was picked as the wheat plant height for evaluation. The results were evaluated with use of reference dataset which was created with field measurements.

2.1. Image acquisition

The images were acquired with use of low cost UAV Walkere QR350 and GoProHero3+ action camera on December 7th, 2015. Totally, 477 images were taken but 55 of them were selected for the process.

Figure 2 . Used UAV (left) and GoPro camera (right).

The reference dataset was collected with terrestrial fieldwork. A special circle with 1.5m diameter was placed above the harvest parcel and the average wheat plant height in the experimental area which intersects with the circle was reported as wheat plant height for the selected parcel.

2.2. Image preprocessing

The acquired images are high resolution and very useful for generating accurate surface models. But images contained noise and they were needed to be eliminated. The images contained noise because of various reasons e.g. atmospheric effects, and the sensor itself.

Pre-processing contains three steps; estimating the noise, noise reduction [11] Wallis filtering [12] forces the mean and the standard deviation of the image to fit given values. An adaptive edge preserving smoothing filter [11] is used for reduction of the noise. This filter preserves edge features like one-pixel line, corners, and line points.

2.3. Generation of surface model and orthoimage

Image orientation is a must to perform image do matching and 3D reconstruction from the preprocessed dataset. The exterior orientation was performed with automatic tie-point extraction using bundle adjustment and ground control points (measured on Google Earth imagery). Images are processed and the point cloud and orthoimage were created with the use of using Agisoft Photoscan software. The elevation of the ground control points is interpolated from ASTER based 30 m resolution digital elevation model.

For calculation of wheat plant heights, terrain model has to be generated. Reduction of the generated digital surface model allows producing the terrain model. For this purpose, a progressive morphological filter method [13] is applied. The method starts with morphological opening operation on the surface model to generate a secondary surface. The elevation difference between the cells is compared with previous and the current ones during the iteration. If the difference reaches a defined threshold, the cell is classified as a non-ground object. The used threshold is calculated with a predefined slope value (s). The window size of filtering kernel (dhT,K) has been increased, and the derived surface has been used as an input for the next operation. This is defined by Zhang et al. [13]

$$\mathrm{d}_{\mathrm{h}_{\mathrm{T,k}}} = \left\{ \begin{matrix} \mathrm{dh}_{\max} & \text{if } \mathrm{d}_{\mathrm{h}_{\mathrm{T,k}}} > \mathrm{dh}_{\max} \\ \mathrm{s}(\mathrm{w}_{\mathrm{k}} - \mathrm{w}_{\mathrm{k-1}})\mathrm{c} + \mathrm{d}_{\mathrm{h}_0} & \text{else if } \mathrm{w}_{\mathrm{k}} > 3 \\ \mathrm{dh}_0 & \text{else if } \mathrm{w}_{\mathrm{k}} \leq 3 \end{matrix} \right\} \quad (1)$$

Where is the $\mathrm{d}_{\mathrm{h}_{\mathrm{T,k}}}$ height difference threshold, $\mathrm{d}_{\mathrm{h}_0}$ is the initial elevation difference threshold which approximates the error of DSM measurements, $\mathrm{dh}_{\max}$ is the maximum elevation difference threshold (m), c is the grid size (m), s is the estimated terrain slope and w_{k} is the filtering window size (in number of cells) at th iteration.

3. Results and Discussion

Substruction of terrain model from the surface model gives the normalized surface model, which will be used for calculation of the wheat plant heights in harvest parcels. The height map of the wheat plants in the experiment is shown in Figure 3.

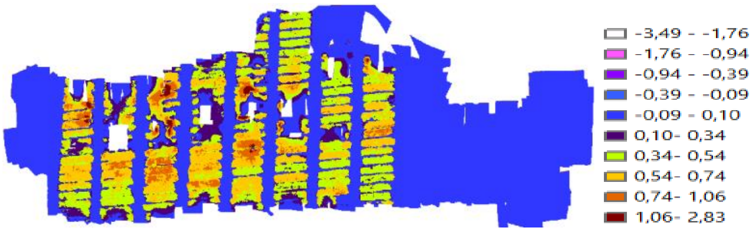

Figure 3. Crop Height Model

For comparison with the field measurements, 55 parcels have been selected.

For each parcel, the maximum, minimum and average height values are calculated. Since the generated surface model is produced with the photogrammetrical method, the gaps between the wheat parcels are also present and these gaps affect the statistical values negatively. Therefore, only maximum height values are chosen for calculation of the wheat plant heights.

Wheat heights | Pi =max(nDSM) Pi ,i[1,2,3...n]

For n parcels, the wheat height for the parcel n is determined as a maximum elevation in the parcel n. There is a high correlation between the height values derived from field measurements and the calculated values from the proposed method. The calculated statistics mean, median and standard deviation values are listed in Table 1.

Table 1. Statistics of the difference between field measurements and the calculated plant heights(cm)

Mean	Median	Std.Dev.
4.66	3.75	13.78

The mean, median, standard deviation is calculated as 4.66 cm, 3.75 cm., 13.78 cm. .Regarding statistical t-test between the field measurements and plant heights from DSM, t-value is calculated as 1,82 and p-value are 0,071. Since t-value is larger than 0.50, the values between traditional method and our approach are highly correlated considering the fact that p-value confirms this result. In a previous work [14] barley heights are measured as 72.6 cm with 15.2 cm standard deviation with use of traditional methods.

5. Conclusions

In this work, it is concluded that UAV imagery is effective to measure the wheat length as an alternative method for the ground measurements. The filtering method has direct influence in the final results. Any improvement in the filtering of surface model will allow an increase in the quality of the results. As a future work, laser scanning can be applied to compare its performance to measure the wheat length.

Author Contributions: Nusret Demir developed the idea and wrote the paper, Semih Unal run and complied the experiments , Namık Kemal Sönmez contributed in processing of aerial imagery for crop height purpose and developed the statistical methods, Taner Akar planned and conducted the field works and contributed in the statistical analyze.

Abbreviations

DSM:Digital Surface Model

nDSM:Normalized digital surface model

UAV:Unmanned Air Vehicle

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