Estimation of Wheat Canopy Height Using UAV Derived 3D Point Cloud Data

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ABSTRACT

Objective:

Accurate plant height estimation is important for crop status monitoring and yield prediction. The plant height can be used as an indicator to estimate crop phenology and biomass. The rapid development of the Unmanned Aerial Vehicle (UAV) system and digital cameras provides high spatial resolution and overlapping images which could be used to generate digital surface models (DSMs) using the photogrammetric methods. Currently, many researchers generate two DSMs, one for the canopy elevation and the other for bare soil elevation to determine the canopy height from the difference between the two. This method requires a high accuracy of the DSM data which is dependent on the absolute accuracy of the 3D point cloud data. The objective of this paper is to develop an alternative method using UAV-derived 3D point cloud dataset through a statistical analysis method to determine the canopy height. In this method, the canopy height will be determined using one point cloud measurement without the need of both bare soil and crop canopy DSMs.

Methodology:

The UAV-derived 3D point cloud data with internal ground control points can achieve very high relative accuracy. Although the point cloud data still has a lower absolute accuracy, the relative accuracy makes the point cloud data to retain spatial properties of the plant. Due to the high resolution of the UAV based images, the single pass 3D point cloud data contains points for both bare earth and crop canopy surface. The 3D point cloud data can be divided into many 3D columns that are over the same grid cells. The highest and lowest points can be determined in each column as the canopy and bare soil points; thus, the canopy height can be extracted from the 3D point cloud data for the entire field. Due to the different photogrammetric algorithms and the existence of noise, a method is developed to eliminate point cloud outliers.

Results:

To test the proposed method, the UAV data was collected in a size of 50m by 50m wheat field in Melbourne, Ontario. 240 images were captured using the DJI phantom 3 UAV system with a 4K digital camera. The 3D point cloud data generation and processing were carried out with the UAV images processing software Pix4D. The point cloud was divided into many columns at a size of 2m by 2m and the highest and lowest points were extracted for each column. An outlier elimination method was applied to the point cloud data to remove the outliers in each column using C++ with the point cloud library. After the elimination of the outliers, the height of each column was calculated from the highest and lowest points that is the height of the canopy in this column. The relative accuracy of the 3D point cloud data was 0.02m horizontally and 0.04m vertically that was improved using 24 ground control points. A total of 15 measured canopy heights were collected in the test field. The estimated canopy height was calculated for the entire test field in this study. The RMSE between the estimated and measured canopy heights for all 15 sampling points was 3.41cm.

This study used the spatial distribution of bare earth and crop canopy surface points in the 3D point cloud data to determine the height of crop canopy in the wheat field. This method achieved the measurement of crop height and only used one set of UAV-derived 3D point cloud data.