CROP HEIGHT DETERMINATION WITH UAS POINT CLOUDS

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ABSTRACT:

1. INTRODUCTION

Accurate determination of the crops height is in many respects of great importance. For example, the development of the plant height of maize is a very good indicator of the coming crop yields Yin et al., 2011. Similar, though less significant relationships have been observed for several winter crops, e.g. Girma et al., 2006. Basically, there are statistically very close relationship between the plant height and biomass, for example, Ehlert et al., 2009, Zhang and Grift, 2012.

For vehicles (tractors) various technologies for crop height measurements have been tested, either stand alone or in combination, e.g. ultra sonic, radar rangefinder, stereo camera systems, laser scanners and light curtains, see Busemeyer et al., 2013. Regardless of the sensors used, there are high demands to be fulfilled for tractor-based technologies. Thus, the canopy height should be determined with an accuracy of about 1 cm and at best regardless of external conditions, i.e. dust, vibration, and sun. Ehlert et al., 2009 have generally shown that, laser scanners are able to meet these requirements. However, tractor-based systems are bound to the tramlines to measure the plant height. This means the measurement are accurate, but the areal coverage is quite limited.

1.1 Photogrammetric height determination of vegetation surfaces

The determination of a surface model using photogrammetric methods has improved dramatically in recent years. Several developments from the field of computer vision enable an automatic orientation of almost any kind of imagery. Using so-called "Dense matching" methods a coordinate triplet may be computed for virtually every pixel of an aerial photographs, e.g. Haala, 2013. The height accuracy is related to several issues and the theoretical limit is generally around one pixel.

In the case of surface vegetation two special issues have to be considered:

1. As mentioned above, the objects of interest (vegetation surface) should not move during the aerial survey for successful matching or highly accurate position determination. That cannot be guaranteed for agricultural crops. Especially with mature grain, even a little wind is enough to cause problems.

2. At coarser image resolution the vegetation surface appears relatively homogeneous, because within a single pixel parts of one or more plants and their shadows merges into one signal (canopy level). At a ground resolution of a few cm, the single plant as well as the shadows casted by them and the soil surface in between the crops are dissolved (leaf level). Thus, in theory it be possible to separate the soil surface and the canopy signal in the 3D point cloud. However, this may work only if the canopy is not too dense, and the leaf area index is low. Nevertheless, the geometric properties of the ground points are bad and error-prone, see figure 1.

2. METHODS AND MATERIALS

In the paper, two different approaches to crop height determination will be presented:

1. (*Difference Method*) Determination of canopy height by taking the difference between a current UAS-surface model and an existing digital terrain model that, e.g., was obtained by a parallel tracking system or an initial UAS-flight campaign. The advantage of this method is that the reference surface is always the same and the height measurement of the canopy surface is accurate and reliable throughout the entire growing season. However, a prerequisite of this method a reference DTM of correspondingly accuracy.
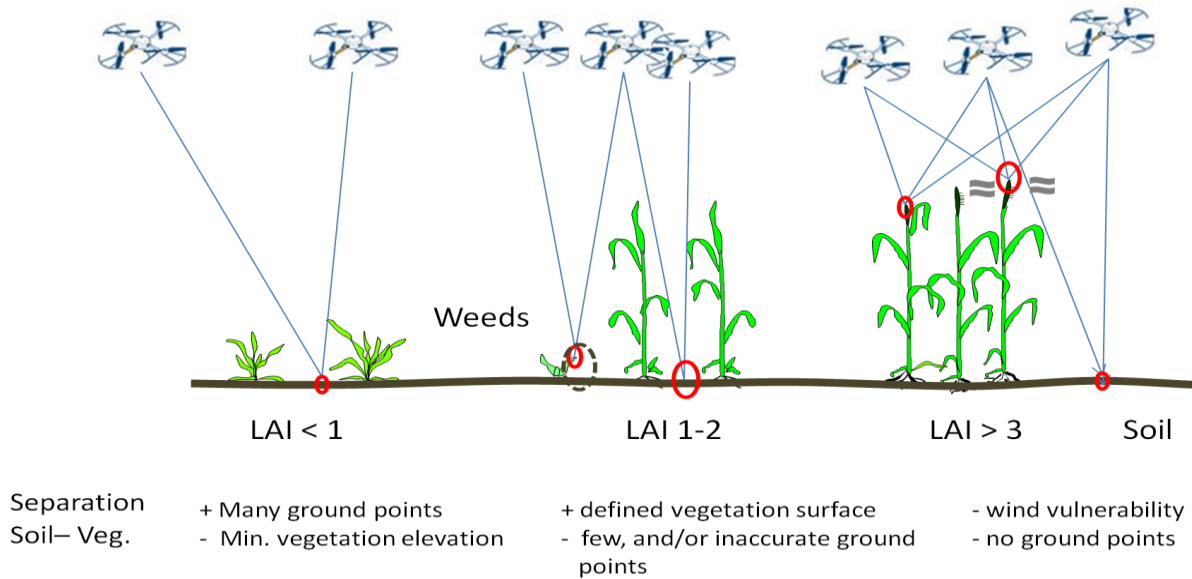
Figure 1: Possibilities and problems of UAS based photogrammetry for the derivation of crop surface models

2. (*3D-point cloud analysis*) Determination of canopy height by a statistical analysis of the 3D point cloud. The 3D-point cloud method, which is presented and analyzed in this work, was designed specifically for evaluating mono temporal UAS-surveys. The particular difficulty is to determine the plant height of the plants, even without a DTM. Due to the high ground resolution of the UAS images the point cloud contains not only the vegetation surface, but also partly the ground between the plants. Thru a classification in soil and vegetation points, a DTM and a DOM is derived from the point cloud. These are then used in the same way as in the difference method to determine the basis for the plant height of the crops. The LAS file format, as well as the software for the evaluation and classification of LAS data in the point cloud were developed for LiDAR data sets. Therefore, the parameter settings in the present case had to be adjusted. It should be noted that this method is not an approach to determine heights or growth of individual plants. Rather, the most accurate possible area-based measure of the canopy height is desired. Therefore the terms "ground point" and "vegetation point" are used. In a narrower sense, the amount of individual plants is not calculated, but all points representing the canopy and the soil surface. Alternatively, certain percentiles of height values from the 3D-point cloud shall define the ground and the canopy surfaces. For the ground surface the 5% percentile is often appropriate, while the 95% for the canopy surface model - or the 99% percentile can be calculated. The advantages of this statistical approach are, it is quite simple and single tall plants do not determine the height of a grid cell. This method was successfully tested on natural grasslands for which no or only a very rough DTM was present, see Grenzdörffer and Bogdanov, 2013.

3. TEST AREA AND UAS-SURVEYS

The UAS test flights were conducted at the field trials University of Rostock, Germany. The field trials different agricultural crops with a variety of plant cultivation experiments can be found. In order to investigate the possibilities and accuracies of the point cloud method several agricultural crops and experiments were covered with during each flight, especially:

- a winter wheat test plot with a potassium-enrichment trial, as well as a sulfur trial took place,
- an oilseed rape trial area as part of a crop rotation experiment,
- an alfalfa and grass test plot, as part of a field crop experiment, and
- a maize trial field with several cultivars.

For the investigations four UAS image surveys (epochs) were conducted in the course of the growing season in 2013. The four flights with the UAS took place at: 03 May, 24 May, 02 July and 22 August. Since the area of interest was flown directly after harvest (epoch 4), a DTM of the terrain surface could be created, thus allowing for plant height calculation with the difference method and serving as a reference for the point cloud method. The results thus obtained are used to compare them with those of the 3D point cloud method.

For the UAS-surveys of the experimental plots the Quadrocopter MD4-1000 from Microdrones GmbH was used. As a camera the Olympus PEN E-P2 was used with a fixed focal length of 17 mm. The image resolution of the camera is 4032×3024 pixels. All UAS flights followed the same flight plan. In each case, approx. 300 images were recorded over a distance of about 1.6 km. The flight time was about 10 minutes, with the average altitude of 52 m above ground, which corresponds to a GSD of approx. 1.3 cm. For the surveys an endlap 80% and a sidelap of 60% was chosen. One flight covered about 3.8 ha. 18 control points were each designed and measured with a Leica GX1230 RTK-GPS receiver for geo-referencing.

The processing of the data and the calculation of point clouds was carried out with the software Photo Scan Agisoft. The residuals at the control points were between 1-2 cm in position and 1-5 cm in height, Zacharias, 2013. The accuracies achieved are in line with similar projects, e.g. Bendig et al., 2013.

3.1 Results

In the paper results and achievable accuracies for different crops and experiments will be presented. Thereby the influence of the use of different point cloud software will be presented.

Vegetation indices can be computed from the RGB images, which improve the statistical the correlations of crop height against yield. Furthermore results of an extensive grass land experiment will be presented.

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