TERRESTRIAL LASER SCANNING OF AGRICULTURAL CROPS

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ABSTRACT:

Laser scanning is a new technology that provides accurate and dense 3D measurements from the object. Development of laser scanners and techniques has led to several successful applications in the field of land surveying, forestry, industrial design and city planning. However, airborne laser scanners have not broken through in the field of agriculture and precision planning due to high expenses and insufficient accuracy, where as terrestrial laser scanners on the tripod are considered to be impractical for operational use. However, in the future we may have low-cost laser scanners mounted e.g. on UAVs enabling the cost-efficient use of laser scanning for precision agriculture as they are presently used in forestry. The goal of this study was to investigate how laser scanners and laser point data can be exploited in agriculture and precision farming. Growth height and ear recognition of cultivated plants were investigated using laser scanner data. The test area of this study is located in the Kotkaniemi Experimental Station of Kemira GrowHow Ltd in Southern Finland. Cereal cultivars were sown in plots of 1.25 m x 10 m on 6th May 2006. Plots were fertilized at various rates corresponding to 0, 40, 80, 120 and 160 kg of N/ha. Three small grain cereals (barley, oat and wheat) with five different rates of fertilizer were scanned six times using Faro terrestrial laser scanner during the growing season of 2006. Faro laser scanner was mounted on a movable rack specially made for this study. The rack was about 3 meter high and Faro scanner scanned the ground beneath it. Test plots were signalled using white plastic disks and their location was measured using tachymeter. Besides, digital photographs, soil moisture values and growth height using tape measure were collected from each test plot and meteorological station observations were recorded. Growth heights were determined from each test plot using laser scanner data. A single test plot was divided into smaller grid cells and growth heights were determined from each cell. Precision harvesting was made on the 16th August 2006 with a combined harvester and total fresh weight of grains was weighed. Moisture content of grains was determined and fresh grain weight was converted into grain yield value (kg/ha) using grain moisture content and plot area. Growth height measures were compared to threshing results and there was strong correlation between measured growth heights and grain yield from each studied cultivars. Besides, ears of spring wheat cultivar Picolo were determined. An algorithm was developed to automatically recognize ears and estimate their size from laser scanner data. This result also correlates with the grain yield but the problem was to find suitable parameters for the algorithm and algorithm provide rather relative than absolute results of grain yield.

1. INTRODUCTION

Terrestrial laser scanners are becoming widely used in the field of close-range sensing. They are easy to use and they provide three-dimensional point cloud from the object surface in a few minutes. Spatial resolution of terrestrial laser scanners is high and they can measure several thousand or even more points per square meter depending on the distance between laser scanner and measured object.

Several image-based remote sensing studies have been made for agriculture and precision crop management. Aerial cameras and multispectral scanners of remote sensing satellites are proved to be useful tools for regional and global area crop management (Idso et al. 1980; Moran et al., 1997a; Seelan et al., 2003). Due to the development of Synthetic Aperture Radar (SAR) instruments and generalization of SAR satellites, several SAR studies in the field of agriculture are made (Chakraborty et al., 1997, 2005; Moran et al., 1997b; Karjalainen et al., 2001, 2002, 2004a & 2004b).

Airborne laser scanners are widely used to model terrain surfaces and city areas and to measure forest parameters such as stem volume and tree height. Unfortunately, airborne laser scanners, in general, are not suitable for agricultural applications because of their expenses and insufficient accuracy. The expenses are high especially when multi-temporal data sets are needed. There are only a few studies concerning laser scanning and agriculture (Grenier and Blackmore, 2001; Schmidt and Persson, 2003) and they are mainly focused on modelling field surface.

Terrestrial laser scanners are accurate enough to obtain very detailed information about agricultural crops but they considered to be impractical for operational use. However, this study is based on the assumption that in future we probably will have e.g. low-cost unmanned airborne laser scanners. And different crop parameters will be extracted from agricultural field point cloud and used in precision farming likewise they already do in the field of forestry.

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The goal of this study was to investigate how laser scanners and laser point data can be exploited in agriculture and precision farming. Growth height and ear recognition of cultivated plants were investigated using laser scanner data.

2. STUDY AREA

2.1 Kotkaniemi test area

The plot trial was established at the Kotkaniemi Experimental Station of Kemira GrowHow Ltd, situated in Southern Finland (N 60°21'28" E 24°22'16") about 50 km from Helsinki. Field experiments of fertilization and plant protection are made in the Experimental Station and its area is 294 ha, from which 90 ha of agricultural fields.

The two-row spring barley cultivar Justina, spring oat cultivar Belinda and spring wheat cultivar Picolo were sown in plots of 12.5 m2 (1.25 m x 10 m) on 6th May 2006. Justina is a medium late barley cultivar, which is mainly used as raw material of feed. Belinda is a late oat cultivar and used both for feed and food supplies purposes. Picolo is a medium late wheat cultivar which can be used for milling because of its' good quality traits.

Figure 1. Kotkaniemi Experimental Station of Kemira GrowHow Ltd is located in Southern Finland. Cultivars were sown in narrow rows.

Plots were fertilized with NPK compound fertilizer (N-P-K 20-3-8) at various rates corresponding to 0, 40, 80, 120 and 160 kg of N/ha. Thus, an increase in N application rate resulted also in an increase in levels of P and K.

3. DATA AND METHODS

3.1 Movable rack for the scanner

Faro laser scanner was mounted on a movable rack specially made for this study. The rack was about 3 meter high and laser scanner was fastened upside down to the cross-bar of the rack and it scanned the ground beneath it. The rack has four wheels and it was easy to move throughout the test plots and it was made at the Finnish Geodetic Institute.

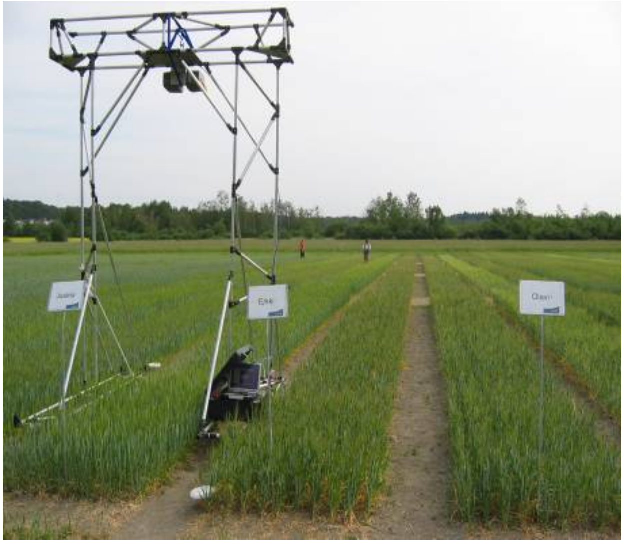

Figure 2. Faro scanner is mounted on the rack.

3.2 Laser scanning test plots

Plots with different cultivars and different amounts of fertilizer were scanned six times using Faro terrestrial laser scanner during the growing season of 2006:

- 1st scan - 15th of June
- 2nd scan - 21th of June
- 3rd scan - 29th of June
- 4th scan - 6th of July
- 5th scan - 19th of July
- 6th scan - 8th of August

Every time, three cultivars (Justina, Belinda and Picolo) with five different rates of fertilizer were scanned and altogether 90 scans were made during growing season 2006. Scans were made using ¼ resolution and hundreds of laser signals were recorded from white signal plates of about 2 dm^2

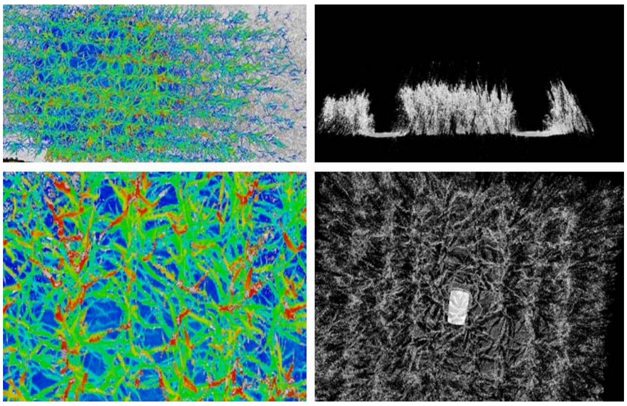

Figure 3. Images of 3D point cloud data. Points are colour coded according to distance from the sensor (on the left side).

3.3 Field works other data

Test plots were signalled using white plastic disks and their locations were measured using tachymeter to orientate the data scanned at six different times.

Figure 4. Digital photographs of oat plot during the growing season.

Besides, digital photographs and growth height from three random places from each test plots were collected using tape measure. Similarly, ground moisture measurements were collected from five random places from each test plots using moisture meter and Kotkaniemi meteorological station observations were recorded for each scanning day.

Plots were threshed on the 16th August 2006 with a combined harvester designed for harvesting trial plots. The whole plot was threshed and total fresh weight of grains was weighed. A 1 kg sample was taken for each plot to determine moisture content of grains. Fresh grain weight was converted into grain yield value (kg/ha) using grain moisture content and plot area. Measured grain yield was reported at 15% moisture content.

4. RESULTS AND DISCUSSION

4.1 Initial works

Laser data was filtered using Faro Scene Software to remove noise and points generated from both the ground and vegetation.

4.2 Growth height estimation of crops

Growth heights were determined from each test plot using laser scanner data. A single test plot was divided into smaller grid cells and growth heights were determined from each cell. Growth height measures were compared to threshing results and we found strong correlation between measured growth heights and grain yield from each studied cultivars.

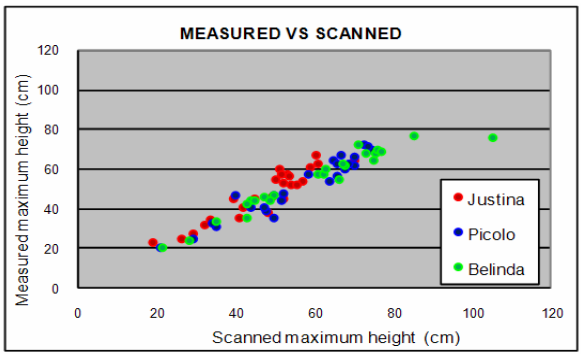

Figure 5. Measured and scanned maximum growth heights of Justina, Picolo and Belinda.

4.3 Ear detection

Ears of spring wheat cultivar Picolo were determined. An algorithm was developed to automatically recognize ears and estimate their size from laser scanner data. The algorithm was based on the idea that point cloud was converted into voxel model and voxels with enough laser points were marked. Several marked voxels side by side in vertical direction were associated as ear of wheat.

PICOLO	**160N**	**120N**	**80N**	**40N**	**0N**
Grain yield, kg/ha	3556	2268	205 9	224 8	887
Estimated ears	2054	1133	123 4	115 4	709

Table 1. Measured grain yield of Picolo at different N levels and grain yields estimated using ear detection of scanner data.

Cultivar	**Measured height**	**Scanned height**	**Estimated ears**
Picolo	0.93	0.93	0.97
Justina	0.90	0.95	0.96
Belinda	0.99	0.88	0.99
Mean	0.94	0.92	0.98

Table 2. Correlation coefficient between measured heights, scanned heights, grain yields estimated using ear detection of scanner data and precision harvesting. Correlations coefficients are calculated using five different rates of fertilization.

Calculated ear size also correlates with the grain yield but the problem was to find suitable parameters for the algorithm and algorithm provides rather relative than absolute results of grain yield. Detailed features were extracted from the voxels of ears based on the idea that overlapping ear voxels contained different amount of laser points and they provide more information about the ear but this study was restricted by lack of very detailed reference data.

5. CONCLUSIONS

In this study, terrestrial laser scanning was found to be a useful tool for growth height and grain yield estimation. Growth height of cereal plants was easy to estimate using laser scanner data and estimated results correlates with tape measures. Besides, ears of wheat were automatically recognized and their size was estimated using laser scanner data.

Thus, our study shows that laser scanner could be used as precision farming tool in agriculture. The scanner that we used is not suitable for operational use but the similar methods can be used for example to estimate data of laser scanner that is mounted on a moving platform. Even if operational laser scanning applications for agriculture seems not so relevant at the time, it is worthwhile to study more this field because development of instruments is fast and ongoing process.

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