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Potential of laser scanners in crop production

To meet the demands for future agriculture toward more efficiency and precision, new sensor solutions are needed. Whether laser scanners can contribute to make crop production more precisely is discussed. Meanwhile, many models of laser scanners with different measuring properties are available; specific tests are necessary to assess the potential for detection of relevant parameters in crop production. The paper presents measuring properties for detection of crop stands, crop edges, tram lines, swaths and obstacles of a laser scanner developed for automobile driver assistance.

Keywords
Precision Agriculture, laser scanner, crop stand, modelling

Abstract
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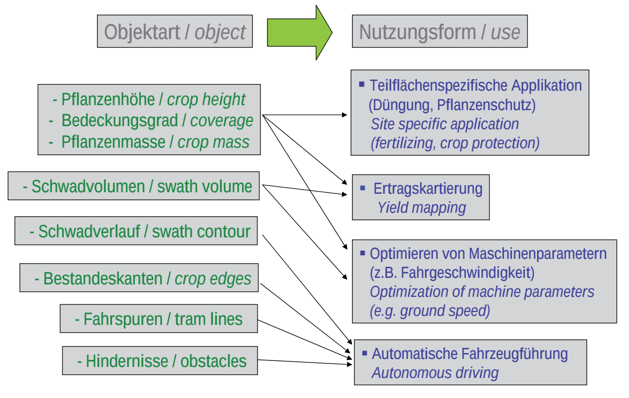
From agricultural engineering exhibition Agritechnica 2009 the trend towards more application of sensor techniques was not only confirmed but forced with a number of new technological solutions. It was evident e. g. an increase in optoelectronic sensors for measuring crop parameters and for detection of loading situations (conditions) on transport vehicles and their positioning to harvest machinery.

In the following article – next to already existing solutions – the potential of laser scanners in crop production will be discussed and results exemplary presented. In crop production laser scanner have a considerable potential for use. **Figure 1** demonstrates potential detection objects and their use in crop production. The crop height, the coverage and the crop mass supply important information can be used for site specific application of fertilizer and agents for crop protection, for generating of yield maps and also for optimization of process parameter on harvesters (e. g. ground speed, rotation speed of rasp-bar cylinder). The measuring of swath volume makes possible to generate yield maps and to adapt the ground speed from forage harvesters and balers to affect maximum harvester

Fig. 1



Detection objects and their use in crop production performance and to avoid blockages. Furthermore, the sensor based detection of swath contours, crop stand edges, tram lines, and obstacles can be used to support autonomous driving (auto-guidance) alone or together with satellite based positioning systems.

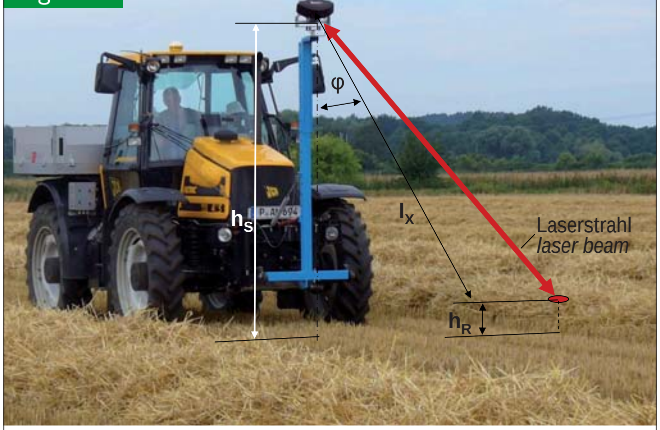
At Leibniz-Institute for Agricultural Engineering e.V. (ATB) scientific investigations are performed to give an answer for the challenges demonstrated in **figure 1**.

Used laser scanner

In investigations a laser scanner – developed for automobile driver assistance (ibeo-ALASCA XT, Automobile Sensor GmbH, Hamburg, Germany) - was used (**table 1, figure 2**).

The laser scanner is an instrument based on LIDAR (LIght Detection And Ranging) technology measuring the pulses' time of flight. The built-in laser generates short rapid-fire pulses, which are transmitted by a tilted rotating mirror. The intensity of the reflected laser pulse is recorded by a photo diode inside the scanner. If the intensity is below a threshold, the measured value is discarded. The laser scanner transmits and analyses up to four echo pulses of different target distances over a period of one measurement pulse. That means that from a single pulse up to four individual echoes are recorded. Because of this the crop stand can potentially be measured in the depth and interfering effects like raindrops or dust can be eliminated to a certain extent. Furthermore, the sensor measures in four layers which have an angle of divergence of 0.8° with respect to each other. A single beam has a divergence of 0.8° in vertical and 0.08° in horizontal direction (user's manual). The beam has the cross section area of 140 mm (height) x 14 mm (width) in the range of 10 m. The layers are arranged on top of each other. With this structure the four layers together scan a band of 0.56 m in height in the range of 10 m. In our investigations the sensor worked with a rotation frequency of 12.5 Hz. From that the following scan angular resolutions resulted: 0.125° for scanning angle $\gamma < \pm 16°$, 0.25° for $\gamma = \pm 16°$ to $\pm 60°$, and 0.5° for $\gamma = \pm 60°$ to $\pm 90°$.

Fig. 2



Test setup of the laser scanner on a tractor

Table 1

Technical data of the laser scanner ibeo-ALASCA XT

Messentfernung *Measuring range*	0.3–200 m
Wellenlänge *Wave length*	905 nm
Scanfrequenz *Scan frequency*	12.5 Hz
Winkelauflösung *Angle resolution*	0.125°/0.25°/0.5°
Spannung *Voltage*	12–15 V
Leistungsaufnahme *Power requirement*	20 W
Sicherheitsklasse *Safety class*	1
Länge/Höhe/Breite *Length/height/width*	204/215/377 mm
Masse *Mass*	ca. 3.0 kg

During scanning, the laser beam rotates in a plane. The sensor does not deliver the measured range l_R and the corresponding scanning angle γ (polar coordinates) but Cartesian coordinates x and y. According to **figure 2**, the distance of the reflection point towards x-axis is characterized by l_X. The potential scanning width is determined by the sensor hardware, the inclination angle ϕ and the sensor height h_S. Furthermore, the scanning width can be adopted according the measuring task by user software.

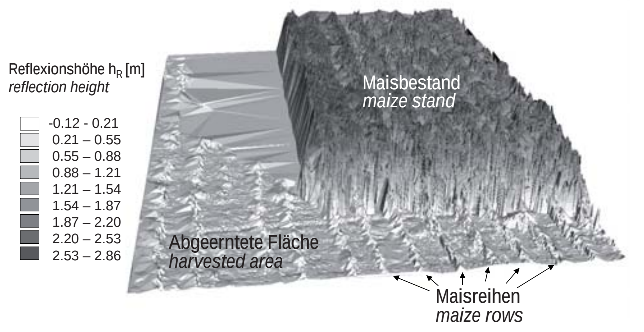
Because the laser scanner is mounted on a vehicle, the measured range l_X depends on the height of the laser scanner h_S above the ground and the inclination angle ϕ of the sensor. As shown in **figure 2**, the measured range l_X is not suitable to describe an object (e.g. crop stand) in a plausible manner. Therefore, the mean height of reflection point h_R was calculated to improve the interpretation of findings:

$$h_R = h_S - l_X \bullet \cos \phi \qquad \text{(Eq. 1)}$$

Modelling of a crop stand

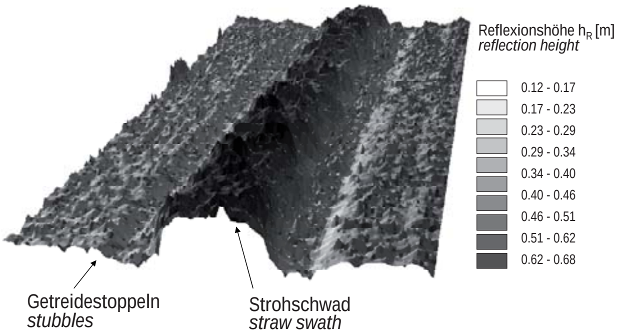
In our investigations, crop stands from oilseed rape, winter wheat, winter barley and maize were scanned. As a result, spatial distributions of the reflection height can be calculated and from this the crop stand can be modelled in a Geographic Information System (GIS, ArcView 3.2). Based on it, the crop height and the coverage can be concluded. In **figure 3** a section of a just harvested maize field is presented. Clearly, the still standing maize plants and the remaining stubbles are reflected. Regression calculations for functional relation between crop biomass and mean reflection height resulted in coefficients of determination $R^2 = 0.95$ for maize and $R^2 = 0.96$ for winter wheat.

Fig. 3



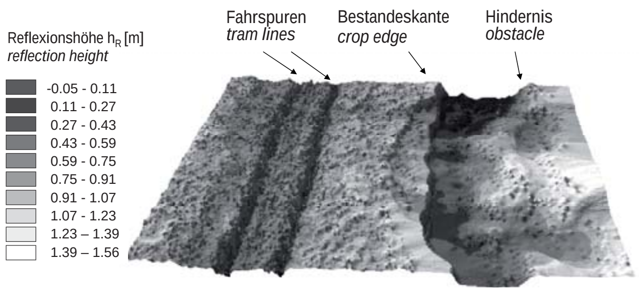
Modelling of a maize stand

Fig. 4



Modelling of a swath from rye straw

Fig. 5



Modelling of tram lines, crop edges and obstacles in a field from winter rye

Modelling of swaths

Compared to crop stands, swaths have a relative strong contour; therefore, they are depicted as compact objects. As an example, this is demonstrated for a straw swath in **figure 4**. To make the scanner data available for a process control on agricultural machinery, robust algorithms have to be developed for a reliable calculation of the current swath volume and its course.

Crop edges, tram lines and obstacles

As an example, it is demonstrated in **figure 5** how can be depicted tram lines, crop edges and obstacles in a field with winter rye. Installed for fertilizing and crop protection, the both tram lines clearly can be detected in the form of strip-depths. The same applies to the crop edge, characterized by an abrupt drop of reflection height. Immediately behind of the crop edge a manure heap was located, that is expressed by increasing reflection height as a compact object.

Conclusions

In crop production there are manifold process relevant objects whose detection with sensors can contribute to make production processes more precisely and more efficiently. Currently, only a few findings regarding the potential of laser scanners in crop production are available. Investigations proofed that the use of laser scanners on agricultural machines results in practicable findings. After calculation and modelling in a Geographic Information System, on the basis of laser measurements pictograms from crop stands, straw swaths, tram lines, crop edges and obstacles were generated. For the practical use of the results, further research is necessary for the development of reliable working software for object detection and interpretation.

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