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Potential for Laser Rangefinders in Crop Production

Exploiting the potential of laser rangefinders for measuring crop stand parameters is only just starting in agricultural engineering research. Additionally, a triangulation laser rangefinder and a time-of-flight measuring sensor were investigated. Judging from the results, the time-of-flight principle seems prospective for future use in measuring crop stand parameters.

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Keywords

Precision agriculture, crop biomass measurement, laser rangefinder

In addition to spectral analytic [1] and mechanical [2] methods, ultrasonic sensors, radar sensors [4], and laser rangefinders [5] are used to measure parameters in crop stands. A laser rangefinder moved at a constant height above the ground will generate readings which are indirectly proportional to the texture of crop stands. Therefore, large ranges will be surveyed in a crop field with sparse vegetation areas, and short distances will be measured in dense areas. Laser rangefinders work according to either the triangulation principle or the time-of-flight principle. Time-of-flight sensors achieve long measuring ranges and triangulation laser sensors show high accuracy with limited ranges. Laser sensors are not used manually under agricultural field conditions, therefore the measuring range must be sufficient for operations e.g. from the tractor cab roof or from a self-propelled agricultural machine.

Application potential of laser rangefinders

For optimum management of field crops, information about process-relevant soil and crop parameters are necessary, mainly for site-specific crop management. In field crops these relevant parameters are in particular the crop height and the coverage level, which correlate well with the crop biomass density. Based on these crop texture parameters, the expected harvest can be appraised to optimise application of the fertiliser and crop protection agents needed in precision crop management [6]. Laser rangefinders only sense physical crop parameters; they cannot measure the content of substances in the crops.

Based on experiences with the mechanical sensor Crop-Meter [2], a potential for laser rangefinders in precision application of nitrogen fertiliser, growth regulators, and fungicides is probable.

A further field of operation is expected to lie in harvesters, as the processed crop mass can be sensed in order to adjust the process parameters such as speed over ground or rotational speed of assemblies already before the crop enters the machine.

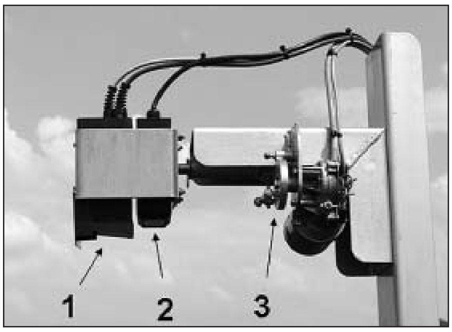

Fig. 1: Investigated laser rangefinders: 1 ACUITY-sensor, 2 LASE-sensor, 3 pivot device

Laser models investigated

In 2003 and 2006 first tests were conducted to find a suitable laser rangefinder for surveying morphological crop parameters. Since the vegetation period 2005, a modified sensor ODS 1600 HT 2 select from LASE company (Denmark) (*Fig. 1*) was used in 2005 and has the following technical features:

Technical data of the LASE-Sensor

Measuring range	0.8 – 2.4 m
Wavelength	670 nm
Measuring frequency	2 000 Hz
Voltage	24 V
Power requirement	12 W
Laser output	10 mW
Classification	3b
Length/ height /width	146/136/50 mm
Mass	1.6 kg
Price	11,400 €

The sensor operates according to the triangulation principle. An emitted laser beam impinges against a surface (e.g. crop part or soil) at a certain distance. The resulting diffuse reflection is registered via a lens on a receiver inside the sensor and generates a signal proportional to the distance.

In 2006 a second laser rangefinder, ACUITY AccuRange 4000-LIR from the American company Schmitt Measurement Systems, Inc., was tested. This sensor applies the time-of-flight principle (*Fig. 1*). By contrast with the LASE-sensor in the ACUITY-sensor, the receiving unit is arranged co-axially to the beam. Because laser light is an electromagnetic wave, in this laser model the phase

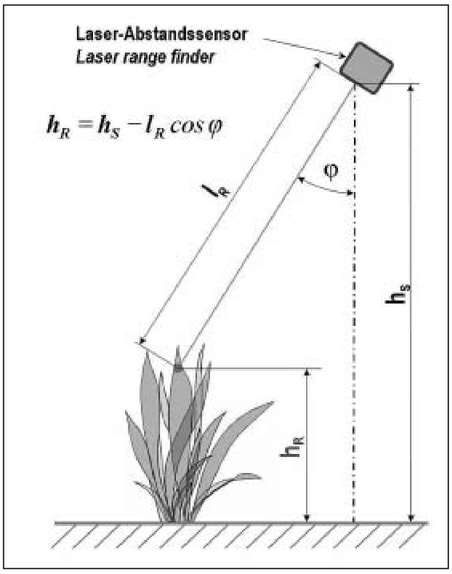

Fig. 2: Calculation of reflection height; h_R reflection height, h_S height of sensor, l_R reflection distance

difference between the outgoing and reflected light beam is measured.

Technical data of the ACUITY-Sensor

Measuring range	up to 16.50 m
Wavelength	780 nm
Measuring frequency	50 000 Hz
Voltage	internal 5 V
Power requirement	1.5 W
Laser output	20 mW
Classification	3b
Length/ height /width	160/80/80 mm
Mass	0.624 kg
Price	6,900 €

To assess the fundamental suitability of the principle of laser rangefinders under field conditions, test runs with both sensors were performed in crop cultivars in 2006. The reference values were readings from the mechanical sensor Crop-Meter for the same plot.

The mean reflection height according to *Figure 2* was calculated to obtain an understandable reading for the texture of crop stands. In the test runs a Hege tool carrier with high ground clearance was used as basic vehicle.

Results

The test runs took place on June 8 and 9, 2006, in a field with winter wheat in the growth stage BBCH 55. The mapping result (*Fig. 3*) shows similarities for all sensor types, as field zones with distinctive crop growth were reflected consistently. All sensors registered dense vegetation in northern third, with a decreasing pattern towards the northernmost point.

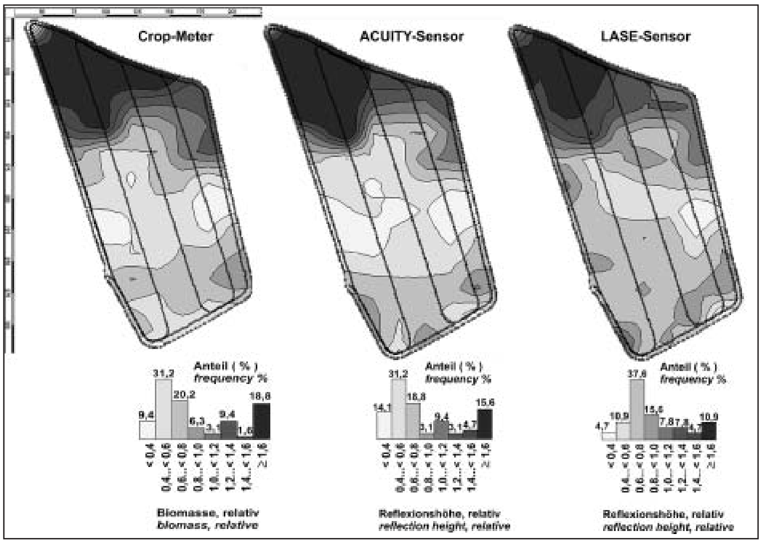

Fig. 3: Comparing mapping results in winter wheat (BBCH growth stage 55)

Also the very sparse crop vegetation in the middle third was sensed consistently, although the contours of the zones were different. This applies mainly for the LASE-sensor.

In the lower area of the figure (south), the crop growth increases slightly including islands with mean crop growth.

To analyse the correlations of the sensor readings statistically, 10•10 m pixel were generated along the tram lines in the GIS program ArcView and the readings were allocated. As the recording frequency was 1 Hz and the vehicle speed 2 ms^{-1}, about 5 readings can be allocated for each pixel. The respective mean values were calculated and expressed in a function (*Fig. 4*). According to the graph the calculated mean reflection height and the Crop-Meter readings are directly proportional with a coefficient of determination of R^2 = 0.77 for the LASE-sensor and R^2 =0.81 for the ACUITY-sensor. The consistently higher reflection heights of the LASE-sensor are noteworthy. One reason for this could be undetected erroneous measurements of the sensors.

Conclusions

Laser rangefinder measurements show high correlations compared with the Crop-Meter reference. This proved that laser rangefinders have a potential for surveying texture parameters in field crops to be used as an information resource for precision crop management. While a mean reflection height of 0.12 m was calculated for no crop biomass in the LASE-sensor, the regression line for the ACUITY-sensor almost passes through the zero point. Taking the resulting higher coefficient of determination into account, it can be concluded that the time-of-flight principle is better suited for surveying plant matter.

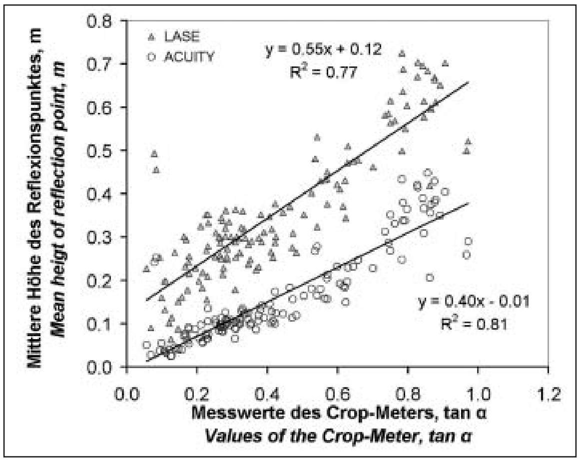

Fig. 4: Functional relationships between readings from the laser rangefinder and reference sensor

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