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Optoelectronic Sensor System for Crop Density Measurement

A new optoelectronic method of measuring canopies is recommended, which is promising in regard to quality and costs. The sensor system is based on low cost optoelectronic distance measuring devices, which measure plant height reliably, even at high driving speeds, and intelligent micro-controller based signal processing. The reduced data are available to the applicator from the CAN-bus for interpretation and for further processing such as in fertiliser application or yield measurement.

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Keywords

Optoelectronic distance measurement, triangulation sensor, crop height, crop density

Precision farming is expected to result in economical and ecological advantage for the farmer and the consumer. Besides the GPS assisted procedures which allow different processes at known management relevant features ("mapping"), online procedures for measuring crop and environmental features are developed [1]. The availability of reliable sensors for field applications, however, is an important marginal condition for the products in this field. The complex demands for field operation with numerous disturbance did not lead to any comprehensive use of sensors in practice. Only few sensor systems are used, whereby - e.g. when making use of spectral sensors for fertilising [2-5] - high investment costs at simultaneous complexity of the measuring data interpretation arise. Alternative systems for measuring crop density are based on mechanical components [6], whereby the signals have to be corrected with additional sensor information, which may result in high maintenance effort in practice.

Within the framework of a co-operation of Messrs. Amazonen-Werke and the University of Applied Sciences Osnabrück a method has been developed for a purely optoelectronic contactless sensor system which shall provide the user with reliable information regarding the crop density at a cost minimum [7]. The available measuring results can then, if applicable, be combined with additional information of sensors or data bases and help to optimise the yield. Aim of this development is initially the determination of the crop height as important feature. Some first work has been done to combine the vegetation index (NDVI: "Normalised Difference Vegetation Index") as spectral signature with height measurements by using ultrasonic sensors [8], however, ultrasonic sensors cannot fulfil the requirements regarding the local resolution and speed. Therefore optoelectronic sensors are used for distance measuring. Already in 1999 when developing a multi sensor system to distinguish crop plants and weeds in row cultures the authors successfully made use of triangulation sensors for the stalk detection [9].

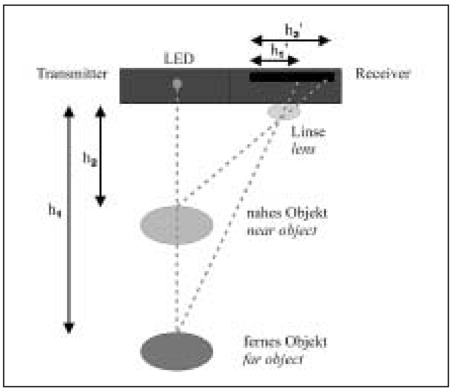

Fig.2: Basic function of a triangulation sensor (example)

Measuring the crop height

Figure 1 shows the measuring principle for the determination of the crop height. The tri-

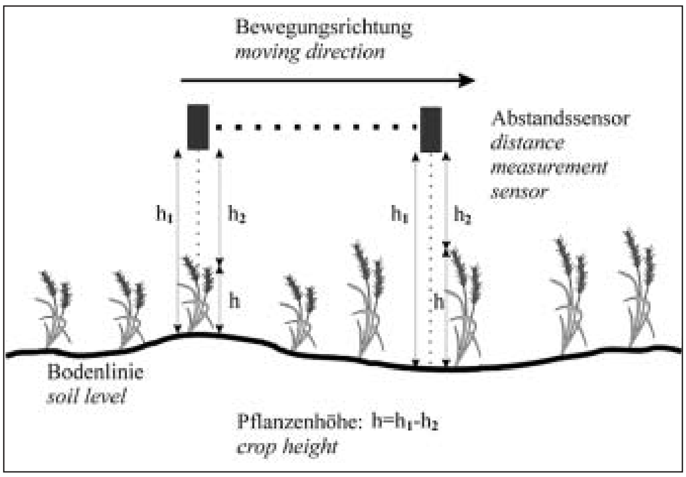

Fig.1: Basic concept for crop height measurement

angulation sensor scans the surface with high geometrical and time resolution so that crop signals as well as soil signals are registered. By forming the difference the height of the plants can be locally determined so that the results consider the soil undulations.

At typical speeds of 10 km/h structures of only some millimetres have to be registered. The resulting time resolutions within the range of 1 ms and less are reached by optical distance sensors. *Figure 2* shows, for example, a principle for triangulation sensors. Depending on the distance of the reflecting object, electric signals are generated in defined ranges on a PSD (Position Sensitive Device) or a CCD line sensor (Charge Coupled Device), so that from this the height can be determined within an accuracy of millimetres. There are different alternatives of optic distance sensors, whereby, e.g. different sources of light (LED, Laser diodes), distance ranges or pulse procedures can be used. Within the framework of the described tests a laser distance sensor of Messrs. Baumer electric [10] was used.

Table 1: Height profile measurements for 2 field sections (oat)

Reference value (manual)	Measuring (mean value)	Measuring (standard deviation)
57 cm	58 cm	2 cm
72 cm	72.5 cm	5 cm

System integration

The triangulation sensor typically scans a surface of a few square millimetres, so that the statistic evaluation of the signals is carried out via software in the connected microcontroller. After the A/D conversion, the measuring data are stored. In addition the triangulation sensor has an error output so that incorrect signals can be filtered. Now reduced data (e.g. average height or the number of plants per area) can be made available to the user via CAN bus. When the relevant data bases are available, the crop density can be forecasted on account of the measuring data.

Depending on the required accuracy the statistics can be improved by a appropriate long measuring distance or by a larger number of triangulation sensors.

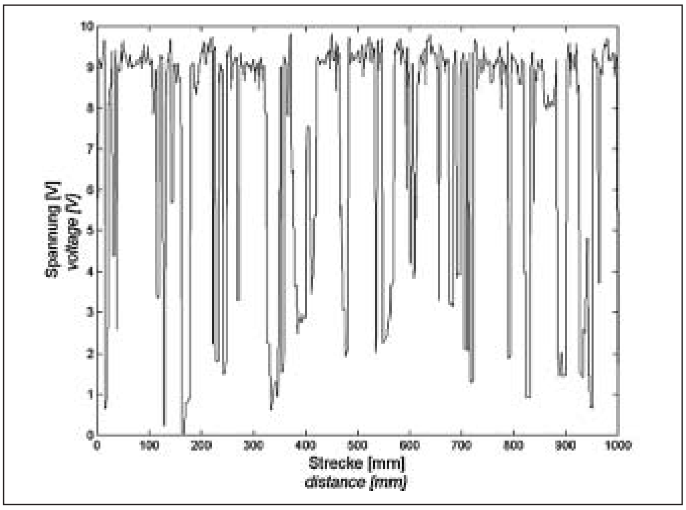

Fig. 3: Height profile for a field section of oats

Test results

On a turntable different triangulation sensors have been tested up to a speed of 10 km/h. With the used Baumer-sensor the widths of the objects of only a few millimetres could reliably be measured in the entire evaluated range of speed. Initial field tests have been carried out. *Figure 3* shows the original measuring data of a field section (1 metre) for oats. The high levels within the range of 9 V come from the soil, the peaks are plant signals. The position has been defined with a resolution of 1 mm.

Figure 4 shows the histogram of a height distribution after the conversion of the sensor signals. In this example the soil and plant signals can be clearly made out. Depending on the existing leaves, plant specific software filter algorithms can be used for height determination.

Compared with a manually determined average height value a good correspondence has been noticed for two field sectors (see *Table 1*).

Result

A new optoelectronic sensor system for measuring the crop density has dynamically been tested within the framework of initial laboratory and field tests and showed results:

- Optoelectronic distance sensors (especially triangulation sensors) can be used for speeds of at least 10 km/h for measuring the crop height.
- Measurements with a resolution within the range of only a few millimetres allow a statistic evaluation of the signals.
- The system operates independent from soil undulations and vibrations.
- The fast microcontroller-based evaluation allows the implementation of filter algorithms and the generation of customer specific data for the bus system for the further processing by the user.

As a next step the systematic investigation for different arable crops in various growth stages under disturbance influence is planned, whereby via relevant data bases the correlation to additional plant features (e.g. plant mass) shall be created.

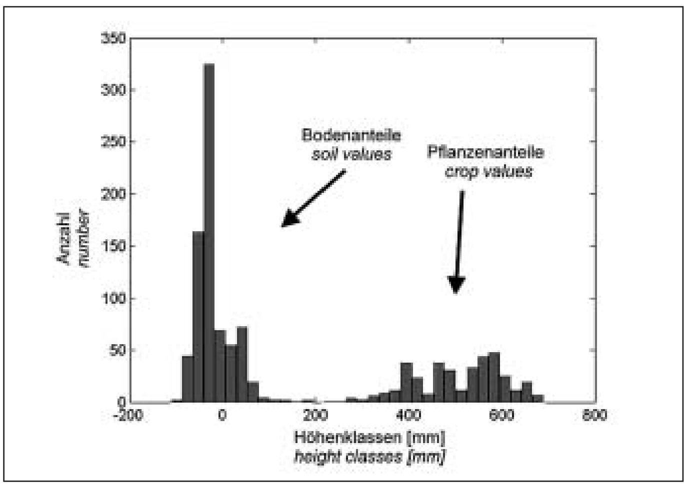

Fig. 4: Histogram for the height distribution of the measured signals

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