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Title:

Field and Lab Tests of Sensors for Cutting Width Measurements at the Header of Combines

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Summary:

The knowledge about the exact actual cutting width of a combine is an essential prerequisite for gaining accurate yield maps and for an automatic guidance of the harvesting machine. So far no solution for practical usage is available, which can provide this information. Therefore a mobile test stand for static and dynamic measurements was developed which allows lab and field tests of various sensor types for measuring the cutting width. With the test stand sensors can be tested at different locations where certain influence factors are predominant.

Results of investigations on a mechnical based contact sensor and a ultrasonic distance sensor, which were gained with the test stand, are presented.

1. Introduction

The knowledge about the exact actual cutting width of a combine is an essential prerequisite for gaining accurate yield maps. So far the operator is entering the cutting width into the yield monitoring system manually. But this method does not meet the requirements for an accurate and continuous performance. Additionally, it is very important to get information from the header for an automatic guidance of the harvesting machine. With such a system the operator's work load could be reduced. Also, the field efficiency of the combine could be increased, because the automatic guidance would allow to use the maximum available cutting width.

2. Performance of sensors for cutting width detection

During the last years different sensor systems were tested for detecting the actual cutting width. The focus was mainly on ultrasonic based sensors which are measuring distances by determining the travel time of emitted sound signals to the crop edge and back. Ultrasonic distance sensors can determine gaps with errors of less than 1 cm and such little deviations are reported by authors [3, 5, 6]. Also, sensors can detect a single stalk, which is a few meters away [6]. But this high sensitivity can impair the cutting width measurement. If a stalk is inclined towards the sensor and detected then the measured distance does not reflect to actual distance to the crop edge (Fig. 1).

On the other hand, if the sensitivity is reduced, another problem may occur. Especially in sparsely standing crops the sound waves may travel through the first or even the second crop row without any reflection. So the distance will be overestimated.

Furthermore the beam angle and the height of the sensor above ground has to be taken into consideration. Spurious echoes may emerge from stubble, if the sensor is positioned too low. An installation higher up can cause unwanted measurements values if the upper part of a row is inclined towards the sensing unit.

For investigating all these factors dynamic measurements are required. But up to now comprehensive and accurate investigations have not been carried out.

First attempts were made for using machine vision systems for detecting the crop edge. BROWN et al. 1991 [1] worked on algorithms for distinguishing between standing crop and

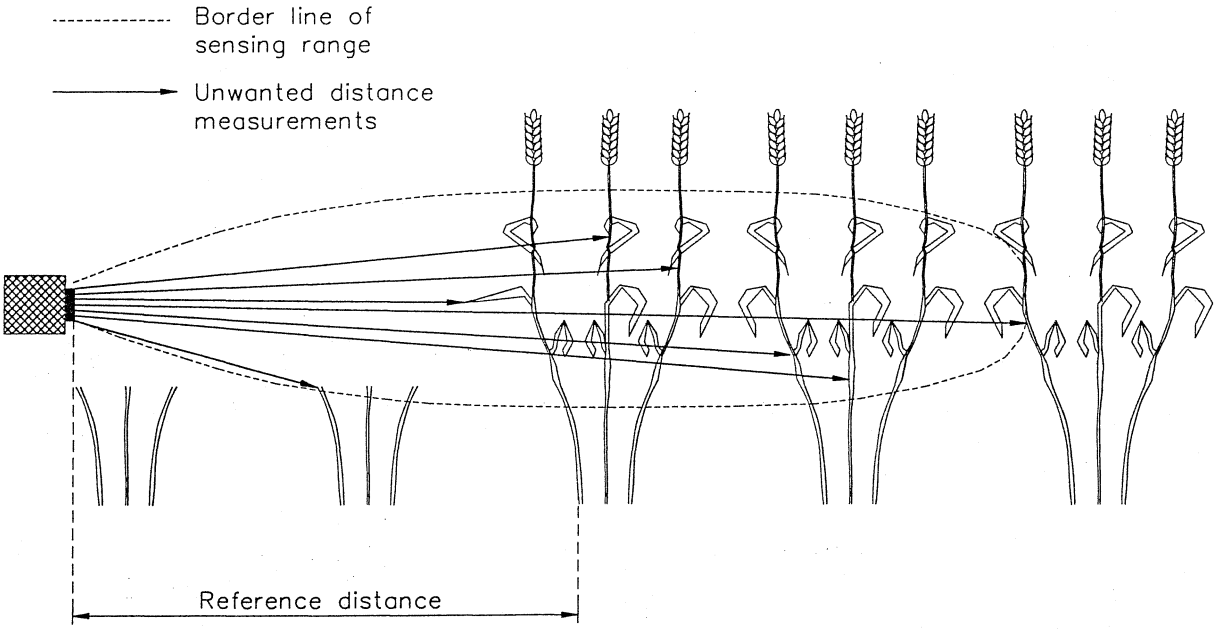

Figure 1: Incorrect distance measurement during cutting width detections with an ultrasonic distance sensor at the combine header.

stubble. HOFFMANN 1996 [2] detected the crop edge with a machine vision system for forage. For practical use, further investigations are required.

SUDDUTH et al.1998 [4] implemented a GPS-based sensing system. It was effective in calculating the harvested area corresponding to each yield measurement. However, the employed GPS equipment is currently expensive and difficult to operate.

3. Objectives

The main goal was to establish a basis for carrying out dynamic measurements with different sensors. Therefore a mobile test stand should be developed which allows investigations in the lab and at different locations with different crops in the field.

Additionally, tests with sensors should be carried out. First, the focus should be on mechanical based devices and ultrasonic based systems.

4. Mobile test stand

The mobile test stand consists of a trolley which runs on tracks (Fig. 2).

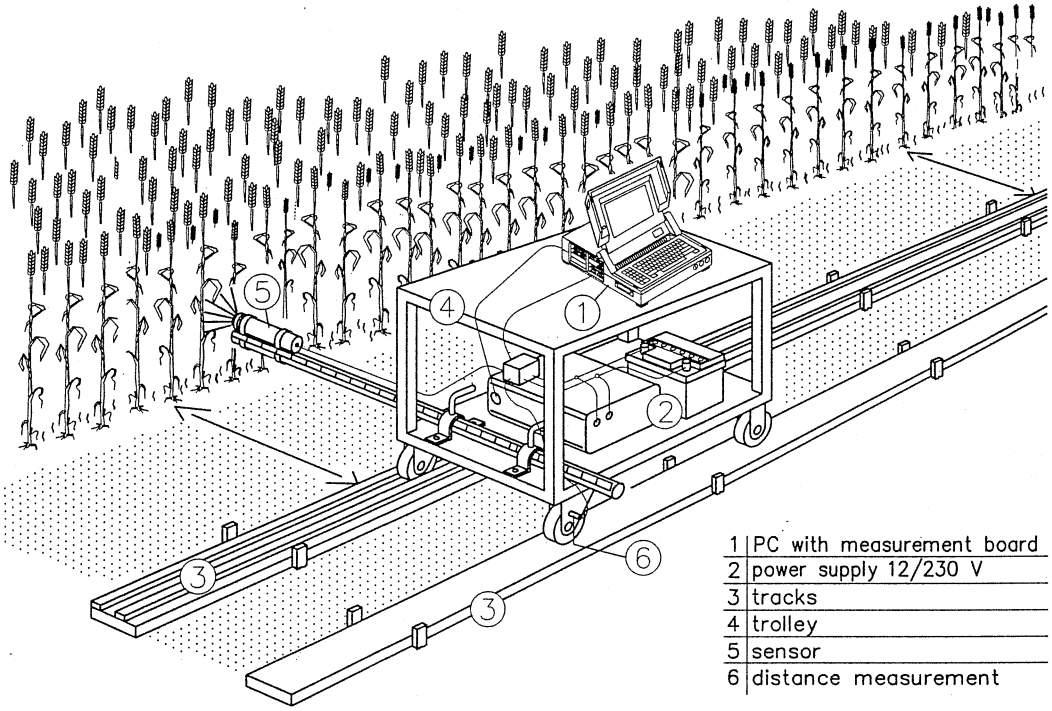

Figure 2: Mobile test stand for investigating sensors for cutting width measurements.

At the trolley different types of sensors or sensing systems, e.g. ultrasonic distance sensors, mechanical contact sensors or video cameras can be mounted. The mounting rod is adjustable so the distance to the crop edge can be varied or kept constant if a row is removed. For detecting the traveled distance of the trolley along the transect a reed contact with two magnets attached to a wheel of the trolley is employed. An acquisition board which is plugged into a PC gathers the data from the cutting width systems and from the reed contact. The detected data are processed by a multi-purpose acquisition and analysis software and visualized on the computer screen. The speed of the trolley is shown in real-time with large figures so it can be watched and controlled by the operator. The trolley is pushed by hand on the tracks which are 20 m long. Ten meter of the stretch are used for testing, the remaining half is required for accelerating the trolley up to the desired speed and for slowing down at the end. Due to the setup measurements can be repeated several times.

With the test stand various sensors under different condition were investigated.

5. Results and discussion of sensor tests

First a mechanical contact sensor, similar to the devices used in self-propelled field choppers or sugarbeet harvesters for guiding the vehicle, was tested. The self developed sensor detects the distance to the crop edge via a contact rod. The stalks of the edge are turning the rod between 0° (no gap between crop divider and edge) and 90° (maximum measurement width). The turning axle of the rod is connected to a resistor. So the turning angle csn be determined by measuring the electrical resistance. For the calibration line a high coefficient of determination (R^2) could be calculated (Fig. 3).

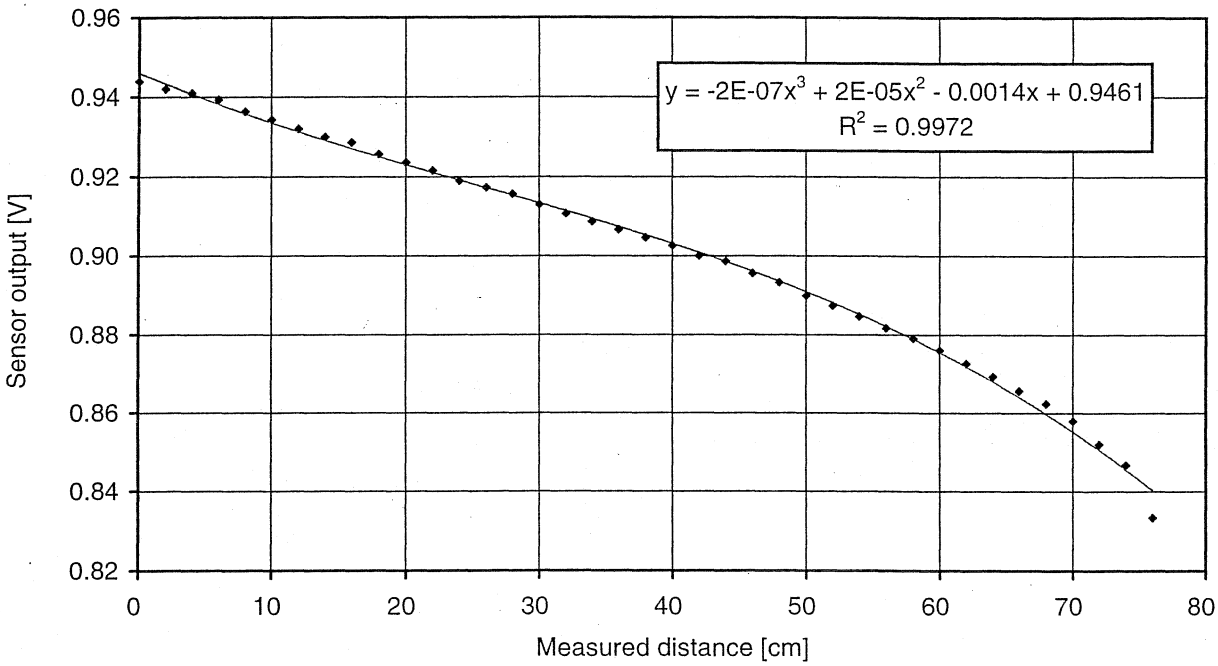

Figure 3: Calibration of the mechanical contact sensor.

One major disadvantage of this mechanical device is the limited sensing range. Due to the design of the header the maximum range is less than 1 m. But it shows a high suitability for guidance system which allows to use the full header width. Leafs or single inclined stalks do not influence the measurement.

From the variety of ultrasonic sensors the results of one model ("B") are shown. The sensor has been calibrated by measuring the output voltage of the sensor and the distance between the sensor head and the smooth side of a straw bale (Fig. 4).

The relation between the output voltage y and the distance x is represented by a regression line with a very high coefficient of determination.

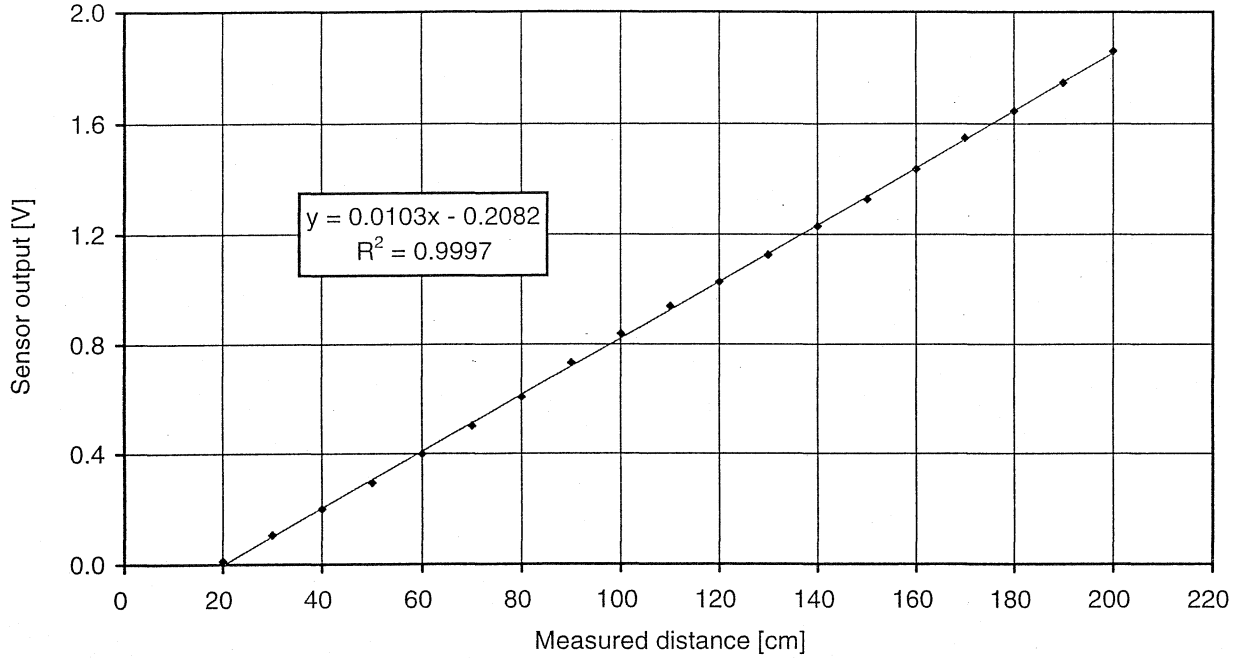

Figure 4: Calibration of ultrasonic distance sensor B.

After calibration the sensor was tested along rows. Measurement were repeated a few time at different distances to the crop edge (Fig. 5).

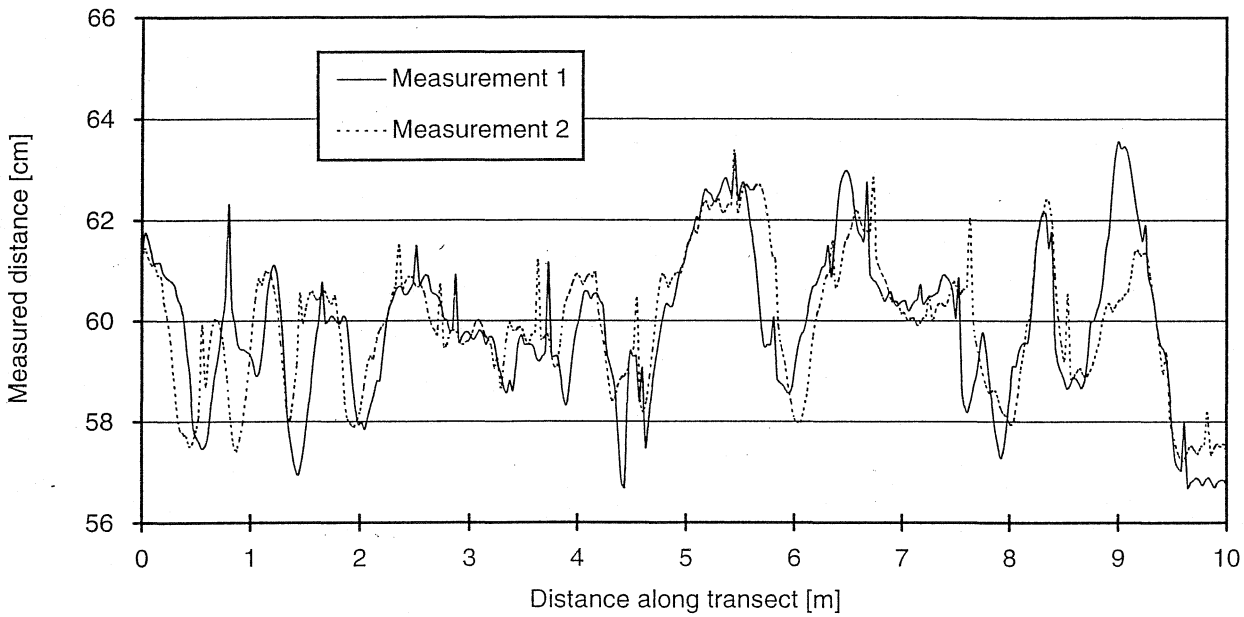

Figure 5: Dynamic test data in wheat at nominal distance of 60 cm measured along crop row (ultrasonic distance sensor B, repeated measurement).

The detected distance values vary by approximately ±3 cm around the reference distance of 60 cm. Both curves show a very similar course, the largest differences between them amount to about 3 cm.

With the ultrasonic distance sensor the same segment of the row was investigated a few hours later again, while the wind speed increased to about 2 m/s. The influence of the wind caused a different shape of the detected crop edge (Fig. 6).

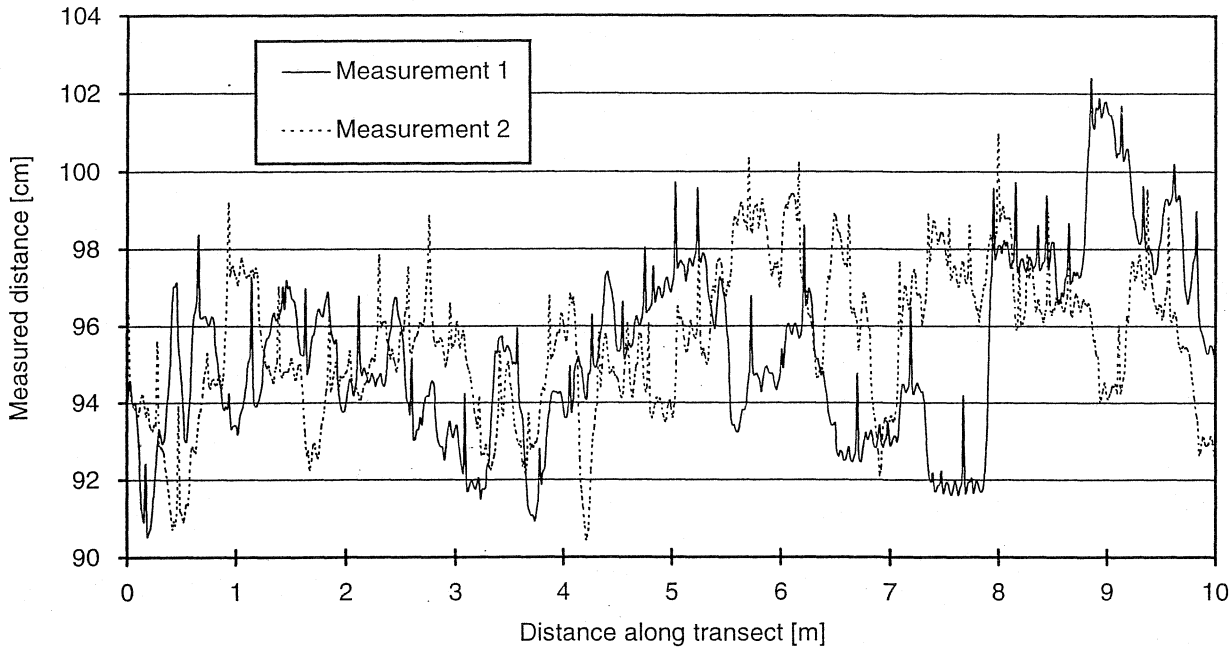

Figure 6: Dynamic test data in wheat at nominal distance of 90 cm measured along crop row (ultrasonic distance sensor B, repeated measurement, wind speed: 2 m/s).

Both curves show more spikes and the differences between them have increased.

Also, distance measurements with the ultrasonic distance sensor were carried out at right angles to the crop row. For these tests a segment which included one track of a tram line was selected. The nominal distance was 30 cm (Fig. 7).

The differences between the values from the sensor and the reference distance are very little. For the gap due to the tram line the deviation is about 10 cm.

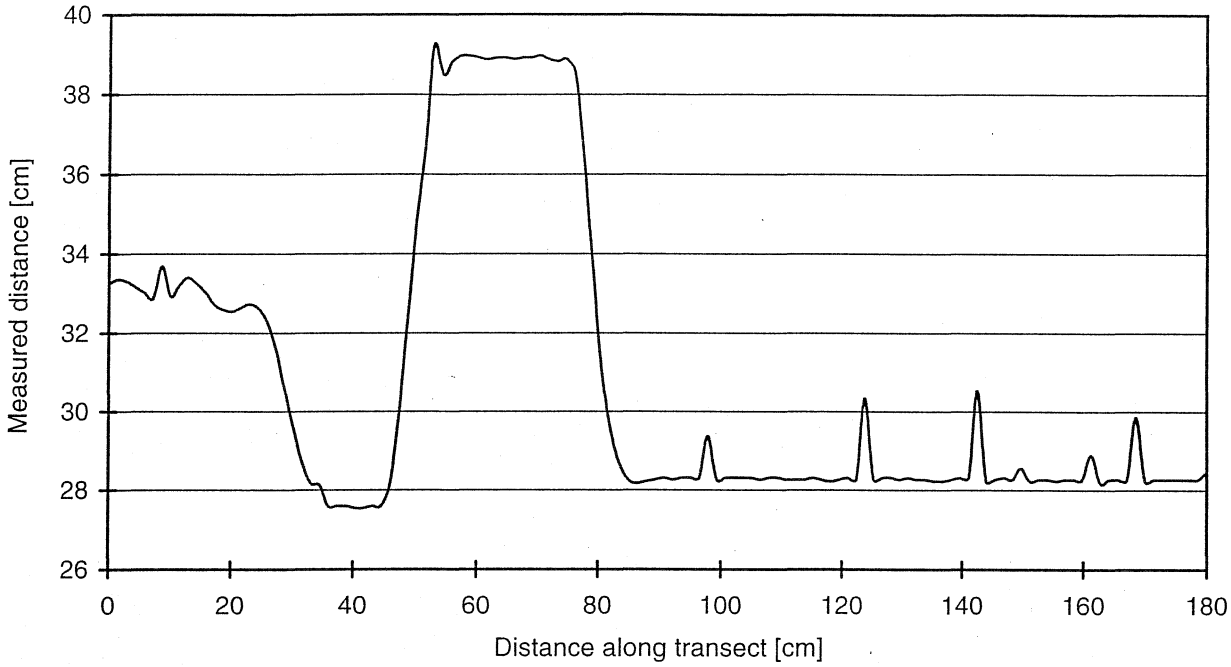

Figure 7: Dynamic test data in wheat at nominal distance of 30 cm measured at right angles to crop row (ultrasonic distance sensor B; with one track of tram line).

6. Conclusions

The results show that the developed test stand provides the opportunity for intensive investigation on different sensors for measuring the distance from the crop divider of the combine to the crop edge.

Ultrasonic distance sensors are quite promising for measuring the distance from the crop divider of the combine to the crop edge. While the hardware of this type of sensor is matured, much more research work is required for developing signal processing software which can handle different crops, inclined stalks, gaps in the row, high stubble, lodged crop, different weather conditions etc. This requires data from test while different influence factors had an effect. The data can be gathered with the developed mobile test stand, because it can be easily moved to various locations, where a special influence factor is predominant.

For the mechanical contact sensor the number of influence factors is much lower. But its major disadvantage is the limited sensing range.

7. References

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Problem

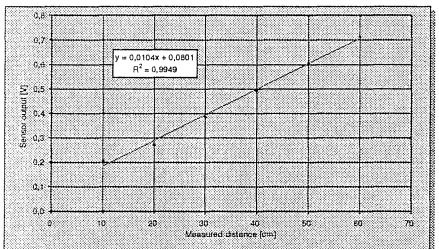
The knowledge about the exact actual cutting width of a combine is an essential prerequisite for gaining accurate yield maps and for automatic guidance of the harvesting machine. Up to now no practical solution is available. Systems based on the Global Positioning (GPS) are still too costly. Ultrasonic based distance sensors show promising results, but further development work is required.

Objectives

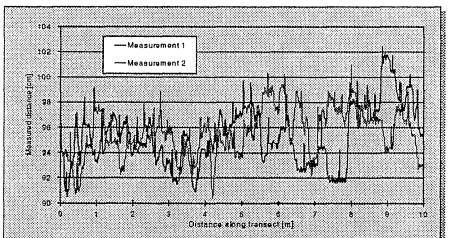
A test stand should be developed and tests of different sensors for cuttings width measurement should be carried out. The test stand should be mobile so investigations could be carried out at different locations with different crops under field conditions.

Results

Test results

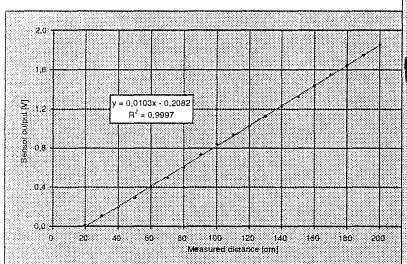


Calibration of ultrasonic distance sensor C

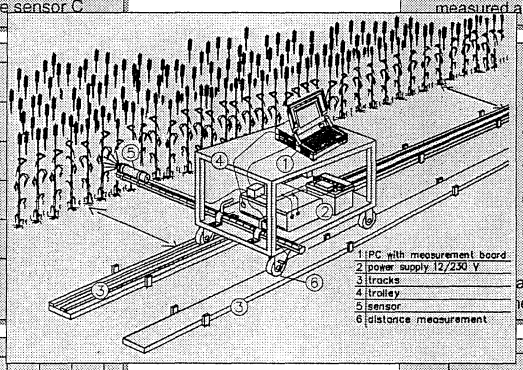


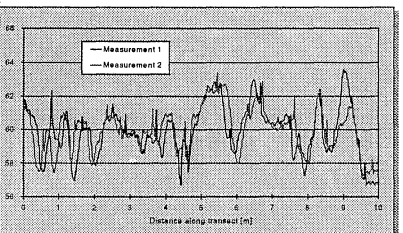
Dynamic test data in wheat at nominal distance of 90 cm measured along row (ultrasonic distance sensor B)

Mobile test stand



Calibration of ultrasonic distance sensor B





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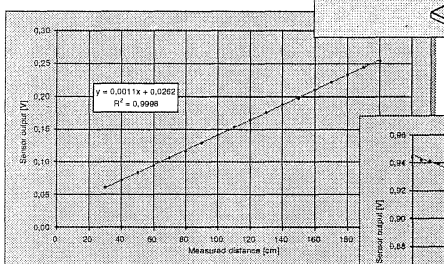
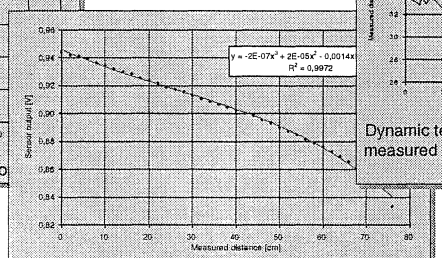
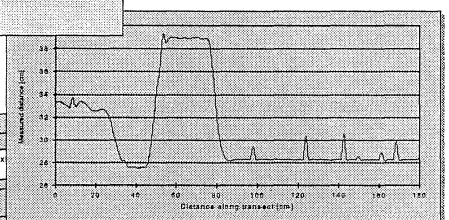


Calibration of ultrasonic distance senso



Calibration of mechanical sensing device



Dynamic test data in wheat at nominal distance of 30 cm measured at right angles to crop row (ultrasonic distance sensor B, gap due to tram line)

Conclusions

The mobile test stand is a very useful tool for testing sensors and for determining sensor settings. The results show that ultrasonic distance sensors have a very high potential for detecting the actual cutting width. The observed errors were below 5 cm. For improving the accuracy by finding adequate sensor settings further tests are necesarry. Also, the data handling requires more investigations. Algorithms have to be found for dealing with stalks and leafes which are sticking out of the row, sparsely standing crops and cutting at different angles to crop rows.

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