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Automation of steering for mechanical weeding

An experimental tool carrier was fitted with an automatic steering system [3] and, in association with a maize inter-row weeder, was tested on a 4 ha trial field. Based on the number of pulled-out maize plants, no more damage was done by the above rig in comparison with a manually steered variation. In that the hoe units on the weeder were fitted at 9.5 cm spacings it can be assumed that the precision of the steering system was ± 5 cm (measured at the hoe frame). Guidelines 90% correctly calculated can be assumed from the, on principal, suitability of the green-red colour difference as entering signal as well as the suitability of the algorithm.

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Keywords

Automatic guidance, image processing, mechanical weeding

Along with water and nutrition, crops require an appropriate amount of plant care. Without control of weeds, these plants can represent real competition for the resources necessary for crop growth. Chemical weed control is criticised by a society increasingly sensitised to the danger it represents to groundwater. This situation has led to restrictive regulations on spraying in water protection areas, as well as increasing herbicide prices. Such economical pressures nowadays tend to make mechanical weeding increasingly attractive once again in that reducing use of chemical herbicide represents the greatest cost-cutting potential of all plant protection work in farming [1].

The main problem of mechanical weeding in rowcrops is, alongside choosing the right time, the low working speed due to the limited working width because of the sowing technology used, and the precision needed for steering in the crop. Mechanical crop care operations can achieve competitiveness through a significant increase in working speed. But it is very stressful for a driver to have to continually operate a front/mid/rear mounted mechanical hoe at 8 km/h through a cereal, maize or beet crop without damaging the plants. For this reason automatic steering is attractive. This allows even higher working speeds to be achieved without ensuing crop damage.

Remote identification of guidelines

Guidance of following machinery via touch-sensor systems is used especially in beet harvesting. However, these can only be used with rowcrop plants that can withstand contact and this is not the case when weeding is carried out. The remote identification of real guidelines is the subject of much research work world-wide. In opposition to systems that work from virtual guidelines such as digital field maps in association with satellite navigation, steering systems based on real guidelines need vehicle or implement steering based on the actual crop lines.

A PC-based colour image processing system comprising a camera, an image processing card (frame grabber) and the host computer (AMD K6/2 300) was mounted on a Fendt Xylon 524 research tool carrier. The images recorded by the camera and transferred to the frame grabber as analogue signal were analysed in video real time, the colour difference between the green and the red channel was established and, from this, a binary image created. Through this action a 32 KB small two-level image of the crop rows separated by the background was created from a 786 KB large colour image during the recording operation.

The guidelines were calculated via a further-developed regression analytical row-following algorithm [2] as illustrated in *fig. 1*. Starting from the mid-point of the row

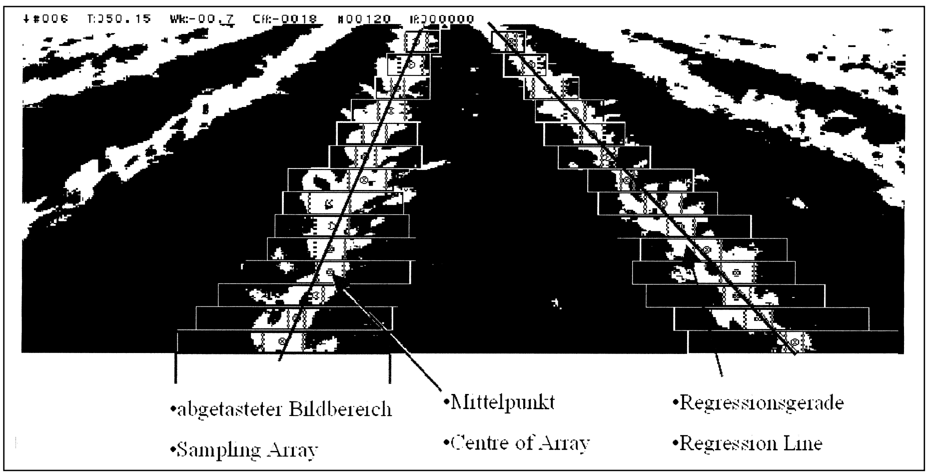

Fig. 1: Calculation of guideline

which, depending on the crop, is known from the initialising data or, when starting with the second journey through the crop, from the last programme cycle, an array (the large rectangle in image) of image dots in each case right and left was tested on the concentration changes of white dots. From field maximum density (small rectangle in image) the mid-point was calculated (dot in image). The linear regression over all grey points gives the fitting straight which reflects the run of the lines (line in image). Using a second crop row, analogue procedures comprising both fitting straight lines were finally tested for parallelism after correction for perspective-caused image distortion. As the result, one receives the deviations from their required positions and direction of the regression fitting straight lines. From these two parameters, which are also described as offset and heading, is calculated the required steering angle necessary to steer the vehicle back to the required position after a defined distance s.

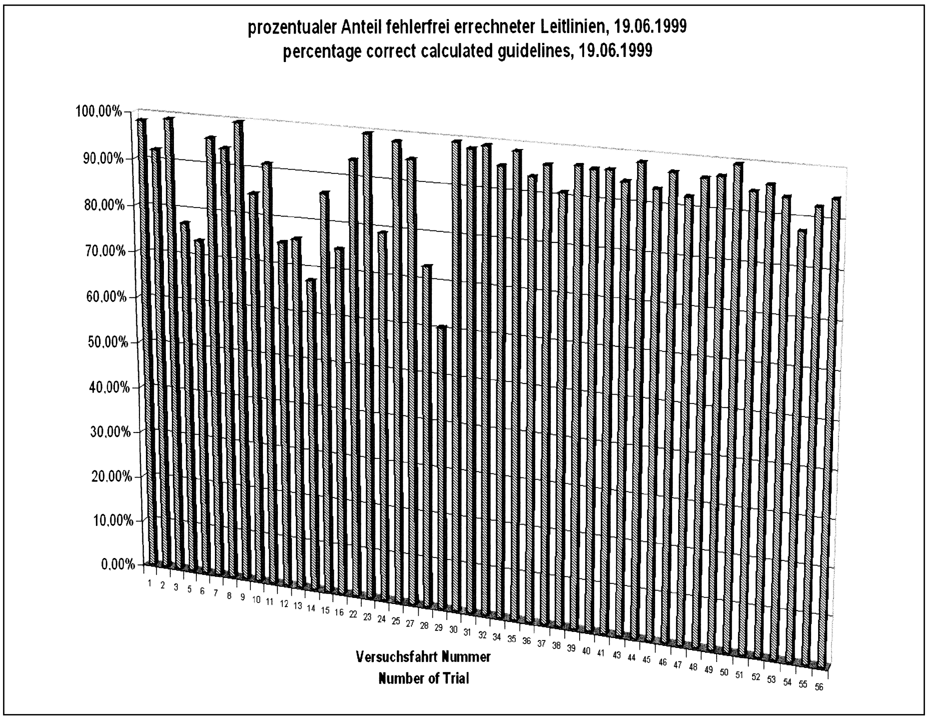

Fig. 2: Evaluation of guidelines

Steering control

The steering control as described above represents the outer control loop of the cascade control chosen for steering automation. The inner control loop (steering angle controller) consists of the wheel angle transmitter, the host computer (AMD 486 DX 133), the programmed PID controller as well as the AD/DA change card for recording the wheel angle and reproducing the correction span on the proportional valve used (Danfoss PVG 32 EM). The PID controller was synthesised as a software solution on the host computer, with regard to the experimentally-investigated transference function of the given steering hydraulic system. The transference of the required steering angle from the image processing computer took place over the RS 232 interface.

Trials – implementation and documentation

From June 17 to 19, 1999 a total of 136 cross-field bouts took place with automatic steering over a 150 m • 160 m field of forage maize. The weed density was normal. A chemical herbicidal treatment did not take place. The 4 ha were covered once with the tractor manually steered, and up to four times with automatic steering. The working direction was north – south. With manual steering, the average working speed was 8.5 km/h and, with automatic steering, around 11.5 km/h.

The weather was good at the beginning of the June 19 trial which started at around 10 am. The sun shone in a lightly-clouded sky. The clouds gathered as the day progressed and, by evening, the sun was mainly obscured. The late-sown maize was in the six-leaf stage. The recording of the manually-steered bouts was restricted to an estimation of yield losses through pulled-out maize plants. The documentation of the automatically-steered bouts was expanded to cover all relevant data during the bouts. The image processing computer, as well as the I/0 computer, recorded all the sensor data as well as the calculated correction values and resultant values. Additionally, every twentieth binary image evaluated by the image processing computer was recorded including the calculated guidelines. Even during the calculations, the images were being checked for validity of binary image (relationship of black to white), validity of calculated regression lines (r^2), parallelity of the calculated lines and retention of the image borders (result within the permitted co-ordinates). In the case of faulty image evaluation, an error code was produced and the image discarded.

Results

107 field bouts were evaluated according to percentage share of correctly-calculated guideline pairs in order to be able to achieve a statement as to the quality of the guideline following algorithm. The counting of pulled-out maize plants showed no significant difference between manual and automatic steering and this lay in total under 1%. *Figure 2* illustrates the percentage share of correctly-calculated guidelines of all recorded trial bouts during June 19, 1999. According to the average for this trial day, this lay at 90.83%.

That, despite almost 10% faulty i.e. not used, guideline calculations, not more maize plants were pulled-out is due to the robust design of the whole system. If an image is not valid, the algorithm calculation from driving speed and actual steering angle gives the present position and then the steering angle to be set according to heading and offset of the last image. Only after 10 faulty images in a row did the programme stop. Additionally, the image processing and control frequence, at 50 Hz, is sufficiently high to calculate a new image every 7 cm at the driving speed given.

In that the spacing between the weeding units on the maize weeder used was 9.5 cm and that, in normal operation, no maize plants were pulled-out the precision of the automatic steering can be assumed to be ± 5 cm.

Literature

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