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The Project Advanced Optoelectronic System (AOS)

Part 2: The Concept of AOS and State of Development

Precision farming will be the future of weed control. Herbicide application or mechanical weed control will be carried out in a targeted manner, only where weeds have exceeded a certain economic threshold. Optical methods are mostly used for localising weeds - primarily image analysis and optical sensors. At the Institute of Production Engineering and Building Research the goal is to use a "spectral fingerprint" to distinguish between weeds and useful plants and to use a multi-sensor system to ensure that within the same work process herbicides are accurately applied to the weeds which have to be controlled.

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Keywords

Target directed weed control, image processing, optoelectronic, sensor

The measurements of reflection of useful crops and of weeds were carried out with the special field wagon (*Fig.1*). In 2003, three fields were available with weeds and the crops oats, winter wheat and maize, as well as four fields without crops and thus the reflection data for a vegetation period.

These measurements serve as the basis for the algorithms for plant differentiation being developed at this time.

The optimisation of sensor combinations includes the elimination of influences for error through the individual components such as blind slits, filters and photo diodes. The blind slit is determined by the field portion selected that is to be documented by the sensor. Most important here is that the weeds of a particular size can be recognised at every point of the sight field. This is made more difficult by the sensitivity curve of the photo diode which runs in a cosine form over the width of the field view.

In order to maintain the sensitivity in the entire documentation area, different correction systems were tested. Lens systems weakened the reflected light up to a factor of 100, which requires a very high increase in the photo energy amplifier. Much better results were achieved with a graduated grey filter. With the appropriate delineation, the sensitivity of the photo diode over the field view was made linear.

Fig. 1: Field wagon to measure reflection of crops and weeds

During use of the AOS it must be established that every photo diode sees exactly the same portion of the field, independent of the particular position of the spray boom. The solution up to now for the spatial organisation of the photo diodes in sensor containers is not adequate, particularly if the spray boom swings in a vertical direction. For this reason a solution was found with only one photo diode and a disk which rotates in front of it with multiple (max. 8) selected filters. Through the blind slit with the above mentioned graduated grey filter, for every wavelength of the ambient light the part of the field seen is equal, independent of the position of the spray boom. These photo diodes can then have a much greater level of reach. Through the increased areas, the light sensitivity of the photo diodes is also increased, reducing the required amplification. The chosen solution also allows the simultaneous measurement of the ambient light directly for the interesting wave lengths. Therefore, changes of the ambient light during the day or produced by clouds can be considered. The testing station have been built and will be put into practice.

As an automatic measurement system AOS must use ambient light as the light source, recognise it and show if the available

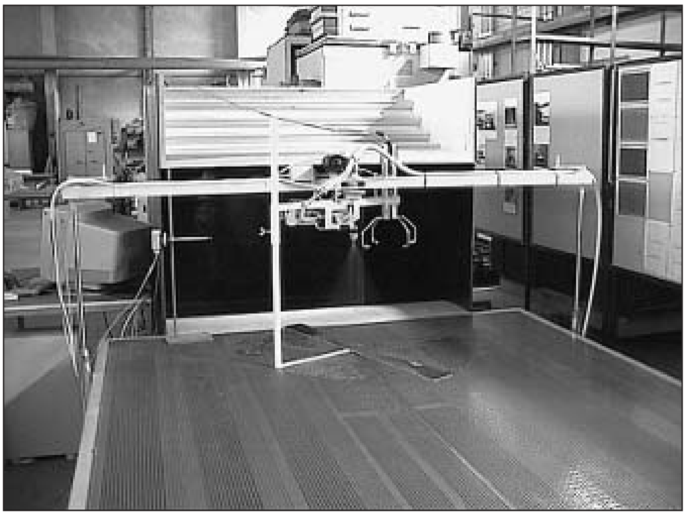

Fig. 2: Test stand for spray nozzle adjustment, dependent on the wind

light is within or without its measurement range. In order to document the total dynamic range of light performance without a switch in measurement range in multiple decades (amplification errors and measurement value losses occur) the photo current of the photo diodes is measured with a logarithmic amplifier. In a test with a light strength of six lux, a photo current of 1µA, which is still three factors of ten below the actual lower limit of the amplifier. Thus the sensor can be used both under very weak light conditions as well as by values of more than 100 000 lux [22].

If weeds are detected by the spray sensor and should be sprayed due to a previously set threshold of economic loss, then it must be ascertained that the sprayed area is identical to the area detected on the field, independently of the influence of the wind. This requires the installation of a wind sensor on the tractor and a subsequent steering of the spray nozzles. In practice the speed and direction of the wind are measured with the wind sensor and passed on to the central monitoring unit of the AOS system. The necessary adjustment of the spray nozzles (two-dimensional) are calculated with an appropriate algorithm. For the development of the algorithm, a testing station was built with which wind speeds of up to 5 m/s could be created homogeneously and free of turbulence. And wind direction changes of up to ± 45° and more deviations from the travel direction (0°) could be simulated. The positional adjustment of the spraying nozzles takes place with two motors, which are placed at a 45° angle to the travel direction. It is planned within the project to replace the conventional spray nozzles with a jet cutter, which allows the production of homogeneous monodispers spectra of droplet sizes. This allows the reduction of spray drift to a minimum [22].

Future Perspectives

The methods developed and tested up until now for the partial area specific weed control have possibilities for weed recognition and documentation, but also their limits with regard to recognition and differentiation rates as well as the resolution, related to the partial width of the field sprayer or to the weed size. Further developments in sensor technology and information processing promise further progress, but the question remains open, whether the solution for a partial areas specific chemical and or mechanical plant protection is in one approach, or whether it lies in the combination of different approaches to the problem. Here the cost factor must also be considered since this is decisive in the introduction to broad agricultural practice.

Literature

[1] Autorenkollektiv: Precision Farming im Pflanzenschutz am Beispiel Unkrautbekämpfung. KTBL-Schrift 402, 2001

[2] *Dzinaj, T. et al.*: Multi-Sensor-System zur Unterscheidung von Nutzpflanzen und Beikräutern. Z. für Pflz.krankh. und Pflz.schutz, Sh. VI, (1998), S. 233-242

[3] *Ruckelshausen, A. et al.*: Fremdlichtunabhängige Messung der Flächenbelegung in Pflanzenkulturen: Entwicklung von Low-Cost-Systemen mit neuen Spektralsensoren und gepulster Beleuchtung. Proc. VDI/MEG-Tagung Landtechnik, (2002), S. 145-150

[4] *Blasco, J. et al.*: Robotic Weed Control using Machine Vision. Biosystems Engineering 83 (2002), no. 2, p. 149-157

[5] *Madsen, T. E. and H. L. Jakobsen*: Mobile Robot for Weeding. Master Thesis, Techn. Univ. of Denmark, 31. 1 2001, 159 S.

[6] *Christensen, S. and H.-W. Griepentrog*: Robotic Weeding. DIAS Bygholm, KVL (Taastrup), Dänemark

[7] *Baerfeldt, A.-J.*: Vision-Guided Mechanical Weed-Control. Proc. 2nd Int. Work shop on Mechatronical Computer Systems for Perception and Action, 10.-12. Febr. 1997, S. 135-138

[8] *Gerhards, R. et al.*: Einsatz der digitalen Bildverarbeitung bei der teilschlagspezifischen Unkrautkontrolle. Z. PflzKrankh. PflzSchutz, Sh. XVI, (1998), S. 273-278

[9] *Gerhards, R. et al.*: Site-Specific Weed Control in Maize, Sugar Beet, Winter Wheat and Winter Barley. Precision Agriculture, 3 (2002), S. 25-35

[10] Pressestelle der Rhein. F.-W.-Univ. Bonn: Unkrautspritze sieht, wo sie spritzen muss. http://www.uni-bonn.de/aktuelles/presseinformationen

[11] *Yang, C.-C. et al.*: Development of an Image Processing System and a Fuzzy Algorithm for Site-Specific Herbicide Application. Precision Agriculture 4 (2003), S. 5-18

[12] *Wartenberg, G. und K.-H. Dammer*: Teilflächenspezifische Unkrautregulierung im Echtzeitbetrieb. Proc. VDI/MEG Tagung Landtechnik, (2000), S. 281-287

[13] *Dammer, K.-H. et al.*: Sensor-controlled variable rate real-time application of herbicides and fungicides. Proceedings of the 4th ECPA, (2003), S. 65-70

[14] *Felton, W. L. and K. R. McCloy*: Spot Spraying. Agric. Engng. (1992), H. 11, S. 9-12

[15] *Biller, R. H. et al.*: Verminderung des Aufwandes an Herbiziden in der Pflanzenproduktion durch zielflächenorientierte Applikation. Abschlussbericht zum DBU-Projekt 06331, Bericht aus dem Institut BB (FAL), Nr. 255, Juni 2000, 75 S.

[16] *Biller, R. H. und W. Ihle*: Pflanzenunterscheidung mit optischen Sensoren. Landtechnik 55 (2000), H. 2, S. 148-149

[17] *Biller, R. H. und W. Ihle*: Die sehende Feldspritze - Unterscheidung von Nutzpflanzen und Unkräutern - online mit Hilfe optoelektronischer Sensoren. Agritechnica '97, Hannover, 9.-15. 11 1997

[18] *Hollstein, A. und R. H. Biller*: Weiterentwicklung eines optoelektronischen Sensorsystems zur Unkrautkontrolle. Agrartechnische Forschung 4 (1998), H. 1, S. 11-17

[19] *Biller, R. H. und R. Schicke*: Multi-frequency optical identification of different weeds and crops for herbicide reduction in precision agriculture. In: Proc. of the 5th Intern. Conference on Precision Agriculture, 16.-17.07. 2000, University of Minnesota, St. Paul, MN, USA

[20] *Wang, N. et al.*: An application of Fuzzy Logic in weed detection. ASAE No. 993139, (1999), 12 S.

[21] *Wang, N. et al.*: Design of an optical weed sensor using spectral charakteristics. Transact. of the ASAE. 44 (2001) 2, S. 409-419

[22] *Sommer, C. et al.*: Entwicklung und Einsatz eines Advanced Optoelectronic System (AOS) zur Online-Unterscheidung von Nutzpflanzen und Unkräutern und abdriftfreie zielgerichtete Applikation von Herbiziden durch Verwendung des Strahlschneiderverfahrens. 1. Zwischenbericht BMBF-Projekt 0330118, Bericht aus dem Institut BB (FAL), Nr. 377, 2003, 19 S.