Sensor Fusion Meets GPS: Individual Plant Detection

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Introduction

In precision farming offline and online methods are used. Offline technologies are based on GPS (Global Positiong System) where a map is generated in a sampling step and correlated with field parameters such as weed population. In the application step this map is used. In the last years the availability of new sensor and information system technologies strongly pushes developments and finally products for online methods. This means that sensor-based systems measure crop or soil characteristics in real-time and are used directly for the application. GPS is not necessary in this case but is useful for site-specific electronic documentation.

By increasing the knowledge of field parameters new sensor technologies have become one the most important issues for optimising agricultural processes with respect to economical and ecological aspects as well as food tracking. In particular imaging technologies have been applied for crop and weed detection (Åstrand 2004 and 2005, Oebel 2006, Wartenberg 2005). The technological improvements in electronics and communications have now opened a new field for future technologies, thereby having a look even at a single crop plant as for example during seeding (Griepentrog 2003).

In this paper the concept of sensor fusion for the online measurement of crop plants is combined for the first time with a precise GPS information. For row cultures such as maize this method allows a rating of each individual plant: The position of the plant is measured by several sensors, the GPS-position is stored and the corresponding plant can be find again in a later run. Using this method the properties of individual plants at different times or growth stages can be determined automatically. Thus complete new setups of experiments in plant breeding can be designed, based on individual plant detection.

Multi Sensor Architecture

Based on previous works on multi-sensor technologies for crop/weed detection in row cultures (Ruckelshausen 1999 and 2004) the authors have realized a sensor fusion concept thereby implementing various sensors as shown in figure 1.

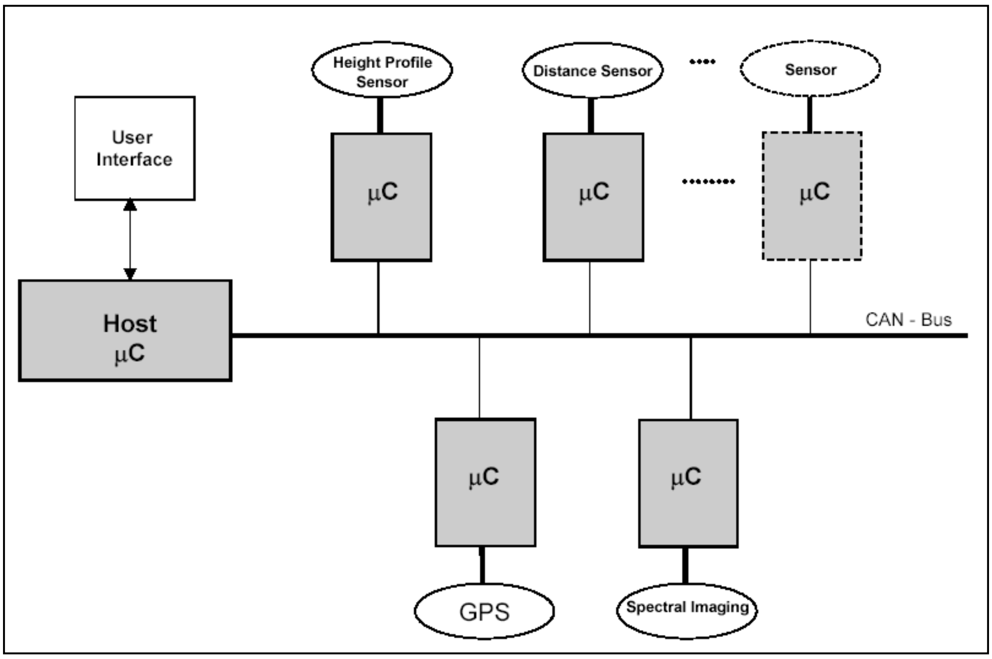

Figure 1: Multi-sensor architecture based on the integration of different sensors, GPS and a user interface.

This architecture compensates for a lower selectivity of a single sensor due to variations of field and plant conditions. Moreover a user interface is integrated for the setup and control of all components as well as for electronic documentation. The authors have integrated different imaging and optoelectronic systems based on own development or practical experiences.

The profile of row cultures can be measured with a stack of light barriers (Fender 2005). Such *photo-diode arrays* offer new options for the reliable analysis of geometric signatures, whereas the binary data are directly available thereby resulting in high processing speeds. Figure 2 shows the result of a photo-diode array for a section of a maize row. The resulting data are analysed with image processing methods.

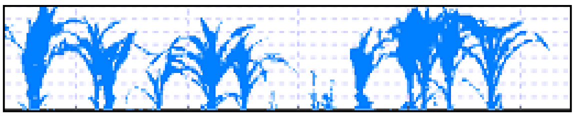

Figure 2: Measurement results of a photo-diode array (as constructed by the authors), which measures the plant profile.

Another sensor system used in the architecture is a *hyperspectral imaging system* (In der Stroth 2003). For each geometric line a wavelength-position-matrix is generated by a commercially available optics as shown in figure 3. This 2D-array is analysed by a fast CMOS-camera where only selective wavelengths are picked out. The results of the point wise spectral analysis are integrated to an image, where – in this application – the shape of the plants from a top view is calculated (Fender 2005).

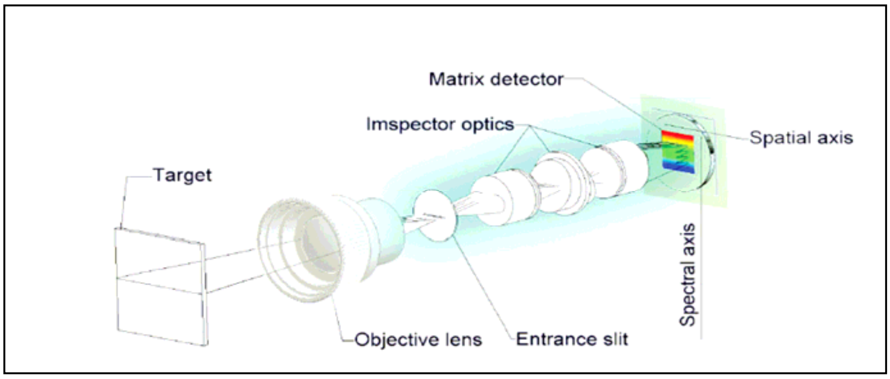

Figure 3: Principle of the hyperspectral imaging system ImSpector (Source: www.specim.fi); the image is taken by a CMOS-camera for further image processing.

Next to shape and spectral information the distance of the plants with respect to the sensor system is measured by using fast *triangulation sensors* (Thösink 2004). For maize plants a high selectivity for stalk detection can be obtained. Intelligent real-time algorithms use the reduced data to detect the relative position of a crop plant.

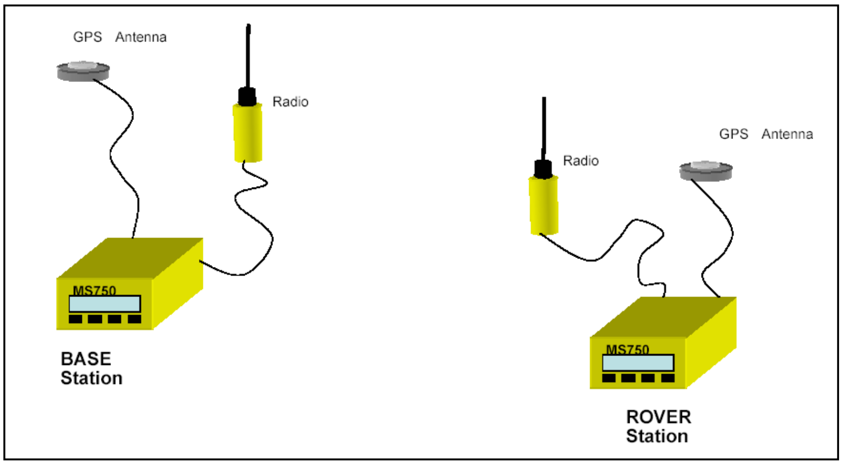

Figure 4: GPS system with BASE and ROVER Station.

In order to have positions of single maize plants for re-detection the accuracy of the GPS system has to be in the order of a few centimetres, at least less than the typical distance of two maize plants within a row (5 – 12 cm). This high accuracy can be achieved with a RTK-GPS-system, such as the MS750 from Trimble (www.trimble.com) which has been used by the authors. Real-time-kinematics (RTK) positioning is based on at least two GPS receivers, a reference and one more rover receiver (see figure 4). Using a DGPS system with a measured accuracy range of about 1 – 2 m, the variations can be reduced to less than ± 2 cm when applying a RTK-fixed method and interpolation of shaft encoder information. Such a system has been integrated in the multi-sensor architecture and offers the option for mapping the absolute position of each single plant in a field.

Field Tests and Conclusions

A mobile sensor unit has been used for field measurements (see figure 5). The photo-diode arrays, the spectral imaging system, distance sensors as well as the system technology and the GPS equipment have been integrated. The results of a series of 4 different measurements of the same row of maize plants in figure 6 demonstrate that each single maize plant can be detected, might be "named" and measured again at a different time. The data of figure 6 have been visualized with the GIS-tool OpenJUMP, an open-source application based on JAVA (see www.openjump.org).

To summarize, online sensor fusion and GPS have been integrated for the realtime detection and re-detection of single crop plants. This technology offers promising applications for the automated characterization and documentation of crop fields – based on individual plants - and "ultra-high precision" agricultural methods.

Figure 5: Sensor mobile unit with the RTK-DGPS-system in field tests.

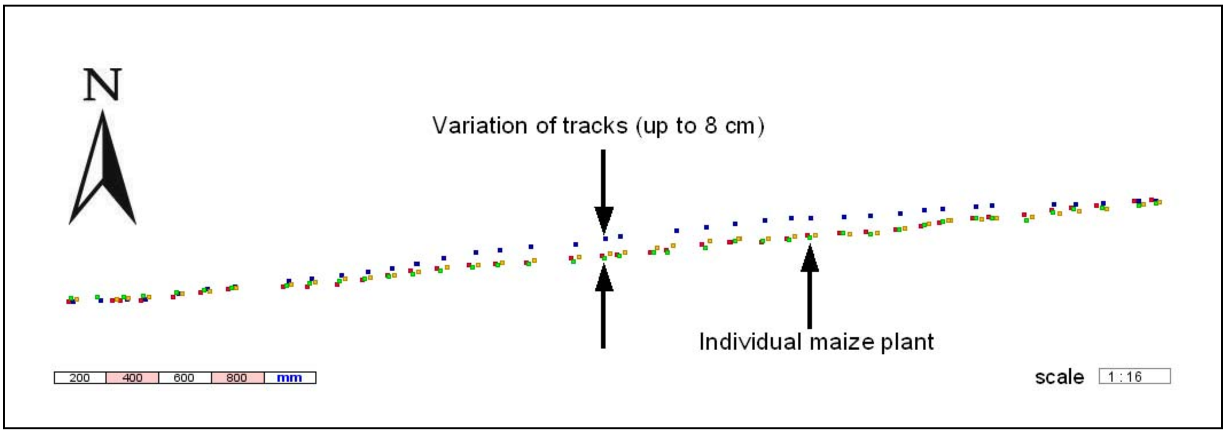

Figure 6: GPS positions of single maize plants measured in 4 different runs, the vertical variations are due to different tracks of the mobile unit.

References

B. Åstrand ,A.J. Baerveldt, Plant recognition and localization using context information”, Proc. IEEE Conference on Mechatronics and Robotics 2004 – special session Autonomous Machines in Agriculture, Aachen, Germany, September 13-15, (2004).

B. Åstrand , Vision Based Perception for Mechatronic Weed Control, PhD Thesis, Chalmers University of Technology Göteborg and Halmstad University, 2005.

F.Fender, M.Hanneken, A.Linz, A.Ruckelshausen, M.Spicer, Messende Lichtgitter und Multispektralkameras als bildgebende Systeme zur Pflanzenerkennung, Bornimer Agrartechnische Berichte, Heft 40, 2005 (ISSN 0947-7314), S.7-16.

H.W.Griepentrog, M.Norremark, H.Nielsen, S.Blackmore, Individual plant care in cropping systems, Proceedings of the 4th European Conference on Precision Agriculture, 247-251,2003.

S. In der Stroth, B.Ramler, A.Linz, A.Ruckelshausen, Weed detection based on spectral imaging systems with CMOS cameras, 4th European Conference on Precision Agriculture ECPA, Berlin, Programme book, ISBN 9076998345, 2003.

H.Oebel., R.Gerhards, Camera-guided weed control – a technology for practice, Journal of Plant Diseases and Protection, Proceedings 23rd German Conference on Weed Biology and Weed Control, 2006, 181-188.

A.Ruckelshausen, A.Linz, B.Ramler, S.In der Stroth, Innovative methods in non-chemical weed control, Proeceedings of the 15th International Plant Protection Congress, Beijing, China, 2004 , Foreign Languages Press, ISBN 7-119-03698-X.

A.Ruckelshausen, T.Dzinaj, F.Gelze, S.Kleine Hörstkamp, A.Linz, J.Marquering, Microcontroller-based multi-sensor system for online crop/weed detection, Proceedings 1999 Brighton Conference, Vol.2, 601-606.

G. Thösink, J. Preckwinkel, A.Linz, A. Ruckelshausen, J.Marquering, Optoelektronisches Sensorsystem zur Messung der Pflanzenbestandsdichte, Landtechnik 59, S.78-79, 2004.

G.Wartenberg, H.-R.Langner, H.Böttger, H.Schmidt, A.Ruckelshausen, S.In der Stroth, A.Linz, B.Ramler, U.Urbansky, L.Schulze, D.Deppner, R.Buschmeier, T.Wischke, D.Heinze, Messsystem zur Bewertung des Unkrautvorkommens, Bornimer Agrartechnische Berichte, Heft 44, Potsdam-Bornim, 2005.