Intelligent functions for crop production automation

Pasi Suomi[1)], Timo Oksanen[2)], Liisa Pesonen[1)], Jere Kaivosoja[1)], Hannu Haapala[1)], Arto Visala[2)]

[1)] MTT Agrifood Research Finland

Vakolantie 55, FIN-03400 Vihti, Finland, E-mail: forename.surname@mtt.fi

[2)] Helsinki University of Technology (TKK), Automation technology laboratory,

Otaniementie 17, FIN-02150 Espoo, Finland, E-mail: forename.surname@tkk.fi

Abstract

ICT assisted Precision Agriculture (PA) is the key technology to fulfil the demands that are set to agricultural production in the near future. Possibilities that novel PA technologies can offer are investigated and demonstrated in this study of ISOBUS compatible prototype system. The functions that are built into the prototype automation system include intelligence that enables precision and efficiency, and integration to external systems. The intelligent functions are classified to assisting driving-time functions such as site-specific application control, headland sequences and delay control, background functions such as fault diagnostics, and embedded instructions such as automated calibration and computerized user guidance. Four machines were investigated, two combined drills, a sprayer and a spreader. The performed tests assured that the intelligent functions were usable and useful.

Key words

agriculture, machine, implement, intelligent function, ISO 11783, ISOBUS, drill, sprayer, spreader, calibration

Introduction

Globalization of the market and increasing competition has forced agricultural machinery manufacturers to develop new products. Since the availability of agricultural workers in main market areas is rapidly reducing the manufacturers are producing larger and more efficient machines than before. Meanwhile, there are also growing demands for agriculture to become an integrated part of the information society meeting the needs of both private and public sector. Efficient production processes, quality assurance and traceability are required (Opara 2002, Sarig 2003). ICT assisted Precision Agriculture (PA) is the key technology to fulfil these demands (Haapala 1995, Sigrimis et al. 1999, Auernhammer 2003, McBrantney et al. 2005). However, the full benefits of PA are not yet clearly shown. There is a need to investigate and demonstrate the possibilities that novel PA technologies offer. The new solutions can not only provide automation but also make agricultural systems more usable, reliable, efficient and sustainable - and integrate them to the society.

Intelligent functions needed

In order to be able to implement the needed properties in agricultural machinery, new intelligent functions need to be developed. The functions include intelligence that enables precision and efficiency, and integration to external systems. Auernhammer (2003) considers that mechatronics, the combination of mechanics and electronics together with hydraulics, makes intelligent components available which then can be connected using electronic communication. User centric design is essential since intelligent functions include interaction with the human users that have limited control resources (Wickens 2002, Haapala et al. 2006). The allocation of tasks between the human operator and automation should be done carefully to make it possible for the human and machine to collaborate to achieve the operating objectives (Hollnagel & Bye 2000). When the human capabilities are taken into consideration in the development of automation, the automation can help in control and the driver can concentrate more on decision making and monitoring the system.

The networked tractor-implement information and control system as specified in ISO 11783 standard (also known as ISOBUS) allows implementing new kinds of intelligent functions. However, in order to realise the intelligent functions, lots of information about the state of the machine is needed. This means that additional sensor instrumentation is required as compared to present machinery. Larger memories in embedded controllers and the use of ISO 11783 makes it even possible to embed user instructions into the implement controller, not only in text and image format but in numeric format so that this data can easily be utilized e.g. in calibrations.

Automated sequences are common in modern tractors, including almost all controllable resources of the tractor and it is also possible to include simple hydraulic implement sequences (e.g. turning the reversible plough) to it. However, closed loop control has not yet been feasible due to poor standardization.

AGRIX intelligent functions

The research group together with manufacturers made requirements for intelligent functions which then were studied and developed in the project AGRIX. The AGRIX intelligent functions are classified to assisting driving-time functions, background functions and embedded instructions. In this paper the main functions of the case-study machines are presented.

The AGRIX system is based on ISO 11783 standard, which allows the use of tractor hydraulics by an implement controller. For the implementation an ISOBUS Class 3 compatible tractor is needed. In AGRIX the control of headland sequence is located in the implement controller. The controller utilizes the ISOBUS for tractor measurements and activation of tractor hydraulic valves and the user operates the automation using a Virtual Terminal.

One of the basic intelligent functions in AGRIX is the common user interface for all the implements used. AGRIX system functionality is divided into three modes: Transport, Field, and Free. In the Transport mode all implement functions are forced to an inactive state. In the Free mode it is possible to control all functions manually. All functions that may cause danger, mainly hydraulic ones, are controlled by 'press-and-hold'. In the Field mode all the supporting functions are available for the driver, such as the sequences of headland automation. The Field mode is the most critical in respect of safety and must be designed carefully.

Drills

Two combined drills used as AGRIX test cases, Tume Airmaster™ and Junkkari Superseed™ (Oksanen et al. 2005). In Airmaster the coulters are at the rear. Seeds and fertilizer are pneumatically transported from hoppers to the coulters. The levelling board, coulters, markers and tramline functions were automated. At headlands the developed sequences guarantee that e.g. the coulters at the rear of the machine lift and lower synchronously at the same position as the manually controlled front levelling board. The drill controller also lifts the coulters if the driver accidentally starts to drive backwards. In Junkkari Superseed™ the need for automation was different since the drill has few hydraulic functions and fertilizer and seed are transported by gravity.

Calibration of a combined drill is an essential but laborious task causing mental stress some of which can be avoided by computerized assistance. An assisted calibration for the feeders was developed. The procedure is as follows: first the user weighs out a sample at three different settings of the feeder and feeds the results into the controller. Then the implement controller calculates a calibration curve and uses it in control. As reliability and traceability is especially dependent on calibration the user interface was developed as simple as possible. For the calibration basic quality information of the available fertilizers was stored to the implement controller.

Sprayer

In sprayers refilling and mixing the chemicals are in most cases based on estimations. With sufficient specifications and sensor information, however, it is possible to calculate exactly how much material is needed and how it should be mixed. This is important especially in PA. In AGRIX a Junkkari™ sprayer was instrumented and automated. Proper nozzle selection, automatic nozzle calibration, correct mixture dosing and estimation of the required filling level were considered as the most important functions to help the driver. The PA task plan included site-specific dosing and the type of treatment needed.

In order to create an assistant to select proper nozzle, the properties of available nozzles were digitized and loaded into the implement controller. Based on the properties and current wind condition and desired driving speed the AGRIX controller helps the driver to select the proper nozzle (Figure 1). In pressure based application rate control the driver can select the nozzle based on the widest pressure range. If an exact mixture is not essential for the specific chemical the driving speed may be selected. Then the mixture ratio and the filling level are calculated by the controller. A nozzle-specific pressure-to-flow curve is identified during an automatic calibration phase, run before filling the chemicals. The Junkkari™ sprayer's boom was divided into five sections and each of them was controlled by a selection valve. The return flow was passed through a tuneable choke which has to be retuned after every change of nozzle type - for this an assistive calibration procedure was developed.

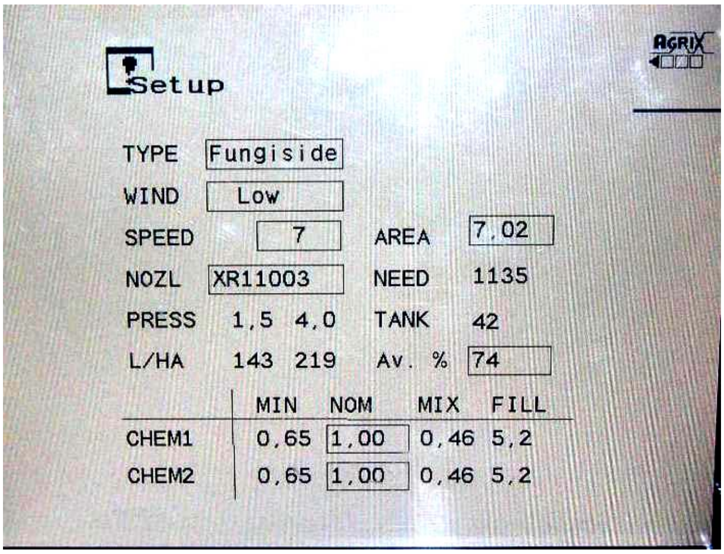

Figure 1. Nozzle selection and refilling assistant

During spraying the system gives an on-line estimate of the remaining treatment area based on tank level measurement and history of swath lengths and the measured dosing rate.

Fertilizer spreader

Tume Airmaster™ is originally a towed combined drill, as described above. For AGRIX the manufacturer modified the drill into a fertilizer spreader by replacing the coulters with a fertilizer spreader of Vicon™. In this solution the fertilizer is pneumatically transported from the Airmaster's hoppers into the spreader. The spreader's original hopper is not used. Consequently, it is possible to control two different fertilizers site-specifically.

The calibration data of the surface spreader was fed into the controller and based on this the AGRIX controller assists the driver to select proper settings of the spreader. Spreading width, driving speed, dosing rate and fertilizer type are selected. The controller includes a similar assisted dose calibration procedure as the drill controller above with the addition of variable spreading width.

The length of the spreader and tractor combination causes trouble especially at headlands. Intelligent headland automation functions were developed to help the driver. In fertilizer spreading headland rounds were driven first so tractor's track was easy to notice. However, the delay from dose rate change command to action was remarkable. The total delay comprises of computing delay, control delay in electric actuator of feeder devices, pneumatic transfer delay and falling delay of the granules. The total delay was ca. 4 seconds and this was to be compensated by the controller. The GPS device was on the tractor, and heading information was provided by an electronic compass and a tow-bar angle measurement. During the fertilization work the drop position of fertilizer granules was estimated. In the estimation the hypothetic centre of gravity of the calibrated spreading pattern was used as the estimated drop position. The set point for site-specific dose rate control was searched from application rate map in that estimated position.

For the headland automation, the starting and stopping delay in meters was compensated (Figure 2). The driver only has to input the delays to minimize under and overlapping.

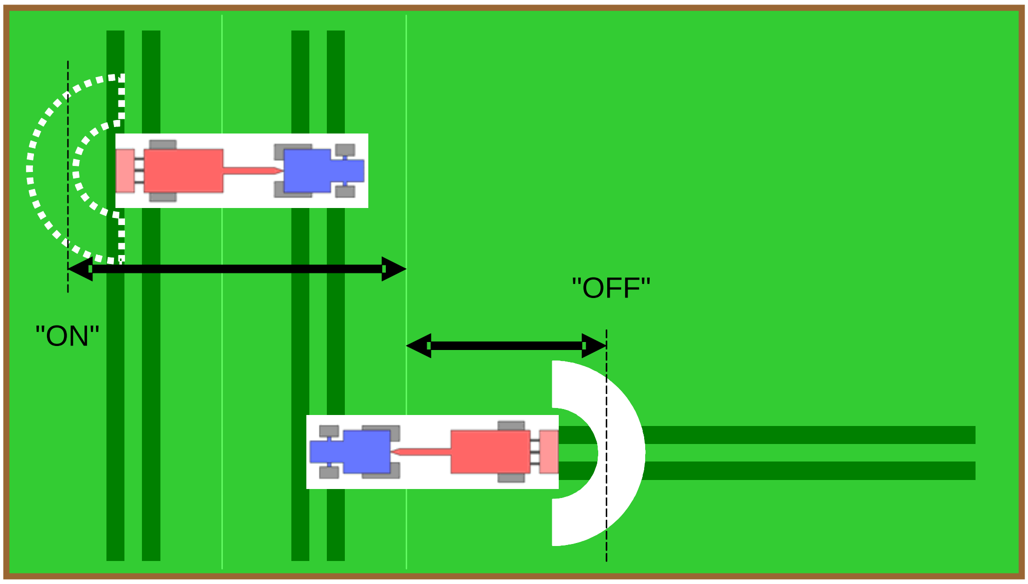

Figure 2. Headland situation of a towed surface spreader. The headland is on the left and the vehicle is in positions where the driver presses 'on' and 'off' buttons

Fault diagnostics

Fault diagnostics is an intelligent background function of automation. Automatic online fault diagnostic functions are monitoring the system condition and verifying pre-known dependencies. The fault diagnostics is not normally visible and is appeared only when something is or is going to be wrong. More about fault diagnostics in AGRIX , see Miettinen et al. (2006).

Conclusions

The required intelligent functions were successfully implemented to the AGRIX implements. The performed tests assured that the intelligent functions were usable and useful. However, it was also noticed that a new attitude is needed for the driver when using an intelligent system. Further studies on usability are needed.

References

Auernhammer, H. 2003. The Role of Mechatronics in Crop Product Traceability. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Invited Overview Paper. Vol. IV. October, 2002. Presented at the Club of Bologna meeting, July 27, 2002. Chicago, IL., USA.

McBratney, A., Whelan, B. & Ancev, T. 2004. Future Directions of Precision Agriculture. Precision Agriculture, 6, 7–23, 2005 (Invited paper, 7th International Conference on Precision Agriculture, Minneapolis, USA, July 2004.)

Haapala, H. 1995. Position Dependent Control (PDC) of plant production. Diss. Agricultural Science in Finland 4 (1995): 239-350.

Haapala, H., Pesonen, L. & Nurkka, P. 2006. Usability as a Challenge in Precision Agriculture – case study: an ISOBUS VT. Agricultural Engineering International: the CIGR Ejournal. 9 p.

Hollnagel, E. & Bye, A. 2000, Principles for modelling function allocation. International Journal of Human-Computer Studies, 52, 253-265

Miettinen, M., Oksanen, T., Öhman, M., Suomi, P. & Visala, A. 2006. Fault Diagnostics in Agricultural Machines. Proc. of Automation Technology in Off-road Equipment 2006, Bonn. ASABE.

Opara. L. 2002. Engineering and Technical Outlook on Traceability of Agricultural production and Products. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Invited Overview Paper. Vol. IV. December, 2002.

Oksanen, T., Suomi, P., Visala, A., Haapala H. 2005. ISOBUS compatible implements in the project AGRIX. In: (edit.) J.V. Stafford. Precision Agriculture ´05. 565-572.

Sarig. Y. 2003. Traceability of Food Products. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Invited Overview Paper. Vol. V. December 2003. Presented at the Club of Bologna meeting, November 16, 2003. Bologna, Italy.

Sigrimis. N., Hashimoto. Y., Munack. A. & De Baerdemaeker. J. 1999. Prospects in Agricultural Engineering in the Information Age: Technological Developments for the Producer and the Consumer. CIGR Journal of Scientific Research and Development. Invited Overview Paper. Vol. I, December, 1999.

Wickens. C., D. 2002. Multiple resources and performance prediction. Theoretical Issues in Ergonomics Science. 2002, VOL. 3, No.2, 159-177