ISOBUS compatible implements in the project AGRIX

T. Oksanen[1], P. Suomi[2], A. Visala[1] and H. Haapala[2]
[1] *TKK Helsinki University of Technology, Automation Technology laboratory*
[2] *MTT Agrifood Research Finland, Agricultural Engineering (VAKOLA)*
timo.oksanen@hut.fi

Abstract

Intelligent implement systems are needed to realise Precision Farming. The ISOBUS standard (ISO 11783) for agricultural machines provides standardized communication between a tractor and implements. Implementation of the standard, however, is not an easy task to perform. In the project AGRIX an ISOBUS compatible implementation has been developed for three implements: two combined drills and a sprayer. The paper describes the R&D process starting from specifications to prototypes and testing. It shows major modifications for implements were needed to implement ISOBUS. These are described. First test results are presented.

Keywords: ISO 11783, ISOBUS, implements, automation, control, sensors, actuators, seed drill, sprayer

Introduction

Intelligent implement systems are needed to realise Precision Farming. An intelligent system is more intensively instrumented than a conventional one because the system needs to know the exact real-time-status of the implement-tractor combination. The implements become more complicated system and are therefore also very challenging in terms of safety management. It is important to study what kinds of features are needed to realise a usable control system. Thus, in the design of intelligent machines a lot of knowledge and experience is required.

The ISOBUS implementation of the standard ISO 11783 for agricultural machines provides standardized mobile communication between a tractor and implements. Standardized communication is needed to ensure compatibility and interoperability of components from different manufacturers. Implementation of the standard, however, is not an easy task to perform.

There are still so far only a few practical installations of ISOBUS compatible tractor-implement systems available in the market. The market is waiting for practical and tested solutions that meet the user requirements of reliable and usable techniques. In order to be operational, ISOBUS systems should be built with care. The conformance and interoperability of ISOBUS implementation has to be tested in the Plugfests. Reliability issues should be emphasised.

Compatibility should be extended not only to the techniques of the tractor and implements but also to the data management, i.e. FMIS (Farm Management Information System) of the whole farm. In the ISOBUS standard, the functionality of FMIS is not specified; only the connection between mobile system and FMIS is described (Fig. 1).

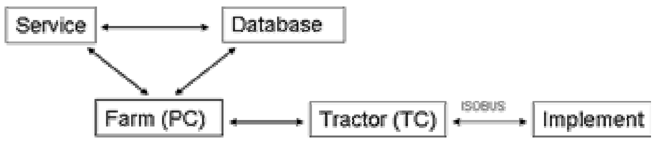

Figure 1. The FMIS (Farm Management Information System) consists of services and databases connected to e.g. a farm PC. The ISOBUS control system can be connected to FMIS.

In the project AGRIX (Automation System for Agricultural Implements), system architecture was considered to be the crucial point of realisation. Compatibility to farm data management was set as an important goal. In the AGRIX an ISOBUS compatible implementation was developed for three implements: two combined drills and a sprayer. Some major implement modifications were needed, as well as extensive installation of sensors and actuators, not to mention the development of software for the VT, TC, implement controllers and testing software. The goal of AGRIX was to make an open system with standardised interfaces. The system is made open for manufacturers and software developers. The use of AGRIX solution is not limited to agricultural use only but also applications as well.

ISO 11783 parts

The ISO 11783 standard is sometimes called ISOBUS. More precisely ISOBUS is the specification based on the ISO 11783 standard (VDMA 2002). The specification is intended for manufacturers to help implement ISO 11783. ISOBUS specification is practically one to one with ISO 11783 and ISOBUS implementation group will support the compatibility in the future. (ISOBUS, 2004).

The Virtual Terminal (VT) is used to provide a user interface. A virtual terminal has a graphic display, softkeys and some means to enter data. The standard specifies only aspects that are necessary for interoperability and leaves the implementation details to the terminal manufacturers. An implement controller uploads its user interface to the terminal. The standard does not give guidelines for user interface design, it only defines the components from which the interfaces are built. (ISO, 2004a).

The Tractor Electronic Control Unit (Tractor ECU) is responsible for transmitting the tractor's status information to the ISO 11783 network. The ISO 11783 specifies three tractor classes. Class 1 includes only basic measurements, and it is not recommended for new tractors. Class 2 contains advanced measurements, e.g. the horizontal force of rear hitch and hydraulic valve flow. Class 3 supports control functions by which implements can control tractor resources. For example implements can control 3-point hitch, PTO and hydraulic outputs. The standard also specifies two additional features: front hitch and navigation abilities (GPS-based position). The Tractor ECU messages are specified in ISO 11783 part 7 (ISO, 2002).

All the controllers on a single implement form a working set. In a working set, one controller assumes the role of the working set master. The working set master is responsible for transmitting the user interface to the Virtual Terminal. In a simple machine there may only be one ECU, which is the working set master. In complex or modular implements there may be several implements, one of which is the working set master. The implement controller is not specified in such details than other modules of ISOBUS. A lot of freedom is let for an implement ECU engineer. Only the communication between modules is standardized, e.g. Virtual Terminal and Task Controller, but it is left to the controller engineer how to create the functionality.

The planned tasks are sent to the Task Controller (TC). The TC is used for the execution of work tasks and the results of then tasks are sent back to a Farm Management Information System, e.g a stationary farm computer of the farmer or the contractor. A FMIS computer is used for planning and evaluation of field work. The standard specifies only aspects that are necessary for interoperability and leaves the implementation details to the Task Controller manufacturers. For example the designer is free to decide how task selection is implemented. The ISO 11783 part 10 is still under development. (ISO, 2004b)

Machines in AGRIX

In AGRIX the main research topic is the open automation system for agricultural implements. In order to test the automation system, three machines were chosen as case implements: a Tume Airmaster™ combined drill, a Junkkari SuperSeed™ no-till combined drill, and a Junkkari™ sprayer (Fig 2). The drills were towed machines and the sprayer hitch mounted. All the implements were chosen from the manufacturers´ regular range.

Figure 2. The implements used: Tume Airmaster™, Junkkari ™ sprayer, and Junkkari Superseed™.

The Tume Airmaster™ is a towed combined drill where the coulters are at the rear. Its working width is four meters. Seeds and fertilizer are pneumatically transported from hoppers in to the coulters. The machine contains several hydraulic cylinders. The Junkkari Superseed™ is a towed no-till combined drill with the coulters under the hoppers. The working width is three meters. Fertilized rate is set with an electric linear actuator and seed rate is controlled manually. Rotation of the feeder mechanism is measured with an inductive sensor in both drills. The 1300 litre Junkkari™ sprayer is connected to the rear hitch. The spraying boom is 15 meters wide and hydraulically foldable with two cylinders. The boom is divided into 5 blocks. The tractor PTO operates a four cylinder diaphragm pump giving 200 litres per minute. The main line flow is measured with a flow sensor. The pressure is measured with a manometer with a pressure ranging of 0 to 10 bars. The working height of the boom is controlled with hydraulics and the inclination of the boom with an electric linear actuator.

A Valtra HiTech 8950™ tractor equipped with an ISOBUS adapter was used. The tractor supports ISOBUS messages. In the AGRIX basic prototype, the following messages were used: wheel speed, ground speed, PTO speed and hydraulic valve messages. The tractor has four two-directional electrically controlled hydraulic valves that can also be controlled by the implement using standard ISOBUS messages.

Specifications

The research group and the manufacturers agreed jointly the implement functions to be implemented. The main goal was to make the system as easy as possible to operate. Consequently, automation was used to perform multiple sequences which support the driver in controlling the system. In headland driving, it is possible to activate all the required functions by pressing only one VT button. In the Tume Airmaster™ drill the levelling board, coulters, markers and tramline functions work automatically. The required specifications were first tested with an AGRIX fast prototype (in more detail: Oksanen et al. 2004).

Performance requirements were calculated based on the need to react to normal changes in the dose of seed, fertiliser or pesticide. In precision farming, a typical accuracy requirement for the targeting of fertilization would be ± 5 meters in the driving direction (Haapala, 1995). Normal driving speed of the tractor being about 9 km/h in sowing and 6-9 km/h in spraying, it takes two seconds to drive five meters. In that time the control should respond to changes in the rate of fertilizer, seed or pesticide. The accuracy requirement of seed, fertilizer and pesticide rate was set to ± 10 % from the target rate. Actually, in the case of fertilizing it is not critical for the plant growth if the fertilizer rate varies 10 % from the target rate but it is more an economical question for the farmer. The same fits for spraying, too (Alness & Hagenvall 1994). Accurate control saves inputs.

The control system of AGRIX aims to be both safe and user friendly which are to some extent conflicting requirements. Due to the fact that ISOBUS systems tends to be complex the driver may be unaware of the state of the machine. Studies with other vehicles show that there is a danger that in the future drivers will be overwhelmed by all the functionality on offer within their vehicles. This is often at the cost of increased visual and mental demands (Burnett 2001). In vehicles development, the R&D has taken a step towards a design-oriented user interface. Thus, the specific user requirements are seen as the corner stone of a well-functioning and safe user interface (Pått 2004).

In AGRIX both safety and user friendliness issues were considered. To be able to do both, the research team decided to use various usability inspection methods, which complement each other. To start with, a heuristic evaluation was carried out to find most of the usability problems by following the list of heuristics (usability principles of interface design, Nielsen 1993). User experiences obtained by observing users were very useful and complemented the findings of the heuristic evaluation.

System functionality was divided into three modes, which were considered common for all kind of implements: Transport, Field, and Free. In Transport mode all implement functions are forced to an inactive state. In 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 Field mode all the supporting functions are available for the driver, such as the sequences of headland automation. Field mode is the most critical in respect of safety and must be designed carefully. The system must have an emergency stop button to abort all functions. VT views are separated into driving view, setting, calibration, alarms and report. The calibration phase is designed to be guiding, interacting and simple.

Implement modifications and control

Tume Airmaster™

The Tume Airmaster™ has seven two-directional hydraulic functions. Originally the control of hydraulic cylinders was coupled because of the design requirement that only one hydraulic output from the tractor was needed. Magnetic valves were used to select the function of a specific hydraulic output. In AGRIX the original hydraulic control was replaced with a new valve block that allowed all the hydraulic functions to be controlled separately. Now a continuous hydraulic flow is required from the tractor.

To enable feedback control, linear position sensors were installed to measure the position of the levelling board and coulters. The levelling board position control is relay type, it can be driven both directions or hold still. A simple threshold with dead band was chosen to control the position of the board. The lower position of the coulters is tuned with the physical position of a magnetic sensor. There are no sensors for markers so the control of markers is based on a timer.
Electric linear actuators were installed to adjust the fertilizer and seed rate. The linear actuator has an internal position sensor, which can be used in control. Rotation of the feeder mechanism was measured with an inductive sensor. The fertilizer and seed level in the hopper were measured with photocells. Calibrations were carried out at three points, freely chosen by the driver, and a calibration line was fitted to these results.

Junkkari Superseed™

In the Junkkari Superseed™ there were only two basic hydraulic functions, the lift of the drill and the loading of the coulters. In the new installation, the electrically controlled intelligent hydraulic valves of the tractor were used. ISOBUS messages were used to control the valves. The working position of the drill as well as the load on the coulters was measured with a potentiometer. Both the position and load were controlled in a feedback loop. The set point value for load was obtained from the user interface and the headland automation controlled the position. The level of fertilizer and seed in the hoppers was measured with a capacitive sensor at the bottom of the hoppers. An electric linear actuator was installed to adjust the fertilizer rate.

<u>Junkkari™ sprayer</u>
The liquid level in the tank was measured with a pressure sensor installed at the bottom of the tank. Position sensors were installed to measure the height and inclination of the boom in order to enable feedback control. A pressure sensor was installed next to the original manometer.

The spray rate was controlled with a crossover valve. The actuator had a DC-motor directly driving the valve rod. It was found that the pressure control actuator was highly nonlinear and in the most used pressure range very sensitive. The realised control strategy was cascade, the pressure control in the inner loop and the flow control in the outer one. Because of the fact that the liquid returned to the tank if some blocks were closed the flow measurement was only an estimate in these cases.

A setup programme was developed for choosing proper nozzles. The properties of available nozzles were loaded in the system. The calibration was made very simple through that the AGRIX system calibrates itself automatically. The controller of the sprayer compensates for speed variation. The boom height was operated manually with the tractor hydraulics but in the future feedback control will be implemented.

System monitoring and validation measurements

The performance of the AGRIX system was studied in laboratory and field conditions using a reference monitoring system. The reliability of the data documentation was tested, as well. This is important because the data from precision farming is valuable for administration, farm management and contractors, only if it is reliable.

The AGRIX monitoring system was based on a mini-PC installed on the tractor. The monitoring system stores measurements of main functions of each implement and also data from additional sensors installed for the validation purposes. A multi channel data acquisition card and a 10 Hz GPS were connected to the PC. Measurements from all the channels were stored with GPS-coordinates, GPS-velocity and a timestamp, the sample time being 100 milliseconds.

In the drills, the fertilizer and seed controller positions were validated with accurate linear displacement transducers, the ranges being 0-10 V DC and the resolution 0.05 millimetres. The connection mechanism clearance of the transducers was found to be roughly one millimetre which corresponds to 20 kilograms per hectare in typical fertilizer rates and 10 kilograms in seed rate. The measured feeder roll position indicated directly the actual dose rate. Corresponding measurement and control actions were also recorded by the AGRIX control system.

In the sprayer, a pressure sensor was installed to the end of the boom. The AGRIX monitoring system measured also the control valve movement and the main line pressure. The site-specific dose (litres per hectare) was calculated by using the pressure transducers, nozzle properties and velocity information derived from GPS.

Calibrations and laboratory tests

The drills

The prototypes were calibrated before each field test. Rotation tests were done to check seed and fertilizer rate control. The transducer output information was calibrated against the actual seed and fertilizer rates. In laboratory test the feed mechanisms were rotated by an electric motor at an equivalent working speed of 10 km/h. Response tests were made by changing the base rate using the VT. A marker was stored at that time moment in the recording file (Fig. 3). When the AGRIX control system changed the set point value from 23 % to 20 % the fertilizer rate decreased from 175 kg/ha to 145 kg/ha. The target reaction time was reached since an accurate enough (± 10%) dose rate was reached in less than two seconds.

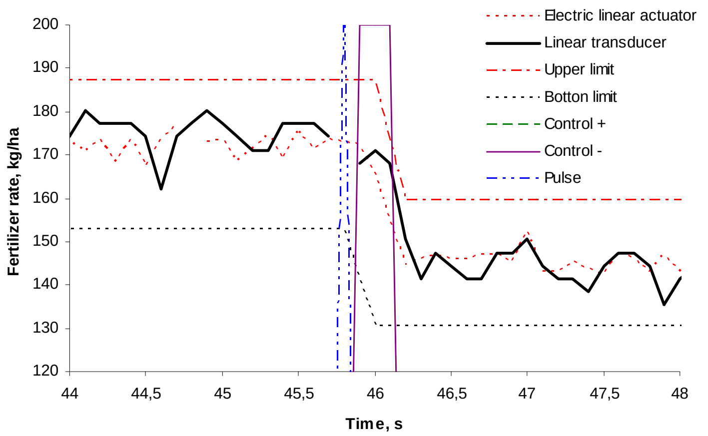

Figure 3. Response test of Tume Airmaster™.

The sprayer

The prototype Junkkari™ sprayer was tested and calibrated before the field tests. Spraying pressures were measured with two parallel transducers at the main valve and at the end of the boom. The pressure transducers were calibrated against the nozzle output (l/min), which was collected and weighed. According to the tests the output was accurate; correspondence to Bernoulli's law was excellent.

Starting the spraying at the headlands turned out to be a challenging control task. As required, when the driver presses the button to start spraying the target rate should be reached in two seconds. The results are shown in Figure 4, where the target rate was 220 l/ha. An acceptable dose rate (± 10% of the target) was achieved in roughly in five seconds, not reaching the required 2 seconds. The target dose rate was reached faster when the control steps were smaller.

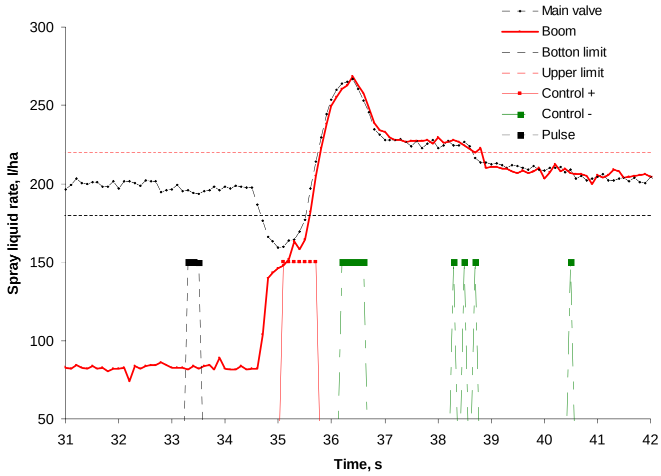

Figure 4. Response time of Junkkari™ sprayer.

There were two reasons why the requirement was not reached. Firstly, the boom block switching valves were not instant; the change of state took about one second. During this switching time the routes both to the boom and to the tank were simultaneously open, and the pressure dropped temporarily. This can be seen at time period from 34.5 to 35 seconds (Fig. 4). The controller tries to compensate for this. As a conclusion, the crossover valve was not the best valve type to control pressure.

Field tests

AGRIX prototypes were tested in a area of 15 ha field of malt barley. The soil types in the three different field blocks were variable. To avoid difference in positioning data the same GPS-system was used both in AGRIX control system and in AGRIX monitoring system. The optimum targets for fertilizer and seed rates where determined by the Precision Farming projects of MTT Agricultural Engineering Research. Optimum fertilizer rates varied from 200 – 400 kg/ha and seed rates from 150 – 340 kg/ha.

The Tume Airmaster™ was used in the spring sowing. The validation test was carried out in Kirjava field where fertilizer rates chanced from 120 kg/ha to 360 kg/ha and seed rates from 190 kg/ha to 310 kg/ha. The AGRIX controls reached the target rates nicely when the fertilizer rate was between 120 – 260 kg/ha. At higher rates the control did not work as correctly as on the lower fertilizer level. The most important reason for not achieving the target rate was a human error in calibration of the AGRIX system, the calibration was made for the range 120 – 260 kg/ha and above that extrapolation was used.

Application rates for fungicide spraying were calculated by the Kemira GrowHow Loris™ system. Spraying rates changed from 160 to 210 l/ha in the application map that was made for Uutela field. The other test fields were sprayed using a constant dose rate 200 l/ha. The slow response time was also found in field tests. When spraying was started in the headland, it took over five seconds for the control to reach the target dose rate.

Conclusion

ISOBUS compatible implements contain increased level of automation. Automation needs the knowledge about the state of the machine, and typically more sensors are needed. Some sensors need calibration, which leads to complexity. However automation can help the driver in calibration. The usability of multifunctional implement-tractor combination is very important because the human has limited resources. Automation can help in control and the driver can concentrate more on making decisions and monitoring the system. Future research will include user testing in connection with the product development.

The requirements for AGRIX control system were set and the automation system functionality was developed based on them. The implements were modified and several sensors added. Most requirements were met. Only the control of sprayer liquid pressure did not function properly. This was due to the fact that wrong type of actuator valve was used for precision farming purposes. In the future the actuator valve will be replaced with an electrically adjustable pressure relief valve. Additionally calibration of the driller has to be made more reliable to reduce possibility of making human errors. Also the intelligence of implements will be developed and more tests will be done. Connection to FMIS systems is also a great challenge to be met.

Acknowledgements

This work has been supported by Tekes (National Technology Agency of Finland), and companies: Bitcomp Oy, Junkkari Oy, Kemira GrowHow Oy, Mitron Oy, Tume-Agri Oy, Valtra Oy, Vieskan Metalli Oy and ProAgria. The other partners in research group were TTS Work Efficiency Institute and University of Helsinki Deparment of Agrotechnology.

References

Alness, K. & Hagenvall, H., 1994. Dose-response in research and practice. 35th Swedish Crop Protection Conference. Uppsala 26-27 January 1994: 201-211.

Burnett Gary E., 2001. Ubiquitous computing within cars: designing controls for non-visual use. Int J. Human-Computer Studies (2001) 55, 521-531.

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

ISO. 2002. ISO 11783:7 Implement messages application layer. International standard.

ISO. 2004a. ISO 11783:6 Virtual terminal. ISO 11783. International standard.

ISO. 2004b. ISO 11783:10 Task controller and management information system data interchange. Part 10 Draft Document N289/03E, ISO/TC23/SC19/WG1.

ISOBUS. 2004. http://www.isobus.net.

Nielsen, J. 1993. Usability Engineering. Academic Press. SC.

Oksanen, T., Öhman, M., Miettinen, M., Visala, A. 2004. Open configurable control system for precision farming. Proceedings of ASAE international conference on Automation Technology for Off-road Equipment. Kyoto 2004, Japan. pp. 184-191.

Pått, K. 2004. User and Usability Requirements in Work Vehicle Cabins. Conference presentation; Future Ground 2004: Design Research Society International Conference. 17-21.11.2004. Melbourne. Australia.