

ISO 11783 – STANDARD AND ITS IMPLEMENTATION

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Abstract: For years electronic control has been used to enhance the performance of various components in agricultural machinery e.g. engine, transmission and implement functions. Yet networking these components has potential to significantly improve the performance and modularity of the total system. The ISO 11783 standard specifies the communication between a tractor and an implement. Standardized communication is needed to ensure compatibility and interoperability of components from different manufacturers. In the Agrix Project the automation of agricultural implements is researched. The Agrix Basic Prototype is based on the ISO 11783 standard. The ISO 11783 compatible commercial tractor and virtual terminal are shortly reviewed and the realised implement controller, task controller and GPS-adaptor are presented in this paper.
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1. INTRODUCTION

There are many manufacturers of agricultural machines. Tractors are general purpose machines to which different tools or implements can be connected. An implement is usually connected to 3-point hitch at the front or rear, to towing hook, or sometimes directly to the frame of the tractor. Tractors and implements are usually manufactured by different manufactures. The compatibility of tractors and implements has been a problem. Currently the mechanical interfaces including hitch, hook, power take-off and hydraulic connectors are well standardized, for example ISO standards in ICS 65.060.10.

Electronic controls are used increasingly in modern tractors and implements. Currently a typical implement that contains some sort of intelligence like monitoring, comes with a separate control box which is attached to the cabin of tractor. It also has external sensors for measuring vehicle's state. If a

farmer has many such implements, the cabin will be filled with numerous of different control boxes.

The ISO 11783 standard specifies the data communication network on agricultural machines. The ISO 11783 is still under development. In this paper the ISO 11783 standard is reviewed. The Agrix research project, which studies the automation of agricultural implements, is presented shortly. The implementation of the ISO 11783 compatible Agrix Basic Prototype is presented.

2. AGRIX-PROJECT

The Agrix Project (automation system for agricultural implements) was launched in the beginning of 2003. The main research topics are general purpose configurable implement controller (including the software architecture, hardware compatibility and openness), user interface, positioning and navigation, telematics and fault

diagnostics, wireless communication, precision farming and optimization of field traffic. In project consortium there are three other research partners. There are also eight companies financing the project but most of the funding comes from the National Technology Agency of Finland.

During the spring and summer 2003 the Agrix Fast Prototype was developed and tested. The Fast Prototype was a towed drill with plenty of functions and sensors. A handheld computer was used as the user interface. The Fast Prototype is presented in more detail in paper (Oksanen *et al.*, 2004).

The Agrix Basic Prototype development was started in the autumn 2003 and was completed with field tests in August 2004. The Basic Prototype contains a commercial tractor tailored by the manufacturer to support the ISO 11783, two commercial ISO 11783-compatible Virtual Terminals, three tailored implements equipped with implement control unit, task controller compatible to ISOBUS, GPS-adaptor and analyzer tools. Of the three implements, two are combine fertilizer-seed-drills and one is a sprayer.

3. ISO 11783 Parts

3.1 Overview

In the late 1980's the development of communication network between tractor and implements was started in Germany. The main parts of DIN 9684 were completed by the end of 1991. At the same time similar efforts were made in the United States, targeting SAE J1939 standard. Both standards are based on CAN-bus, but they are totally incompatible. (Stone *et al.*, 1999)

Since 1992 a new standard for agricultural machine communication has been developed by ISO. The ISO 11783 standard specifies the data network for control and communications on agricultural vehicles. Various parts of ISO 11783 are taken from DIN 9684 and SAE J1939. The new standard contains currently seven international standard parts and at least six are still under development. The physical and data link layers of ISO are based on CAN 2.0b protocol with 29-bit identifiers. (Bosch, 1991), (Stone *et al.*, 1999)

CAN 2.0b specifies the length of message identifier to 29 bits and the length of message data to 64 bits (Bosch, 1991). Most messages specified in ISO 11783 fit into one CAN-message. For longer messages ISO 11783 specifies a multipacket transport protocol.

The ISO 11783 standard is sometimes called as ISOBUS. Accurately ISOBUS is the specification based on the ISO 11783 standard (VDMA 2002). Specification is intended for manufacturers to help implementing ISO 11783. ISOBUS specification is

practically one to one with ISO 11783 and will be in the future also.

3.2 Virtual terminal

The Virtual Terminal (VT) is used to provide the 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. A Virtual Terminal works much like an internet browser. An implement controller loads its user interface to the terminal. After loading its interface, the controller can use the terminal to show information. Also, every time a softkey is pressed or data is entered, the terminal notifies the controller by sending messages. The controller works much like a web server. It is solely responsible for the display and the user controls.

The display of the Virtual Terminal may be black-white, 4-bit colour or 8-bit colour. It is divided into two different areas. The data mask area is square-shaped and its minimum resolution is 200 x 200 pixels. It usually covers the most of the display area. The data mask area is used to display various objects to the user, such as buttons, number and string fields, geometrical shapes, meters and bar graphs, and bitmap graphics. The softkey area is used to show the softkey labels. The Virtual Terminal also supports auxiliary inputs, which can be joysticks or button panels. With the help of the terminal, the user can configure the auxiliary inputs to the desired functions.

The controller is responsible for the readability of its user interface on any Virtual Terminal. The terminal can be interrogated about the hardware details such as the display resolution, the number of colours and the number of softkeys. The controller can then scale graphical objects accordingly, adjust the colours and the softkey layout before loading its user interface to the terminal or it can just select the most suitable one from some preconfigured alternatives. The Virtual Terminal functionality is specified in the ISO 11783 part 6, which is an International Standard (ISO, 2004a).

3.3 Tractor control unit

The Tractor Electronic Control Unit (Tractor ECU) is responsible for transmitting the basic information of tractor's state to the ISO 11783 network. The ISO 11783 specifies three tractor classes. Class 1 includes only basic measurements, and it is not recommended to new tractors. Class 2 contains advanced measurements, for example the horizontal force of rear hitch and hydraulic valve flow measurement. Class 3 supports control functions by which implement can control tractor resources, implement can control 3-point hitch, power-take-off and

hydraulic outputs. The standard also specifies two additional features: front hitch and navigation abilities (GPS-based position), marked with symbols F and N respectively. The Tractor ECU messages are specified in the ISO 11783 part 7 (ISO, 2002).

3.4 Implement control unit

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. The objects, which make up the user interface, are called collectively as the object pool. The Virtual Terminal has non-volatile memory where the working set master can save the object pool. Loading the object pool from the memory is much faster than transmitting it over the bus which can take minutes for very large object pools.

The object pool is a hierarchical structure where all the objects are identified by unique object IDs. Data and alarm masks are top-level objects that can contain graphical objects and container objects. Only one data or alarm mask can be shown at a time as they fill the entire data mask area. Data masks are used to display information during normal operating conditions. Alarm masks are used to show warnings or error messages. Container objects are also top-level objects that can contain graphical objects and other container objects. Containers are used to group other objects. Graphical objects such as input and output fields (strings and numbers), geometrical shapes (lines, rectangles, ellipses and polygons), output graphics (meters and bar graphs) and bitmap graphics are used to display information to the user or to collect feedback from the user.

3.5 Task controller

The Task Controller (TC) is used to provide task management for the Mobile Implement Control System which is all the vehicles and implements that are coupled by and use the ISO 11783 network. Process data messages are used for the transmission of, measured data and or set point commands to one or more Electronic Control Units on the implement.

These days management of the farm activities carried out in the fields is essential for farmers and contractors. The planned tasks are sent to the Task Controller which is used in the Mobile Implement Control System for the execution of tasks and the results of the work tasks are sent back to Farm Management Information System (FMIS), stationary farm computer of the farmer or contractor. FMIS computer is used for planning and evaluation of field work. Data Transfer File is a generic term for files in the XML format which are used for standard data transfer between the FMIS and the Task Controller.

FMIS software has to produce and recognize standardized XML format to be ISO 11783 compatible.

Planned tasks may range from mere planned allocations of resources to the inclusion of geographical information for site specific field operations. Selection of an individual task can be done either by the operator through an operator interface or automatically by the Task Controller. The Task Controller design can provide a means for the user to interact with the Task Controller. Interaction may be through a Virtual Terminal or other interface. 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)

3.6 Positioning information

The GPS receiver provides the positioning information to the ISO 11783 network. Navigation messages in NMEA 2000 standard are utilized in ISO 11783. (NMEA, 2000)

4. AGRIX - BASIC PROTOTYPE

4.1 Virtual terminal

Agrocom's Basic Terminal and Kverneland's Tellus Terminal have been used for testing the Basic Prototype. Even though they are quite early versions, they implement most of the Virtual Terminal features required by the standard.



Fig. 1. Virtual terminals used for testing the prototype.

4.2 Tractor and implements

Valtra has provided for the Agrix Project HiTech 8950 AC6 tractor, which is equipped with an ISO 11783 compatible tractor ECU. The ISO 11783 tractor messages utilized in the Agrix Basic Prototype are wheel speed, ground speed, power take-off speed and all hydraulic valve messages.

Wheel and ground based speeds and distances are used in implement controller to monitor vehicles movements, controlling of spreading rate and calculating covered area. Power take-off speed is used in pneumatic drill to monitor the fan speed. Hydraulic valves are controlled by sprayer and no-tillage drill. In sprayer hydraulic valves are used to control the height and packing of sprayer bar and in no-tillage drill to control the height of machine and the drill pressure.

Three implements are used as case examples in basic prototype: Tume Airmaster towed pneumatic combine seed-fertilized drill, Junkkari Sprayer connected to hitch and Junkkari SuperSeed towed no-tillage combine seed-fertilizer drill. Implements are tailored by manufacturers and researchers with additional sensors. MTT Agrifood Research Finland Agricultural Technology unit has been responsible in modifying and testing the implements. The tractor and all implements are shown in figure 2.

4.3 Implement controller

The Basic Prototype's implement controller is based on VIA's EPIA M10000 motherboard which has Nemiah processor running at 1 GHz. The system's operating system is RedHat Linux 9.0. The PC is equipped with ESD's two-channel CAN interface card and Linksys WLAN-Ethernet adapter. WLAN is used for testing wireless communication and also for debugging. The PC has its own backup battery so it doesn't have to be rebooted every time the tractor is started.

All sensors and actuators in the three implements are connected to Mitron CAN controllers. CAN-controllers have 2A outputs, which can be used directly to drive hydraulic valves and solenoids. The same controller was used in the Fast Prototype as the implement ECU. In the Basic Prototype the controller is used only as a simple I/O-box. The controller is connected to the implement PC via



Fig. 2. Tractor and implements used in Agrix Project.

CAN-bus, adapting the ISO 11783 subnetwork architecture.

The machine control system that runs on the implement PC is made with the Constellation software development system. The control system consists of four major software components: ISOBUS, hardware, mode and I/O components.

The ISOBUS component contains data link layer, network layer and network management functionality. The ISOBUS component provides three busses for the other components: VT, TC and PDU2 busses. The VT bus is for communicating with the virtual terminal and the TC bus is for communicating with the task controller. PDU2 messages are broadcasted to all ECUs on the bus. PDU2 bus is used to receive and transmit these broadcast messages.

The hardware component is a hierarchical representation of the machine. Within the hardware component, there are components for every major subsystem that encapsulate the details of controlling the actual hardware. There are also two components that do not represent real hardware: user interface and alarm components. The user interface component controls how the user can navigate through the various displays. The alarm component manages all the alarms in the system in a centralized manner. The hardware component of one implement is shown in figure 4.

The mode component manages the major modes of the control system. The control system has three modes: free, transport and field modes. In the free mode, the user can operate different actuators freely without any intervention from the automation system. This mode is intended for special circumstances such as calibration, maintenance and error recovery. In the transport mode, the machine is locked in its transport position. This makes transporting the machine safe. The actual work is

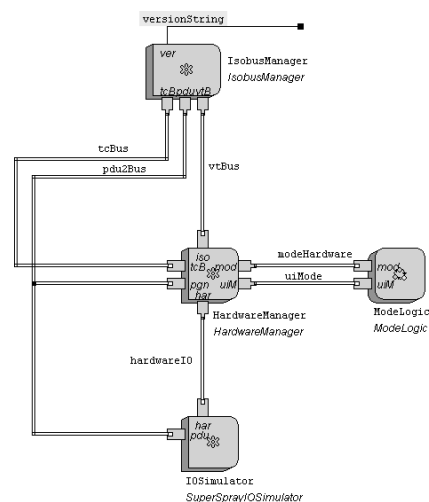


Fig. 3. The major software components of the implement ECU as shown in Constellation software development system

done in the field mode. The field mode is further divided into turn mode and work mode. Selecting turn mode lifts the machine up for turning and selecting the work mode lowers the machine down for working.

The I/O component represents the physical I/O system. Control signals from the hardware component are mapped to the output pins and the input pins are mapped to the measurement signals. The prototype uses proprietary CAN protocol to connect to an external I/O device but changing the I/O subsystem would be relatively straightforward.

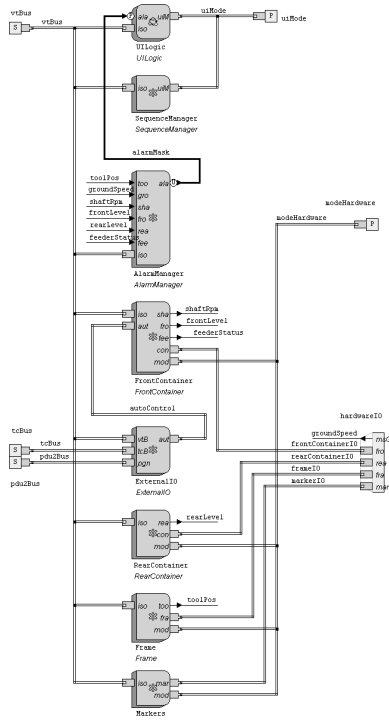


Fig. 4. The hardware component

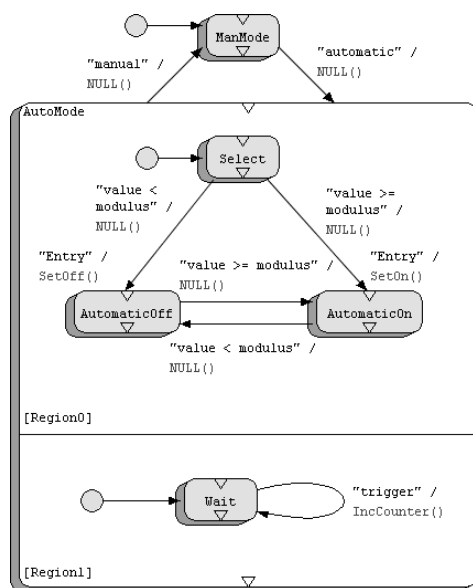


Fig. 5. An example of Constellation state machine

The Constellation software development system supports both sampled-data and event-driven processing. This is nice as a typical machine control system needs them both. Each component in the system can have sampled-data and event-driven parts. High-level components are usually more event-driven as they need to respond to commands and rare events. Low-level components usually perform more sampled-data processing as they monitor, filter or control physical elements of the system.

A state machine diagram shows what actions are taken in response to events. They can be used to represent behaviour, execution plans, processing sequences, or any asynchronous processing. Constellation's state machines provide an expressive graphical language well suited to system's strategic control.

Matlab Simulink is a tool for modelling, simulating and analyzing dynamic systems. The new versions of Matlab Simulink contain also compiler tools, which allow the control system be designed with Simulink and directly compiled and linked to supported target. Constellation supports Simulink models to be used as components.

4.4 Task controller

Task Controller implemented in the project works with the ISOBUS network according to the standard. There was not enough resources to implement full system with standard FMIS software and no commercial ISO 11783 compatible software for TC was available at the time of the project implementation. That is why only requirements specified to mobile side of task controller was implemented in the project. The differences between the standard and implementation configuration are shown in the figure 6.

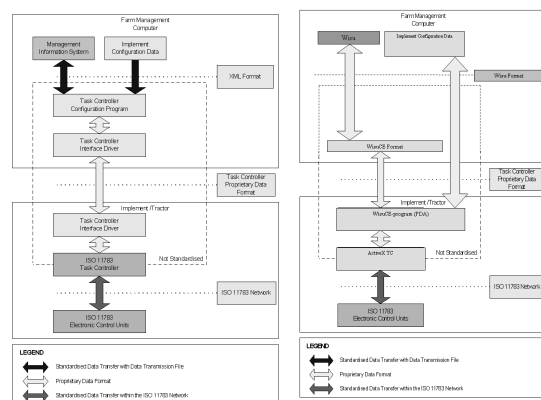


Fig. 6. In left: task controller according to the standard, in right: Agrix implementation (adapted from ISO, 2004b).

In the project a PDA (Personal Digital Assistant) was used as the task controller. PDA's display was used as Task Controller's user interface. According to the standard the user can select a task, start/stop/resume a task and modify a task et cetera. Task data defined by the user was collected on the handheld computer and then transferred to the management computer for verification and evaluation of the field work.

Task Controller should be easy to use, easy to connect to management computer of farm and inexpensive. That is why PDA was considered and chosen for the implementation of ISO 11783 Task Controller. Handheld computer makes data transfer from the field to management computer easy and no extra memory cards for transportation are needed. The handheld computer with built in WLAN was connected to the ISO 11783 network either with serial port or TCP/IP connection through the CAN adapter. CAN adapter was used to transfer process data messages to and from the ISO 11783 network.

Two PDA devices have been used as the Task Controller, HP iPAQ 5450 and rugged Itronix GoBook Q100. HP iPAQ was equipped with PocketPC 2003 and Itronix with PocketPC 2000. The software is written to support both operating systems.

4.5 Global positioning device

There were no commercial ISO 11783 compatible GPS receivers available when the project was started. A GPS adapter was made to supply the position information to the ISO 11783 network (for task controller). It reads the NMEA 0183 position information from a serial port and transmits it to the CAN-bus. The GPS adapter is based on Dallas Semiconductor's TINI board which is programmed with Java programming language. Two NMEA 0183 compatible GPS-receivers were used, Raven Invicta 115 and Haicom HI-202E.

As the tested PDAs don't have a CAN chip, the adapter is also used to connect it to the ISO 11783 network.

5. CONCLUSIONS

The standardization of the communication between tractor and implement gives many benefits. Only one user interface module is needed in tractor cabin, namely the Virtual Terminal. The information of tractor is available to implement controller as well as tractor's services (like the control of general purpose hydraulic valves giving hydraulic power to the implement). The amount of wires between tractor and implement is reduced. Precision farming information inside the vehicle is flexible and also the interface to the Farm Management Information System is standardized.

The Agrix Basic Prototype realized the ISO 11783 Implement ECU, Task Controller, GPS receiver and communication with the Virtual Terminal and Tractor ECU. Implement ECU can be said to be most complex part to implement in the ISO 11783 standard because it is ultimately responsible for coordinating tasks with other ECUs like Virtual Terminal and Task Controller.

Implement ECU functionality is not clearly specified in the standard, which makes it difficult to make an ISO 11783 compatible implement ECU. It has been also found that some parts of the standard are quite loose. For example there is left freedom for virtual terminal producer to make functions in several ways, which causes that the implement ECU has to be ready for all possible ways how to interact with Virtual Terminal. The two virtual terminals tested supported different functions, which lead to some double work in some parts of implement ECU. Actually all ISO 11783 devices have to be designed to handle all possible situations if full compatibility is wanted. More strict specification would limit the user interface developer, but give benefit in compatibility.

Since many agricultural machine producers have already announced to support ISO 11783, it is likely that ISO 11783 is the way of communication in agricultural machines in the near future.

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