Applications of the CAN and ISO 11783 protocols to a Planter Monitor

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Abstract: - Advances in computer technology and instrumentation have expanded the use of embedded systems in agricultural tractors and implements using controllers, actuators and sensors intercommunicating in real time. These applications will benefit of a standard communication protocol. However, it is not any protocol that will suffice. Certain properties of the agricultural environment lead to desirable features of the protocol, discussed in this paper.

A protocol that meets some of these requirements is the CAN (Controller Area Network) protocol, developed by the automotive industry and suitable for use in vehicles because of its robustness, flexibility and ease of implementation. The ISO 11783 proposal is an extension of the CAN protocol, but specialized for agricultural applications. It defines standards for cables, connectors, message types, message transfer mechanisms, operator interface and network topology. The implementation of these protocols is facilitated by the existence of commercial components.

This paper deals with the application of the CAN and ISO 11783 to the redesign of a planter monitor. A previous version of such equipment was implemented based on a proprietary protocol and on RS 232C standard.

A new architecture for the planter monitor using the protocols presented includes several sensor modules, a standard operator interface, a positioning system, a task computer, a maintenance computer and a management computer. The communication between these elements is made possible by using the CAN and ISO 11783 protocols.

The application of the presented protocols to the planter monitor is discussed, including comparisons concerning its current implementation.

Key-Words: - CAN, ISO 11783, planter monitor, communication protocol, distributed control, precision agriculture. *IMACS/IEEE CSCC'99 Proceedings,* Pages:4501-4506

1 Introduction

Nowadays, agriculture requires new monitoring and control equipment and embedded systems for agricultural tractors and implements.

Although only a few commercial systems have a distributed architecture, there is a trend toward this paradigm instead of the usual centralized architecture. The concept of intelligent instruments is one of the key reasons for this trend: instruments with embedded microprocessors providing the capabilities of self-calibration, self-diagnosis and local analog-to-digital and digital-to-analog conversion. The digital transmission of data also increases reliability due to automatic error detection and correction. These distributed systems are composed of several devices like sensors, actuators, control elements and supervision and control units, all of them intercommunicating in real time. In this context, the communication protocol plays a central role

2 Requirements of communication protocols in Agriculture

Some properties of the agricultural environment lead to some desirable features of the data network.

First, consider that the network will be installed on a moving vehicle, that is, a tractor and its implements. This means that the protocol, cables and connectors should be robust enough to withstand the effects of vibration, like wire rupture and poor connections.

Also, as the implements can be attached and unattached from a tractor, so the cables between them should be easy to plug and unplug. Of great importance here is the connector design.

Cables should be protected from the outdoor farm field environment, including humidity, extremes of temperature and dust. Also, the nature of agricultural processes includes exposure to chemical substances. Electrical interference is generated by other on-board equipment.

A big issue is the amount and complexity of wiring required to link the various on-board devices like sensors, actuators and controllers. A common approach is to have a different type of cable for each pair of devices, different types of connectors for each end of the cable and multiple cables leaving each device. Each analog and digital signal uses its own separate wire. This results in a great amount of wiring, making assembly and maintenance difficult and increasing the risk of failure due to cable damage and electrical interference. Thus, a digital network with a few cables shared by the various devices and with standardized connectors is desired.

Another issue is the incompatibility between devices and equipment of different manufacturers. The adoption of a common standard for communication would help in this case. The use of a digital network requires additional electronics in each device. This electronics should be small, of low cost and its parts should be easy to find in the market.

Finally, the communication speed and latency of the protocol should be appropriate for the application.

3 The CAN protocol [1][6]

The CAN protocol (Controller Area Network) was developed by the automotive industry, to support the communication of on-board equipment, in trucks and buses. Its good acceptance caused its adoption as a standard by SAE (Society of Automotive Engineers), and, later, by the ISO (International Organization for Standardization).

The CAN protocol was designed at first to be used in vehicle applications, so it is very suitable for use in agricultural tractors and implements (now it is also being used in factory automation). A single cable with two wires is used to link all modules, and extensive error detection and correction allows it to operate reliably in the agricultural environment.

The bit rate of the CAN protocol can reach 1Mbit/sec, the maximum bus length being 40m with a minimum of 10cm between nodes. Greater distances can be reached by slowing the bit rate. The cable, whose impedance is 120Ω, is terminated at each end by a resistor of this value.

In a CAN network, there is no need for a master to be polling slave nodes. Instead, any node can choose to talk at any instant, and simultaneous accesses are resolved by message priority.

The data carried in each message can be up to 8 bytes long, which is sufficient for most control and data messages. Besides the data field, each message contains an identifier field that indicates the type of information carried in the data, like position, velocity, seed count, etc. This field can also be used to indicate the priority and the source and destination addresses of the nodes involved.

However, the standard specifies how the information is exchanged with no regard to the format and type of information. Also, it does not describe the physical characteristics of the cables and connectors. Various protocols were thus created based on CAN, including the proposed ISO 11783, which is about to become a standard.

4 The ISO 11783 proposal [2][6]

The ISO 11783 proposal specifies a serial network for communication and control of agricultural vehicles (tractors) and its implements. This network, that follows the OSI layer model, has a bit rate of 250kbits/sec.

It uses the CAN protocol in its lower layers, with some differences in the physical layer. The voltage levels are different, the terminators in each end of the cable are powered instead of being passive and the cable has two extra wires conveying power to those terminators. Using active terminators can decrease errors, but existing CAN transceivers cannot be used.

The ISO 11783 proposal assigns the CAN identifier a priority field, a source address field, an optional destination address field and a Program Group Number (PGN) that identifies the contents of the message. PGNs are standardized by ISO, that maintains a global list of types of messages and their associated PGNs. This assures that devices from different manufactures can be compatible and even interchangeable.

An ISO 11783 network can have several segments, connected by bridges. The tractor segment links devices such as controllers for engine, transmission, brakes and lights of the tractor. One or more segments in the implements link the implement devices one to each other, and to the tractor. The reason for having a separate tractor segment is to protect the tractor electronics.

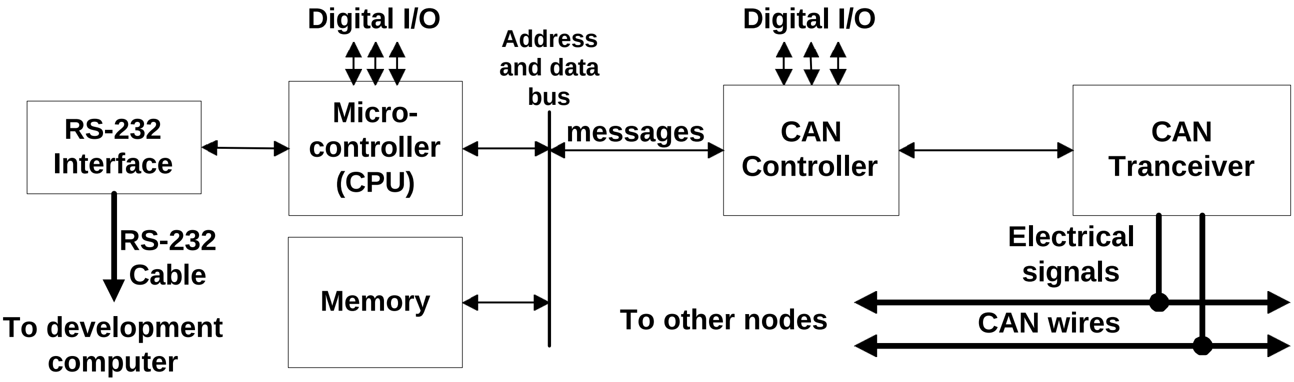

Fig 1 – Implementation of a CAN interface

In the ISO 11783 standard, the transport layer is responsible for packing and reassembling messages longer than 8 bytes, since this is the greatest number of bytes a frame can transport each time.

Each electronic node has a unique 8-bit address, which identifies it as the origin or destination of network messages. This address is dynamically assigned, being independent of the device function, and can even be different each time the device is turned on. This reduces the amount of node configuration.

The proposal still defines a standard for the operator interface by defining a "virtual terminal". Also, a task computer is provided to send control messages to the other devices and to record data for future analysis.

5 Implementation of the CAN and ISO 11783 protocols [6]

A typical CAN node, as shown in Fig. 1, has a CPU, digital and/or analog I/O, a CAN controller and a CAN transceiver. The CAN transceivers read and write bits from the CAN bus. The CAN controllers format data into frames to be transmitted, participate in bus arbitration, unpack received frames and detect errors. Some CAN controllers have an interface to microprocessors, while others are embedded in popular microcontrollers (which simplifies the project). In both cases, the CPU specifies the messages to be transmitted, is notified of the arrival of incoming messages and does not have to worry about the details of the protocol.

The slave I/O devices implement remote analog and digital I/O ports controlled by the CAN bus without the need for a CPU. For example, instead of having dozens of digital and analog signals transported in separated wires, only a CAN cable and various slave I/O devices can be used.

The implementation of the ISO 11783 proposal includes implementing the software layers of the protocol as described in the standard. It could be a difficult task if simple microcontrollers with little memory and low performance are used.

6 Applications

Previous applications of the CAN protocol in agriculture included a proposal for a patch sprayer that applies herbicide to the field according to an application map [5]. The devices linked to the CAN bus included an I/O interface with the operator, a ground speed sensor, a GPS, a computer that controls the system operation and computers that control the pumps and valves.

Also, an air seeder control system was implemented [3]. In this last case the ISO 11783 proposal was followed closely, using the connectors and cables specified and also including a virtual terminal.

6.1 The CAN interface developed

A CAN interface was designed and assembled (Fig. 1) using standard CAN components (controller and transceiver), an 8-bit microcontroller with 32K of embedded EPROM, 32K of RAM memory and a RS-232 interface. A CAN network based on a number of these boards is being tested. A CAN demo board with a slave I/O device is also being used in the tests.

Software and commands for the microcontroller can be downloaded by the RS-232 interface, and later this will also be possible to do using the CAN interface.

The board, that has digital I/O lines, can be used to control devices like sensors and actuators. It can also provide an interface to the CAN bus for devices that have a RS-232 interface, like GPS receivers.

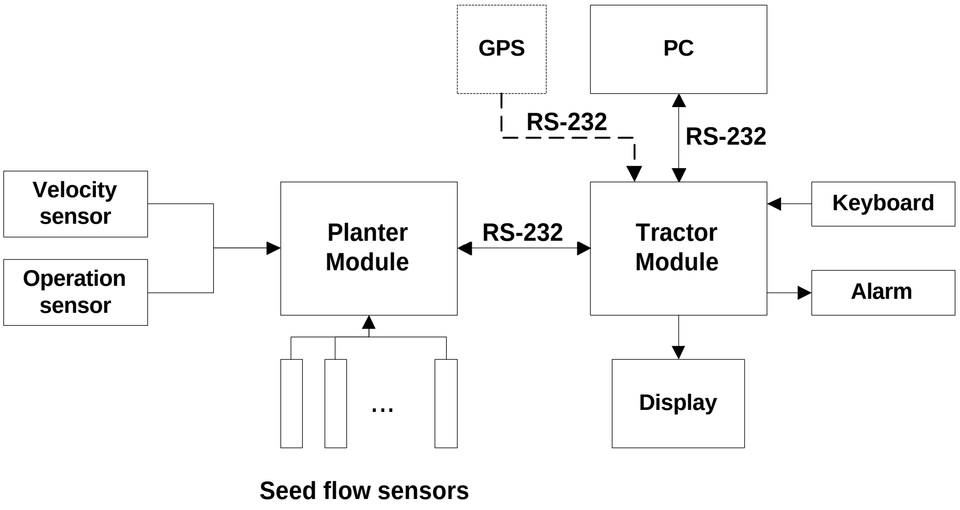

Fig 2 – Current architecture of the planter monitor

6.2 Application to a Planter Monitor

A first application of the CAN board developed is a planter monitor, that was designed in order to [4] performs the following functions:

- It shows its operator some useful information, such as seed rate, seed population, tractor speed, and planted field area.
- It warns its operator about fault operational conditions, such as seed rate out of range, planter out of operational position, and lack of communication between its modules.
- It stores operational statistical data, and sends them to a Personal Computer (PC), for further analysis.

6.2.1 Current Implementation [4]

The system, as shown in Fig. 2, includes sensors of seed flow, speed, and planter position. These sensors are read by the Remote Module, installed on the planter, which sends these data, through a serial link, to the Central Module, installed in the tractor cabin. The Central Module communicates with the operator through the keyboard, the display and the alarm. It can be also linked to an external PC, through a serial interface. The connection of a GPS receiver is being developed, so that the Central Module can also collect positional information and will allow the generation of a seed density map.

6.2.2 Limitations of the current implementation

In the first version designed, a proprietary protocol based on RS-232 was created. It is a simple protocol and easy to implement. However it is little expansible, because the addition of more planter modules would imply the use of more cables and more serial ports on the tractor module.

The RS-485 protocol was considered to replace the RS-232 in this application, because RS-485 uses a single cable shared by all devices. However, it forces the use of a master-slave relationship, the master having to periodically poll its slave devices, wasting bandwidth.

6.2.3 Comparison with a CAN and ISO 11783 implementation of the planter monitor

A redesign of the planter monitor using the CAN and ISO 11783 protocols is being made, aiming at comparing the performance and suitability of the current and new implementations.

A CAN implementation would have fewer cables and be more expansible and modular. The use of the ISO 11783 proposal would increase the compatibility with devices and systems of other designers, because of its standardization of message types and of the mechanisms of message transfer. This compatibility is not possible with the current proprietary protocol.

A decreased performance can be expected by using ISO 11783, because of the overhead in the additional software layers. Also, with a shared cable, the bandwidth is divided among all devices, which does not happen if a single cable between each pair of devices is used. However, the increased bit rate of the CAN protocol could compensate for this.

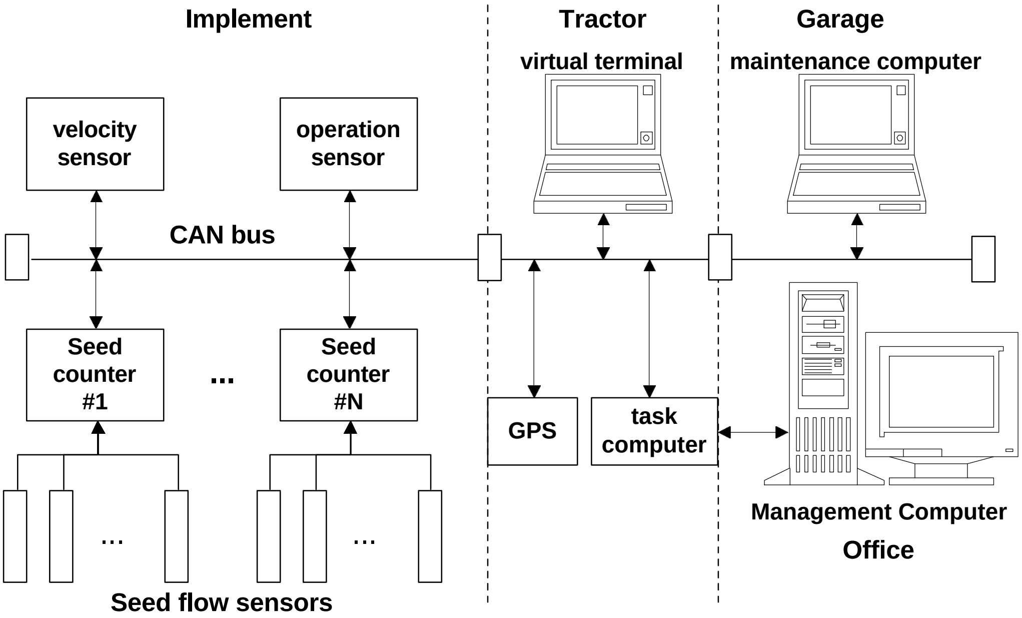

Fig 3 – Proposed architecture of the planter m

7 Future steps

We propose to modify the planter monitor to use the CAN and ISO 11783 protocols (Fig. 3). This will involve designing a new architecture for the planter monitor based on a CAN network. This implementation will be simulated using several of the CAN boards developed.

In the planter, we would have various independent modules, according to the sensor type and need of expansion. The information generated by the sensor modules and by the GPS would be available on the network, being used by the task computer to generate the planter map and by the virtual terminal to give information to the operator. In the garage, a management computer would obtain the stored map and statistics from the task computer. A maintenance computer could diagnose of the entire system by the CAN bus.

8 Conclusions

The proprietary protocol is simpler to implement, is suitable to the microcontrollers capacity and to the system demands, as it is now. However, the CAN and ISO 11783 protocols provide good extensibility, favor a modular approach and allow for interoperability between devices of several manufacturers.

The design of new systems with equipment mounted on tractors and implements has also been motivated by the increased interest in precision agriculture. These systems would benefit from a standard communication protocol as the one described in this paper.

A greater use of these protocols in new equipment for agricultural tractors and implements is expected. This equipment will have lower design and implementation costs, fewer cables, greater ease of maintenance. Compatibility between devices of different manufacturers will be increased.

The application of these standards in the planter monitor will provide a greater understanding of their performance and suitability, motivating their use in future equipment and projects.

References:

[1] ISO 11898; Road vehicles – Interchange of digital information - Controller area network (CAN) for high-speed communication; 1993.

[2] ISO 11783; Tractors, machinery for agriculture and forestry – Serial control and communications data network; parts 1 to 5, 1997

[3] Lang, F. Development of a CAN based air seeder control system. *Proceedings of the fourth International Conference on Precision Agriculture*, Saint Paul, 1998. (in print)

[4] Saraiva, A.M.; Paz, S.N.; Cugnasca, C.E. Improving a planter monitor with a GPS receiver. *Proceedings of the First European Conference on Precision Agriculture,* Warnick, UK, 1997. pp.321-7.

[5] Stafford, J.V.; Ambler, B. A CAN data bus application on a patch sprayer. *International Winter Meeting of the American Society of Agricultural Engineers*, Chicago, 1993. ASAE paper no 95-1534.

[6] Strauss, C.; Cugnasca, C.E.; Saraiva, A.M.; Paz, S.M. The ISO 11783 standard and its use in precision agriculture equipment. *Proceedings of the Fourth International Conference on Precision Agriculture*, Saint Paul, 1998. (in print)