Proposal of a CAN-Based Distributed Control System for Variable Rate Technology in Agricultural Machinery

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Abstract. *Modern agricultural technology is controlled by electronics. Therefore, machines and implements represent intelligent process units with the ability to communicate with other units. These machines and implements are equipped with electronic control units (ECUs) that are interconnected and shared data. This information exchange can originate a complex centralized system. To handle this problem the development of distributed control systems with a communication protocol is necessary. A major trend among the communication protocols for agricultural machinery is the Controller Area Network (CAN). This work presents the utilization proposal of a CAN-based distributed control to a Variable Rate Technology (VRT) system. The VRT system is composed by a tractor-implement that applies a desired rate of a crop production material at a specific time and location. The distributed system consists in three ECUs responsible to the control of the equipment. Two ECUs are located in the tractor with one responsible to the DGPS positioning and other to the RS232 communication with a computer that manages the system. The third ECU is located in the implement and integrates the hydraulic devices to do the variable application. The application map is read by the computer and the information is transmitted by the CAN bus to the ECU in the implement.*

Keywords*: Distributed Control Systems, CAN networks, Electronic Control Unit (ECU), Variable Rate Technology (VRT)*

1. INTRODUCTION

Precision Agriculture is whole of management's techniques and actions considering the variability of soil parameters and the farming behavior in a stand (Menegatti and Molin, 2004). The variability in a distribution of nutriments and inputs depends the experiences and dexterity of farmers. However, it's changed in last ten years, because the enlargement of farming and mechanization that's increasing yield through uniform inputs' application. The agricultural mechanization with the use of informatics and automation gives support to the growth of the Precision Agriculture (Godoy, 2007). In Precision Agriculture, is necessary electronics systems of data collection and applications systems of inputs for Variable Rate Technology (VRT). Consequently, whit the increase the automation in agricultural systems, for example, machinery and implements, greenhouse's control, has been a tendency of the adoption of solutions based in distributed systems with a network communication. The Controller Area Network (CAN) protocol shows high importance and its utilization in agricultural systems is internationally approved in Auernhammer and Speckmann (2006), Survinen and Saarilahti (2006) and nationally approved in Sousa (2002). Others results about this action, are affecting negatively the profitability of agricultural production and environment. For that reason below, arose the first research results and commercial products for machinery and implements using the technology to detect and map the agricultural variability. Nowadays this solution is known and divulged in large-scale as Precision Agriculture. The adoption of precision agriculture, not-only as electronic and information technology, but as concept, have a huge potential for rationalization of a modern agricultural production system due to: a) reduction of quantity of agricultural inputs applied in soil or stand; b) consequential decrease of production's costly and environment's contamination; c) agricultural management and yield map e d) better crop's quality. Thus, the precision agriculture attends the globalized market exigencies, witch require major volume of production, needs precise management of agricultural activity, demands low prices and comes up against techniques or technologies witch could contaminate or degrade the environment.

The soils correctives are fundamental inputs in agricultural exploration. The Brazilian soil is common has high acidity and this condition is unfavorable to plant. So, the correct input application assumes a important signification, in terns of soil fertility, yield and economics factors. This soil correction is typical in Brazil.

The efficiency of the inputs in the agricultural productive process is dependent of the inputs quality and the application way at soil. The occurrence of errors in one of the stages below, affects directly the agricultural yield.

The results in Balastreire and Coelho (1992) show the quantity of distributed inputs applied by spinner box, concentrated in the center in a transversal strip of land and going to decreasing the quantity from the center to border. Consequently is necessary to pass spinner box on the border again trying to reduce the no uniformity.

The advances in electronics and microelectronics components in last ten years provided agricultural machinery with high technology using Electronic Control Unit (ECU) (Guimarães, 2003). Using just one ECU can originate a complex and centralized system, besides the big quantity of cables from the ECU to all system. To handle this problem the development of a distributed communication protocol is necessary, which brings many advantages like robustness, reliable, reduce in the quantity of cables and facility to enlargement the system. The Controller Area Network (CAN) constitutes a good low level base for distributed real-time control system (Törngren, 1996). The CAN protocol (Bosch, 2006) was originally developed to interconnect electronic unites in automotive area, and recently has also been applied to agricultural automation with the ISO 11783 standard.

The proposal of this work is to develop a CAN-Based Distributed Control System for input's application using variable rate technology, this distributed system will be embed in a precision implement of soil corrective applicator with management concept and mount a test system conform, the system will be constitute of:

- Equipment for correctives and fertilizers distribution with trustful accuracy for localized application in Variable Rate Technology (VRT);
- PC embedded which responsible to process and collect data of machines variables and applicator sensor;
- CAN Bus which provides interconnections between sensors, actuators and ECUs (Electronic Control Unit);
- Management software for Precision Agriculture;
- Workbench of Test System Conform;
- In the process of VRT application, the system utilize prescription map digitally stored.

2 MATHERIAL AND METHODS

2.1 Research and Adaptation of Correctives and Fertilizers Applicator

The principal types of correctives and fertilizers machinery applicators are defined by its functionality, there are applicators which works whit gravity and which works with centrifuge force. The gravity machinery in Fig. 1 has the distribution of inputs by continuous fillets. The centrifuge forces machinery has the distribution by spinner box with individuals or conjugates lines, where the inputs application is performed by two kinds of distributors mechanism, one use pendulum and the other use centrifugal motors.

The gravity machinery presents major potential of uniform distribution transversal and longitudinal than the centrifuge forces machinery. For this reason, the prototype in Fig. 1 of gravity machinery will be adapted for VRT application. The characteristics of the prototype are good efficacy, great capacity to store inputs and have tires to avoid excess of soil compacting.

Figure 1. Prototype of the Gravity Machinery

The dosage system of inputs utilizes a rotational agitator which has the same width of the useful machinery width. The rotational agitator is above of the orifices in Fig. 2 and is composed by an endless spiral which the inputs pass thought out to soil.

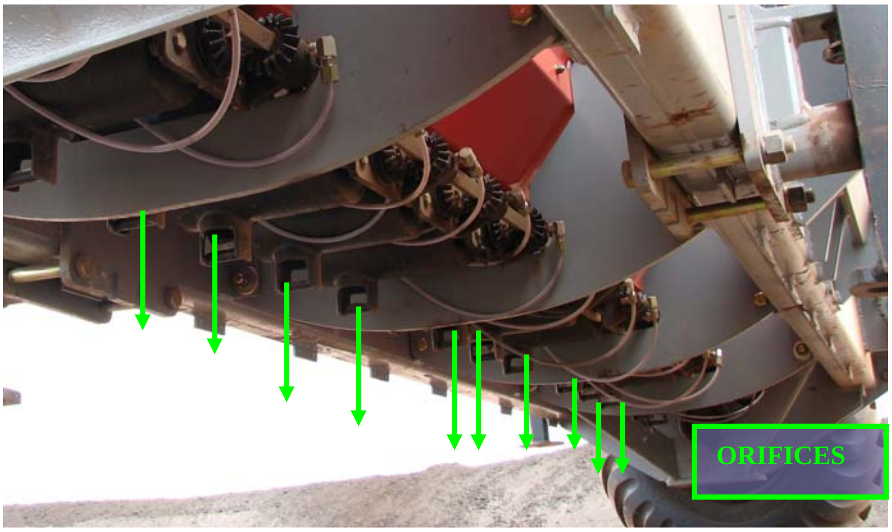


Figure 2. Orifices of the Gravity Machinery

The maximum rotation of the endless spiral in these orifices is going to produce the maximum flowing out of the input, as shown in Fig. 3. The opposite effect occurs when the rotation of the endless spiral equal to zero in these orifices is going to produce the flowing out equal to zero.

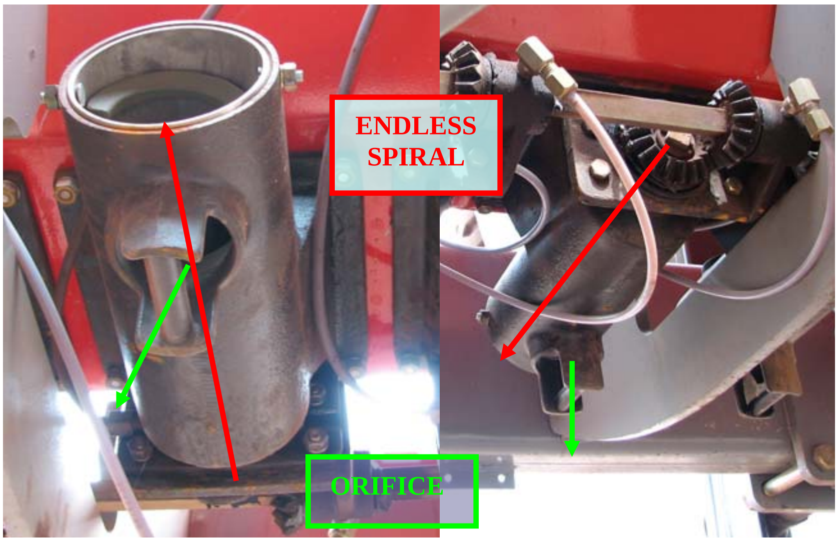


Figure 3. Orifices and Endless Spiral of the Gravity Machinery

2.2 Development of The Central Molude and Embedded Aplication

The central module is responsible for processing the algorithm that reads the recommendation map inserted in memory cards, reads the DGPS coordinates, sends variable dosage to the implement actuator by CAN bus and collecting data from application to build maps “as-applied”. Besides, the central module will log every temporal events of total system, since turn on the system to turn off system.

The central module is a PC embedded PC104 with 128MB of RAM memory, IDE and ISA bus, Ethernet, two serial ports RS232, LPT and VGA driver. According to this configuration, see Fig. 6, establish the follow architecture:

- IDE bus: connect a HD of 40GB to use VRT algorithm, which need 120MB.
- Windows XP Embedded: the operational system.
- Port COM1: serial port RS232 uses to connect to ECU1.
- VGA out: driver on board to video out and manager for touch screen.

2.3 Standard Board of CAN Device (ECU)

The CAN interface is based in Sousa (2002) and is responsible to the integration of sensors and actuators of this project. The CAN standard utilizes is 2.0B version with a bus speed of 250 kbit/s to transmit data. The utilization of microcontrollers, due to its availability on market, consequently, turns easy the implementation of the CAN-Based control system. The CAN node, see Fig. 4, has a microcontroller PIC18f258 of Microchip; a CAN Transceptor to realize the interface among the microcontroller and CAN bus; a RS232 Transceptor to realize the connection among ECU to PC embedded; and has a voltage regulator to transform the source from batteries in TTL level (0 – 5V).

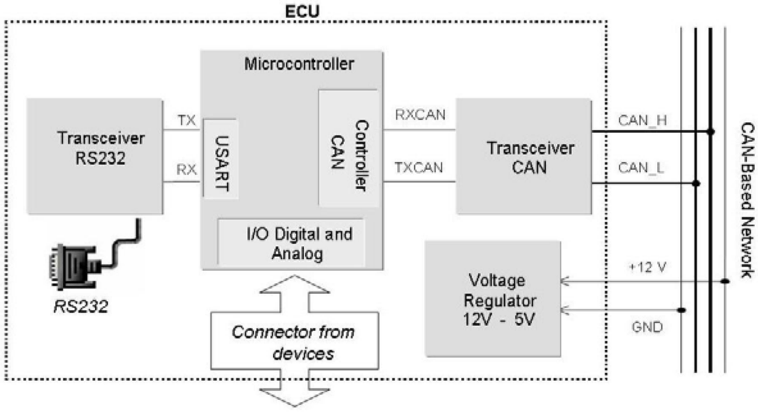
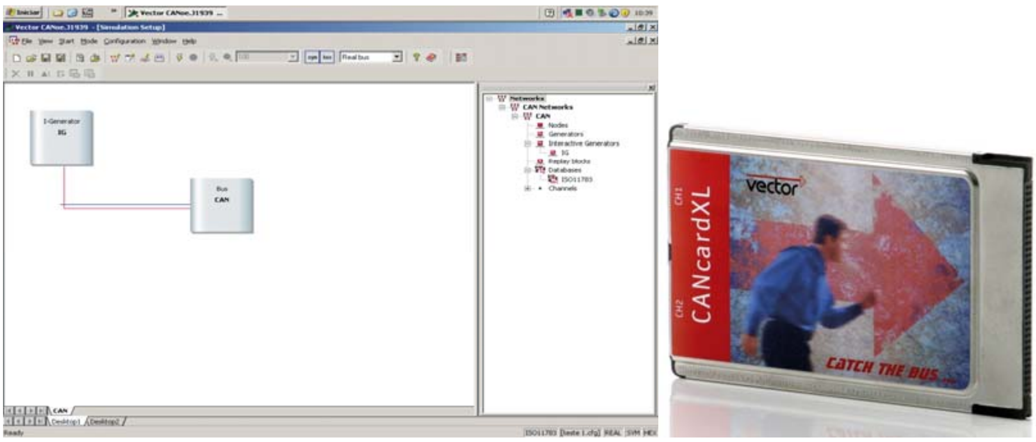


Figure 4. Schematic of the CAN interface (Sousa (2002))

2.4 Workbench of Test System Conform

The test system conform is composed by software and hardware of Vector CANtech, Inc (Ref. Vector), showed in Fig. 5. CANcardXL is a PCMCIA card compounding two channels, CH1 and CH2, which represent ECUs to plug and play at CAN bus. Through this physical connections at CAN bus, we can access, send and receive messages and manage the CAN network whit a powerful software tool, CANoe. Besides, we can create a simulation network, with virtual ECUs and bus as an distributed system that exits in an agricultural machinery.



(a) Software (b) Hardware

Figure 5. Software and Hardware (Vector CANtech)

3 RESULTS

3.1 Proposed CAN-Based Distributed System

In previously section, it was observed an agricultural machinery with a spinner box principle, but without VRT technology. To adapt VRT in machinery is necessary an electronic control, between at least three separated parts to originate a complex centralized control. In that case, is necessary a distributed system to control three parts, with a network communication. It chosen the CAN protocol, because is robust and trustful protocol in low level, and now is necessary an electronic CAN device. There is the work of Sousa, 2000, is a useful and cheap electronic CAN device. Now, the system demands a device to run VRT algorithm and to read, to process and to generate rate from prescription map with DGPS coordinates. It chosen embedded PC to hold this. The prescription map insert by memory card into embedded PC and remove after the work and analyze at farmer computer. To analyze how the algorithm works on the system is necessary a tool, it chosen CANoe software and CANcardXL hardware from VECTORtech (Fig. 5). The Figure 6 is the Proposed CAN-Based Distributed System.

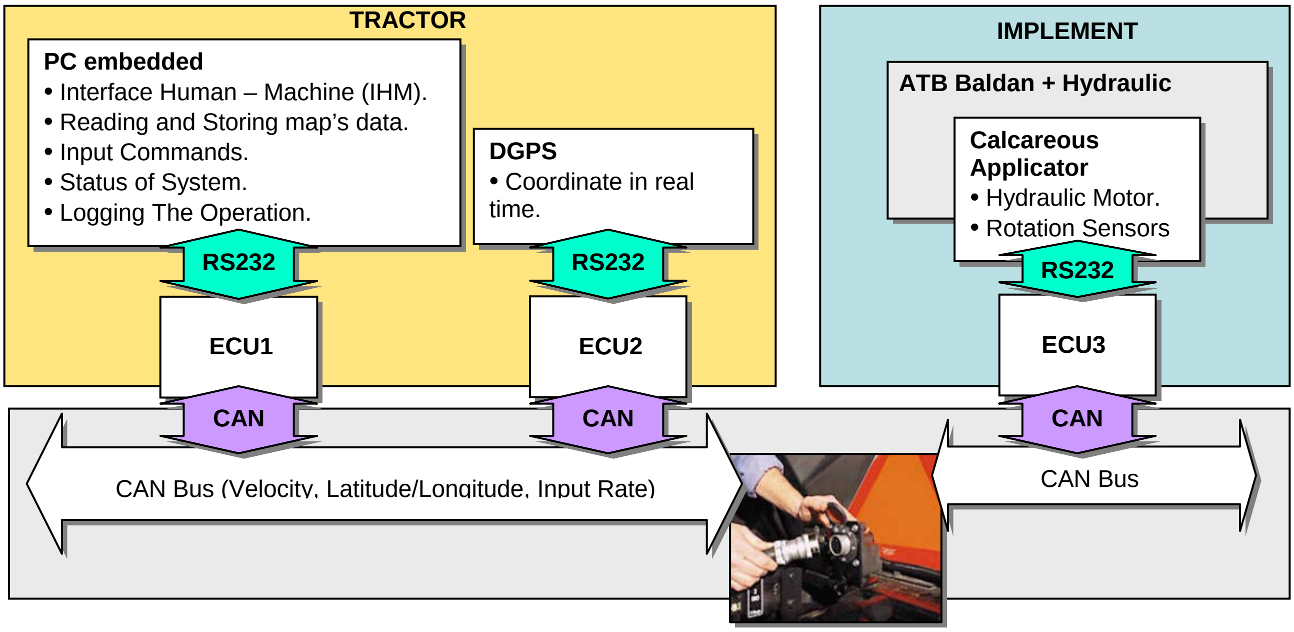


Figure 6. CAN-Based Distributed System for Agricultural Machinery

The rotation of endless spiral will be controlled by hydraulic system with couple action. The hydraulic system will be controlled by microprocessor system in ECU3 and the application rate is send to ECU3 by CAN bus from ECU1. ECU1 receive the application rate from PC Embedded by RS232 Serial Communication. The prescription map is record in PC Embedded, which process the map generating the application rate with geo reference (DGPS) transmitted by the DGPS integrated by ECU2, as shown in Fig. 6.

3.2 CAN Messages of The Proposed System

The CAN protocol has messages of ECUs initialization, data exchange and status during the process, as show in Table 1.

Table 1. CAN Messages based in ISO11783 Standard

Message	Type	Priority	PGN	PF	PS	SA	DLC	Data
Request for address claimed	Initialization	6	59 904	234	DA	SA	3	PGN 60938
Address claimed	Initialization	6	60 928	238	255	SA	8	NAME
Cannot claim source address	Initialization	6	60 928	255	255	254	8	NAME
*GPS	Coordinates	2	129 025	248	1	28	8	Latitude&Long.
Process Data	Communication	3	51 968	203	DA	SA	8	Data messages
ECU1 to ECU3	Communication	7	58 880	230	DA	SA	8	Control Byte
ECU3 to ECU1	Communication	7	59 136	231	DA	SA	8	Control Byte
ECU1 Message	Alive	7	58 880	230	DA	SA	8	Status
ECU3 Message	Alive	7	59 136	231	DA	SA	8	Status

*Defined on NMEA 2000 Standard, based on CAN Protocol.

The ISO11783 standard specifies a serial data network for control and communications, based on CAN 2.0B protocol. This specification is used on forestry or agricultural tractors and mounted, semi-mounted, towed or self-propelled implements. Its purpose is to standardize the method and format of transfer of data between sensor, actuators, control elements, and information storage and display units, whether mounted on, or part of, the tractor or implement. The ISO 11783 standard describes the implement messages application layer of the network, specifying the message set and defining the messages used for communication with and between tractors and connected implements. Based on ISO11783 standard, the Request for address claimed message may be transmitted by any ECU to request the NAME and address of any other ECU attached to the network. Upon its receipt, the receiving ECU shall respond with an address claimed message containing its address and its ECU NAME, while the ECU that is not able to claim an address shall respond with a cannot claim source address message. The exception to this requirement is the ECU that has not yet attempted to claim an address, which shall not send a cannot claim source address message, nor, in fact, participate in any network communications, before attempting to claim and an address. The Address claimed message may be used by an ECU either to respond to a Request for address claimed message or to claim an address on the network. It may be issued either during network initialization or when an ECU is added to a network in operation. If an ECU receives an Address claimed message claiming its own source address, it shall compare its own NAME with the one received and determine which NAME has the higher priority. If it determines it has the higher priority, the ECU shall transmit an Address claimed message containing its NAME and address. A Cannot claim source address message is transmitted by any ECU that cannot claim its preferred address and does not have the self-configurable addressing capability, or that has the self-configurable address capability but cannot claim an address because none is available for use. The message may be sent in response to a Request for address claimed or Address claimed message. The Process Data messages is used to send the rate for the VRT application from ECU1 to EC3, logging data from the total process and read the GPS messages to command the activation of actuators according the prescription map. The GPS messages are available on bus network. The ECU1 to ECU3 and ECU3 to ECU1 are messages used to configure and initialize the monitor ECU1 and implement ECU3. The ECU1 and ECU3 are status messages, to show and command the process by Human Machine Interface (HMI) on ECU1, like messages of alive.

4 CONCLUSION

With the development of this system, we expect these following results: Dispose a CAN-Based distributed system for calcareous applicator with VRT, which have low cost to build this system. Advantages to insert files at system by portable memory card and possibility to plug and play ECUs at CAN bus; National industry will capable to implement VRT technology and going to be prepared to accept the news worldwide tendencies of agricultural machinery; Also, increase the international competitive in agricultural machinery; The rational use of calcareous with odds to adaptation to others agricultural correctives and fertilizers. The farmers will save money and increase yield. Reduce aggression to the environment due rational use of inputs.

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