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Development of a Controller Area Network Based Handheld Data Acquisition System for Identity Preservation

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Abstract. *The development of a diverse, modular and portable system to accurately measure and record field operations is required to effectively bring identity preservation of crops to all farms and farmers. A demonstration system has been built based on a worldwide standard communications protocol and was evaluated for its ability to efficiently measure a variety of field operations and management practices. The CAN Bus 2.0B communication protocol was used to record GPS location data, ground speed and simulated spraying system data. This data was compiled and stored in a form that was compatible with multiple software programs for the purposes of economic and agronomic analysis. All data was recorded on a Compaq® IPAQ using specially-written*

software. Results showed that tracking identity preservation characteristics was feasible with this system.

Keywords. grain identity preservation, commodity tracking, controller area network, CAN Bus, microcontroller, grain handling, crop database

Introduction

Precision farming is a system that allows producers to record geo-referenced information including yield, inputs, seeding rates and other management data, and to use that spatial information to make site-specific economic and agronomic management decisions. Precision farming has revolutionized production agriculture, especially in the production of grain and cereal crops. Many farmers have seen results that include improved ease and quality of record keeping, increased yield, reduced input costs and enhanced conservation efforts (Wenzel, 2001). Parks (2001), a precision farming service provider, reports that the customers he serves usually see a $2 to $6 per acre increase in net profits for variable rate application of certain inputs, which is a result of an intensively managed precision farming system.

Precision farming spatial data could also be used not only to create application maps showing desired placement of inputs, but also to create a post application record of the applied variables. This detailed spatial record keeping can be a facilitator of identity preservation of field crops.

Identity preservation (IP) of field crops begins with compiling a database of recorded information that describes variety selection, agronomic practices and commodity handling. This data is then transferred with the commodity throughout the value chain. An IP marketing agreement allows customers and processors to choose specific product attributes, and the farmers can distribute products though a niche market, ideally for an economic premium (Reichert et al, 2000). An example of a specific product attribute might be the type and volume of liquid chemical and fertilizer inputs added to a field.

There are a number of commercially available systems that can monitor and collect information relative to liquid applications using a boom sprayer; however, these systems are primarily dedicated to a single vehicle. Usually, these vehicles are purchased new with the systems incorporated at the time of purchase. In addition, the commercially available systems do not record all data necessary for complete crop IP.

Objectives

The goal of this project was to propose and evaluate a field data collection system to facilitate transfer of IP information from the producer to commodity processors. This goal will be met through the following specific objectives:

- Design a modular controller area network communication system.
- Develop a universal electronic interfacing node that could be implemented in multiple locations on a vehicle to collect pertinent data.
- Link the interfacing nodes to a data collection unit via a CAN bus
- Demonstrate the utility of the data collection system for a field operation

System Description

The authors have chosen to focus on agricultural field spraying as the demonstration system for the IP data collection system for several reasons. The use of chemicals in agricultural

production is a highly emotional issue, and consumers may be willing to pay a premium for assurances about chemical usage during production of the purchased product. Spraying also provides many operational parameters to measure thus making it easier to verify the robustness of the data collection system. The parameters to be monitored include fluid pressure, fluid flow, mechanical rotational speed, digital valve control commands, global positioning system (GPS) information, and application material (chemical) identification. The accurate collection of this information will provide a positive first step toward a total commodity identity preservation system.

To provide flexibility across unique application machines and to make IP available to farmers that do not have equipment already equipped with a data bus, the authors have developed an experimental system that utilizes a Controller Area Network (CAN) Bus to collect and transfer digital data into a storage device. The University of Kentucky Crop Identity Database System (UK-CIDS) is a flexible system that can be moved to different vehicles and implements to acquire and compile desired operation parameters.

In the UK-CIDS design, Electronic Control Units (ECUs) were placed at each critical data collection point, referred to as a node, located along a vehicle to act as the data acquisition and CAN Bus transmission unit. Multiple ECUs were linked to each other and to a single handheld data storage unit with the CAN bus.

The CAN Bus hardware used in this study, consisted of a four wire twisted quad cable used to transmit CAN messages as well as an additional two wire cable used to supply operational power to the ECUs. The bus provided a high level of noise immunity, because noise in the system occurred on both communication lines but did not affect the relative voltage potential between the two serial data lines. The bus ends were terminated using standard terminator defined by ISO 11783 (ISO, 1998). Bus voltage levels adopted from the ISO 11783 standard were 2.5 V on both communication wires in the dominant state, and 1.5 and 3.5 V on CAN Low and CAN High, respectively in the recessive state (Fig. 1). The number of ECUs on the entire bus system was limited to 254 to stay within the current proposed limits of ISO 11783.

The Bus data transmission speed was set at 250 kbits/sec. Hofstee (1999) showed this data speed is sufficient for transmitting large amounts of information along a vehicle bus while maintaining message latency times less than 6 msec on average. The CAN 2.0B protocol has been followed for all ECU communication. This protocol dictates a 29-bit identifier at the beginning of each message, and facilitates automatic message arbitration, which ensures high priority data are transferred with a minimal latency time. Further detail on specific information related to the CAN bus operation should be referred to the CAN 2.0B Protocol (Bosch, 1991).

Each ECU has been designed to act as a multipurpose communication node. The processor used on each node in this study was an 18F258 programmable interface chip produced by Microchip®[1]. This microprocessor contained hardware CAN ports, analog to digital converters, counter/timers, and serial ports that were essential to data collection. A 20.000 MHz crystal oscillator provided clock timing for the microcontroller. This oscillator speed created bit timing well in excess of the 250 kbits/sec communication speed. A CAN transceiver (model MCP2551 by Microchip®) was interfaced in each ECU and provided proper level shifting from the TTL supplied by the microcontroller to the differential voltage found on the CAN Bus. Voltage regulators in each ECU powered sensors and other signal conditioning circuits when needed.

[1] Mention of trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the University of Kentucky and does not imply the approval of the named product or the exclusion of other products that may be suitable.

Since the handheld data collection unit data did not have CAN communication capability, a CAN to RS232 Bridge was designed and constructed. The function of the bridge node was simply to receive all messages from the CAN Bus, which operates 250 kbits/sec, and retransmit the message via a RS232 link to the handheld data collection unit at a rate of 256 kbits/sec. The bridge ensured that the CAN receive buffers would not overflow with incoming messages by transmitting the message at a bit rate faster than the incoming messages. While this node was operated from the same microcontroller base as all other nodes along the data bus, it contained a 16.384 MHz oscillator to create the serial bit timing of 256 kbits/sec. The CAN message was retransmitted via RS232 beginning with a leading identifier ($) followed by the source address of the message and then the eight message data bytes. The message was delineated by commas and terminated with an ending identifier (#). Table 1 provides an example of a retransmitted message.

Table 1: CAN-RS232 Bridge Message Retransmission

Source Address	10
Data Byte 0	134
Data Byte 1	24
Data Byte 2	56
Data Byte 3	64
Data Byte 4	0
Data Byte 5	0
Data Byte 6	0
Data Byte 7	0

#10,134,24,56,64,0,0,0,0$

A Compaq® IPAQ was used as the data collection and user interface device for this study. The IPAQ received all UK-CIDS messages into the serial data input buffer through the CAN-RS232 Bridge node. A software program was developed to decode the messages after reception from the bridge node. The messages were then individually time-stamped, dated, and stored in a comma-delineated text file. The text file was exported from the IPAQ through the memory card expansion slot or loaded to a desktop computer through a syncing process. Once imported to a desktop computer, it was quickly imported into any database program.

PIC Basic Pro® (MicroEngineering Labs, Colorado Springs, CO) was used to write and compile the machine code to operate the microcontrollers. An EPIC® (MicroEngineering Labs, Colorado Springs, CO) programmer was used to load the hex file into the Flash memory of the microcontroller. The software program that operated on the IPAQ and stored the UK-CIDS messages was developed within Microsoft® Embedded Visual Basic 3.0.

Results and Discussion

A modular ECU was created based on the criteria set forth in the system description. Initial tests were developed to identify the ruggedness and repeatability of the CAN based communication system. A series of ten ECUs were interfaced with various sensors and linked together over a CAN bus. The message transmissions were logged via a CAN-RS232 bridge onto a Compaq® IPAQ, thus modeling the final system. The ECUs were tested for 24 hours at a known message transmission frequency of one hertz. Post processing of the recorded transmission data revealed zero transmission errors occurred over the 24-hour test.

Problems did occur with the CAN transceivers when several nodes were linked and operating sensors. The current draw through the system exceeded the specifications of the transceiver chip and required an additional voltage regulator to create an isolated power supply for the transceiver in each ECU.

The sprayer system concept that was the focus of this study (Fig. 4) utilized a positive displacement pump along with a pressure regulator to deliver a specified fluid amount. As discussed above, several sensors were added to the data acquisition system design to develop a profile of the application process.

Field testing of the CAN data collection system was performed using the University of Kentucky Autonomous Tractor (UKAT) as a test bed (Fig. 5). The vehicle was modified to operate via a CAN bus distributed control system. The vehicle was programmed to maneuver a standard field layout. A 10 meter boom width and no intentional overlap were used for this simulation. The table 2 defines each node that was used on the CAN bus for sprayer simulation. The nodes produced a total of 13 messages per second. With an average message length of 120 bits and a transmission rate of 250 kbits/sec the total bus load of less than 1%. This provided a significant amount of expandability within the system.

Table 2: UK-CIDS Simulation Messages

Message	Number of Nodes	Transmission Frequency	Total Messages per Second
Material Identification	1	1 Hz	1
Sensor One	1	3 Hz	3
Sensor Two	1	3 Hz	3
Transmission Speed	1	1 Hz	1
Digital Valve Setting	1	4 Hz	4
GPS Message	1	1 Hz	1
Total			13

The material identification, sensors, and digital valve settings for this project are mimicked by linking a radio controller with a CAN bus node. A RC transmitter, similar to those used for unmanned air vehicle controls, transmitted the four individual signals to a RC receiver. The receiver then passed the individual messages along to a CAN bus node. One digital signal was used to determine whether the simulated boom valves were in the on or off position. Another digital signal was used to determine whether material A or material B was being applied. The

remaining two input channels provided proportional signals, which simulate the varying analog signal from an actual sensor.

The CAN-RS232 bridge was able to effectively pass all ECU data into the serial receive buffer of the Compaq® IPAQ. The IPAQ quickly decoded the data string and stored the messages in a comma-delineated file as described above. The text file easily converted into several available database and spreadsheet programs seamlessly, including Microsoft® Excel, Microsoft® Access, and ESRI® ArcMap.

With the development of a modular CAN based data acquisition system for identity preservation and agronomic inputs, the authors were able to analyze the compiled information and begin to predict where potential problems and risk in the food chain may occur. GPS location information and digital valve settings of the simulated test are used to create a vehicle field-tracking map (Fig. 6). The 10 meter boom width was then applied to the UKAT position data to create a field application map (Fig. 7). The field application map clearly showed areas within the field that were subjected to inconsistent spray patterns. Further GIS analysis was completed to identify areas of the field subjected to over application and areas where no chemical was applied (Fig. 8).

The GIS analysis was able determine the amount of chemical applied at each point within the field based on the GPS position of the vehicle, the known boom width, and the digital on/off setting of the simulate flow valve. By also incorporating the application material, the crop locations that posed a risk due to over application of chemicals were easily identified.

Conclusions

This study proved that a modular controller area network data acquisition system could be used as the backbone for an identity preservation database. Generic electronic control units could be interfaced to specific sensors to provide real-time application data to a modular, central data collection source. It also proved that a sufficient CAN-RS232 bridge could be developed to transfer high-speed controller area network messages into computer friendly RS232 messages.

The IPAQ personal data assistant proved to be a rugged and reliable means to receive, decode, and store the incoming field operation data. Comma-delineated text files proved to be an effective means to store the bus data and transfer it into a database for further analysis. The application of this technology to agricultural vehicles through a simulated agricultural sprayer confirmed the system is capable of designating areas where crop treatments are inconsistent.

Acknowledgements

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Appendix A: Figures

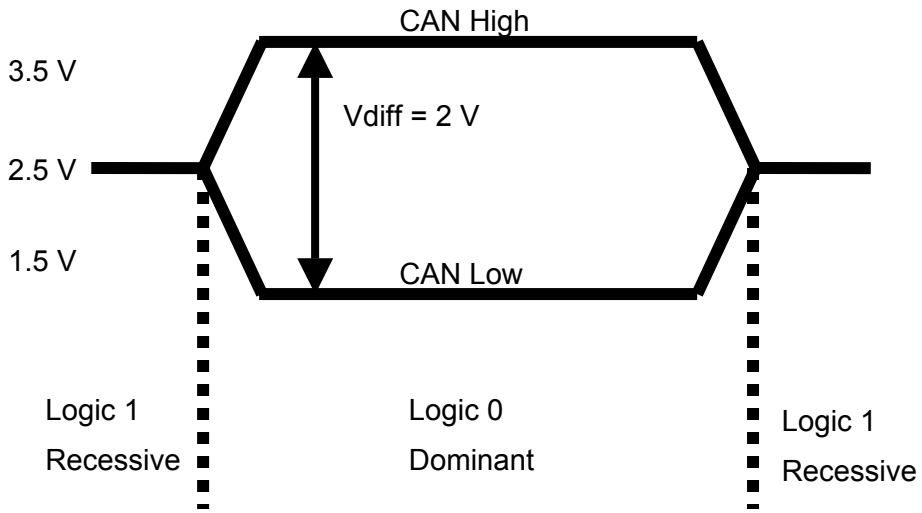

Figure 1: Controller Area Network Bus Logic

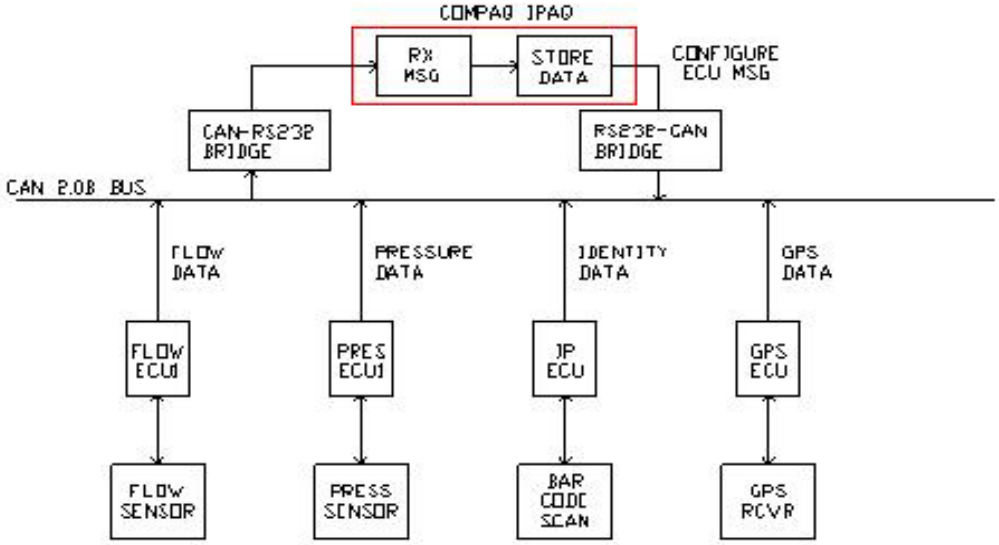

Figure 2: UK-CIDS Bus Topology

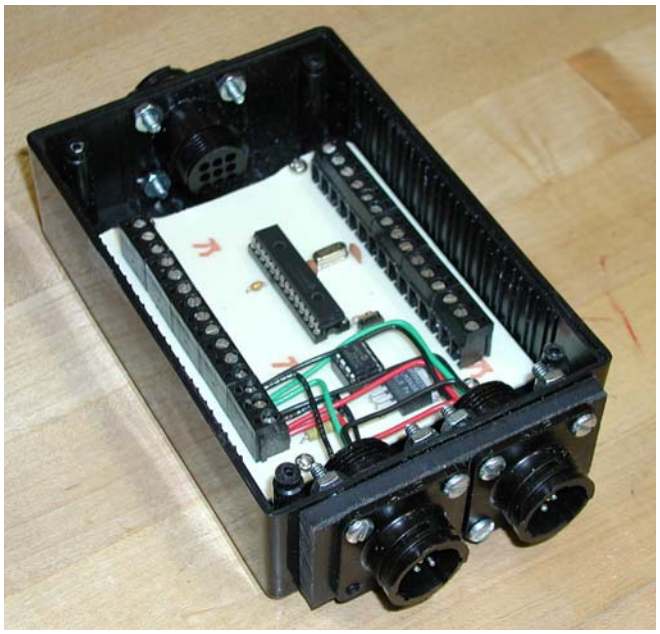

Figure 3: Electronic Control Unit

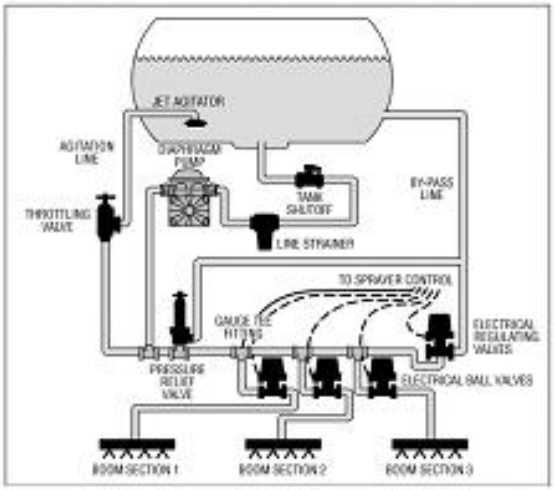

Figure 4: Spray System Topology

Figure 5: UK-CIDS Simulation Vehicle

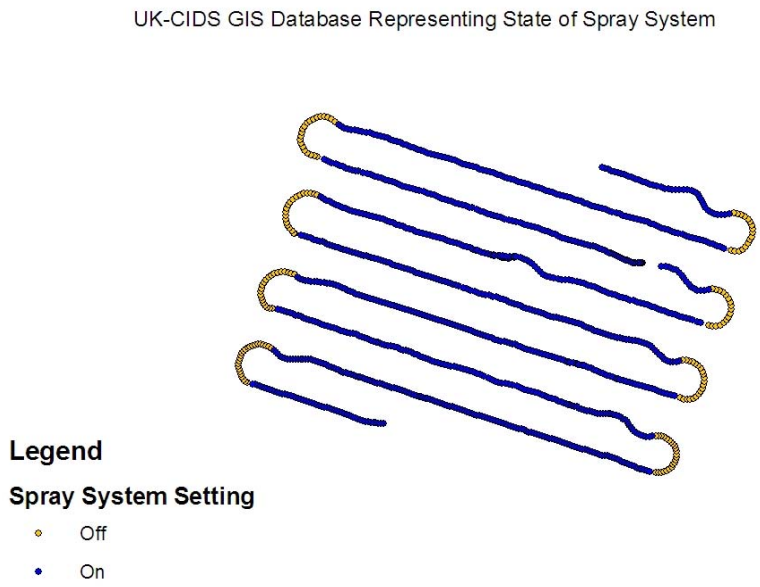

Figure 6: Field Tracking Map

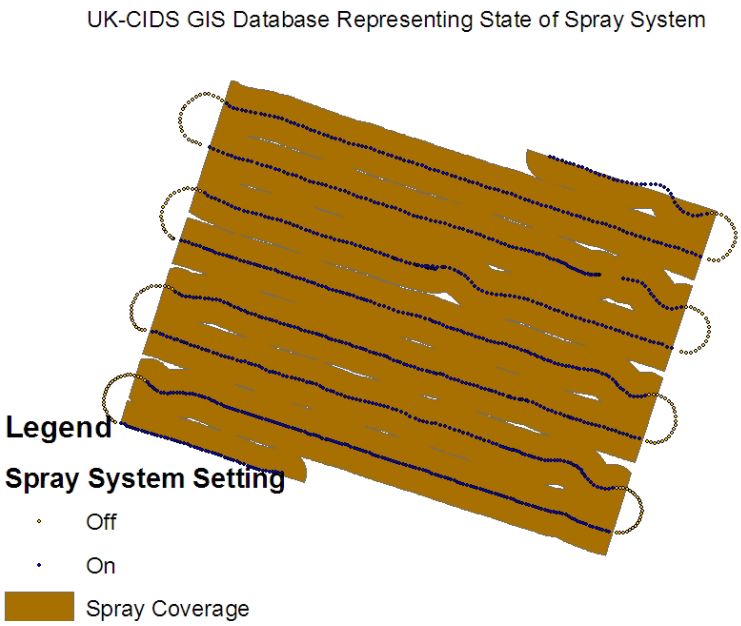

Figure 7: Field Application Map

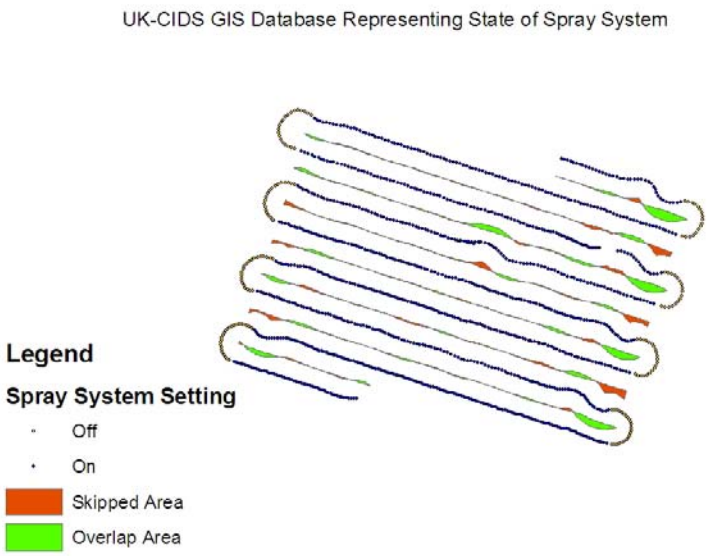

Figure 8: Field Coverage Error Map