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Implementation of Wireless PGN Analyzer for ISOBUS network

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Abstract

Communication between ECUs (Electronic Control Units) in agricultural machineries tends to use ISO11783 widely, that is PGN (Parameter Group Number) based communication protocol lays on CAN protocol by altering its identifier part. Messages in line are transferred and received between ECUs according to ISO11783 standard. This paper discusses about design of wireless monitoring system. We used an ARM Cortex-M3 microcontroller embedded development board and marvel8686 wireless module. The wireless ISOBUS monitoring system, attached to communication line, reads messages, interpret them, and display them on the screen in easily comprehendible form. It can be used to generate messages and monitor the traffic on physical bus systems. The monitoring system connected to ECUs, monitor and simulate real traffic of communication and functionality of the ECUs. In order to support our work, we have implemented the monitoring tool. The development consists of two parts: GUI of the application and firmware level programming. Hence the monitoring system is attached to the communication line and equipped by Wi-Fi module; farmer/dispatcher in a farm monitors all messages in communication line on personal computer and smart device.袥

Keywords : ISO11783, PGN, CAN, Wi-Fi, ARM Cortex-M3

Ⅰ. INTRODUCTION

Agricultural machinery control is an interdisciplinary field of study concerning the integration of mechanics, electronics, and software engineering expertise. Today a new generation of tractors exists with capabilities so advanced they can be assumed in many of the roles and responsibilities once entrusted to their human counterparts. This evolution in tractors is the direct result of continuing research advancements among its constituent disciplines. The ISO 11783 ~ standard has and, continues to be, an active area of research within the agricultural engineering community.

The ISO 11783 standard was jointly developed by tractor and implements manufacturers including the AGCO Corporation, AGROCOM, DICKEY-Jonh Corporation, Deere & Company, and Müller-Elektronik [22]. These manufacturers have also created a specification defining how this standard should be recognized. This specification is commonly known as ISOBUS. All packets, except for the request PGN and address claim packets, contain eight bytes of data and standard header which contains an index called parameter group number (PGN), which is embedded in the CAN message's 29-bit identifier [1-3]. A PGN identifies a message's function and associated data [4-6]. To implement and develop the networked tractor system we need to analyze and control all messages in communication line.

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This paper is organized as follows: In section 2, 3, 4 and 5, we have described an overview of standards, test environment, embedded workbench applications, workbench results and discussion, respectively. Finally, conclusions are presented in section 6.

Ⅱ. An Overview of Standards

The ISO 11783 is a new standard for electronic communications protocol for tractors and machinery in agriculture and forestry. This ISO 11783 standard is sometimes called as ISOBUS [1]-[2]. The network has messages defined to allow communications between any of the components, like communication between the Virtual Terminal, the Task Controller, the GPS ECU and other ECUs.

It consists of several parts: general standard for mobile data communication, physical layer, data link layer, network layer, network management, virtual terminal, implement messages applications layer, power train messages, tractor ECU, task controller and management information system for data interchange, mobile data element dictionary, diagnostic and file server. The structure of electronic data communication according to ISO 11783 is based on the open system interconnect (OSI) model layers, however, the higher functional layers sometimes defined differently.

The purpose of ISO 11783 is to provide an open, interconnected system for on-board electronic systems. It is intended to enable electronic control units (ECUs) to communicate with each other, providing a standardized system. The tractor ECU shall have at least one node for connection to the implement bus.

For this purpose we implemented ISOBUS PGN analyzer in the previous work. When a PGN analyzer reads data from the ISOBUS it needs to know how to interpret what it is seeing and display the output in an easy to read format. It can be used to generate and monitor the traffic on physical bus systems. In order to support our work, we have implemented the PGN analyzer tool for personal computer. To advance our PGN analyzer we developed web based application in STM32F103 development board with wireless module for smart devices. The general architecture of our development system is shown in figure 1.

Development of analyzer consists of three parts: GUI of application in personal computer, web based application in development board and firmware level programming.

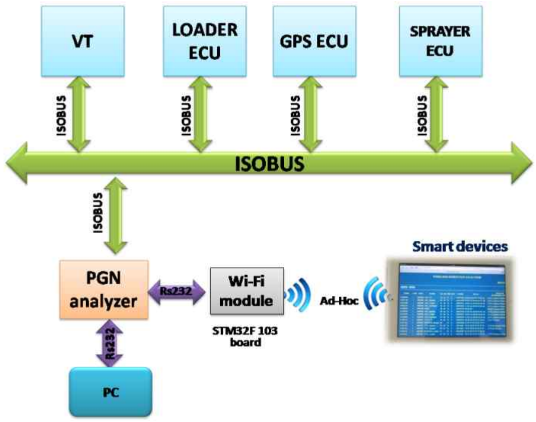

Fig. 1. Threshold-based illumination compensation algorithm for face tracking

Ⅲ. Hardware Design of ISOBUS PGN Analyzer

The PGN analyzer is implemented on the embedded board it's main CPU is 32 bit, 72MHz CortexM3 cored STM32F107 development board with two CAN interfaces. Once development board of analyzer has two serial interfaces we use one serial interface for the communication between the analyzer and application program in PC and communication between analyzer and wi-fi development board for smart devices. The CAN1 channel is used to monitor the ISOBUS. However, CAN2 channel can be used as well, if there is need of monitoring two ISOBUSs. The status information of the PGN analyzer is depicted on the LCD display of the board. We can see the appearance of the PGN analyzer in the Fig. 2. Here ISOBUS connected PGN analyzer and sample ECUs are depicted. We implemented sample ECUs, for example: GPS sensor, lighting, sprayer, tractor ECU and VT.

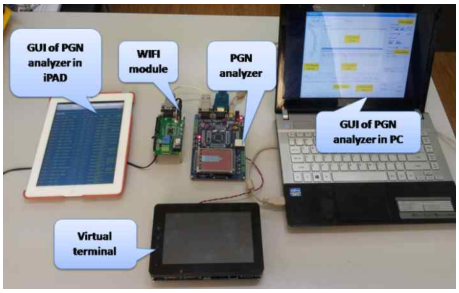

Figure 2. PGN analyzer connected with ISOBUS ECUs

Ⅳ. Firmware Level Programming

For the application program of GPS sensor, we used an open source programming library named ISOAgLib. The IsoAgLib is a C++ library in development of ISO 11783 standard applications in an Object Oriented way to serve as a software layer between application specific program and communication protocol details. The author of IsoAgLib library, Dipl. - Inform. Achim Spangler, licensed with exceptions under the terms of the GNU General Public License (GPL). The simple function calls for jobs like starting a measuring program for a process data value on a remote ECU, the main program has not to deal with single CAN message formatting. This way communication problem between ECU's which use this library should be prevented. The IsoAgLib has a modular design pursuant to the various functional components of the standard ISO 11783. The library has this design to make sure the minimum use of IsoAgLib in program memory of Implement ECU. The IsoAgLib demonstrates the layered architecture to be easily familiar with new hardware platforms. Most of the software can be used without alteration on all platforms. The layered architecture is described by the diagram in Figure 3.

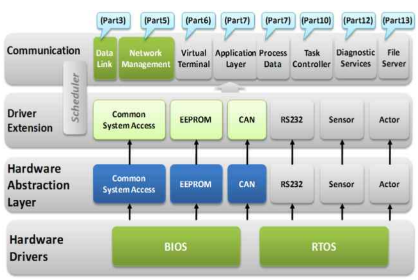

Figure 3. System architecture of embedded workbench applications

The IsoAgLib was developed to be suitable with different systems, and these systems can be an element of processor, memory, Human Machine Interface (HMI) and interface with the CAN bus. Therefore, the IsoAgLib is divided into two sections: the library itself and HAL. The HAL is responsible for communicating with the operating system (OS) or BIOS device that is running the application, as can be seen in Fig.3. We implement CAN-bus in real-time operating system. Here the application program initialized CAN controller and accessing CAN-bus.

The hardware programming is implemented in the firmware level. The Fig. 4 shows the main structure of firmware level program. PGN analyzer's firmware program has been five main functions:

- Receive data from the personal computer via RS232 and the ISOBUS via CAN interface
- Processing received data both RS232 and CAN interface
- Processed data send to the personal computer via RS232 and the ISOBUS via CAN interface
- Processed data send to the wi-fi development board via RS232 interface
- Wifi development board display processed data in web based application for smart devices

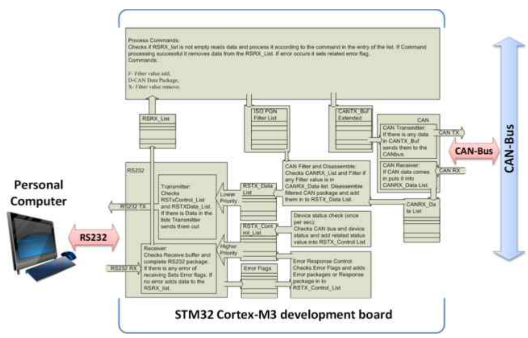

Figure 4. Main algorithm of the buffering method between RS232 and CAN–bus

Receiver side recognizes and accumulates RS232 data into one CAN packet. Application program and firmware program has the predefined structure of data sequence to send and receive CAN package, control and status data.

Receiving part of the firmware program's RS232 data sequence recognition and accumulation process is shown in the Fig.5.

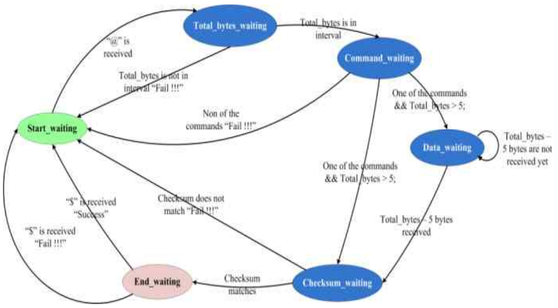

Figure 5. State machine diagram of PGN analyzer

There are six steps, we can see from the Fig.4; start waiting, total bytes waiting, command waiting, data waiting, checksum waiting and end waiting.

During RS232 data sequence receiving function, the Cortex-M3 CPU monitors via SYSTICK time counting value, in order to recognize data loss from the PC. The waiting time is 200 ms, which is allowed to wait for the next expectable byte. If there no byte is received anymore in 200ms, receiving status shifts in to start_waiting state and losses all the in complete bytes that are received yet. The CAN receiver receives and checks the CAN packet from the CAN1 peripheral of the STM32F107 which is allowed to be sent to the PC by filtering with the PGN values in the filter list.

If the packet is allowed, it is repackaged into RS232 data sequence to be sent to the PC: adding head and tail of the sequence (‘@’and ‘$’), command (‘T’), number of total bytes and checksum.

Another function of the firmware is to inform the status of the hardware to the application program via RS232 per second. It sends the status with command ‘L’ (device is alive-status) per second. Therefore, application program can easily recognize whether the hardware is functioning or not at moment.

Ⅴ. Graphical User Interface of PGN Analyzer

There are two graphic user interfaces. One is dedicated for the personal computer which is implemented in the Borland Delphi 7.0 environment with the object oriented Pascal language. Another GUI is for smart or mobile device is developed in HTML5. Delphi is effective to develop this kind of system, because it has rapid application development (RAD) interface and good tool to help against the developing mistakes which cause understanding problems.

The GUI of PGN analyzer program’s backbone some application programs running for parsing RS232 serial data to convert CAN packet and reverse procedure. We used the CAN server, CAN messenger, and CAN logalizer console application tools for parsing CAN packets, those original made from the IsoAglib. In this parsing procedure using named pipes to connect a GUI to a console application in windows environment.

Named pipes allow two processes to share data bi-directionally synchronously or asynchronously. This makes them ideal for putting a GUI front-end on a console application. Software developers usually provide a rich GUI to easily run an application in a desktop environment. However, users sometimes prefer a console application that typically provides access to the fullest range of application options via console interface and may be composed into a pipeline of user interface-less processing steps. The Fig. 6 illustrates received CAN packet parsing procedure until GUI. We capture serial data from RS232 interface then convert to CAN messenger in understandable format.

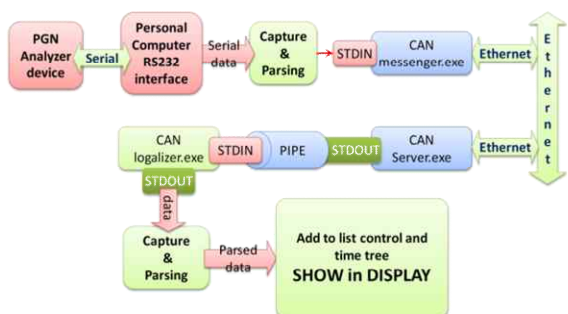

Figure 6. Received CAN packet parsing procedure shown in GUI

The CAN messenger sends to the CAN server by using Ethernet network. The CAN server console application program’s standard output connected the virtual pipe. The pipe connected to CAN logalizer console application's standard input. The logalizer analysis standard input data and interpreting user understandable format. Finaly, those interpreted data parsed then add to list control and tree control.

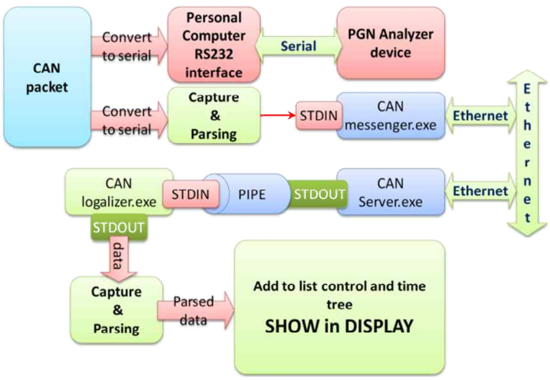

Figure 7. Transmitted CAN packet shown in GUI

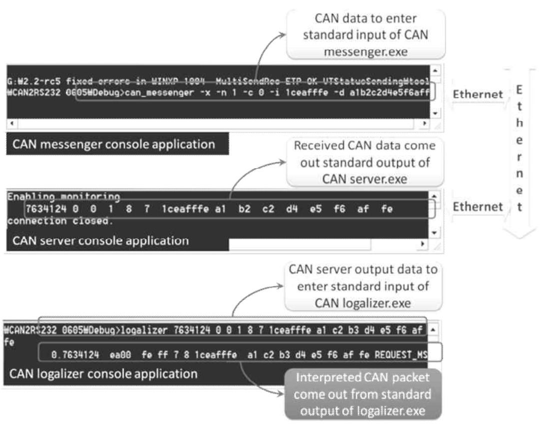

Figure 8. CAN packet parsing and interpreting procedure in the command line

Transmitting procedure is similarly the receiving in GUI. The Fig.7 and 8 are shown in the block diagram of transmission procedure for PGN analyzer. The sample received CAN packets interprets is shown in the Fig.9.

Time	PGN	Src	Dest	Prio	Dlc	ID	D0	D1	D2	D3	D4	D5	D6	D7	ISO11783 Interpretation
0.0033234	f801	80	FF	2	8	09f80180	89	33	b1	1c	57	0c	e3	06	NMEA_GPS_POSITI...
0.0033437	f801	80	FF	2	8	09f80180	89	33	b1	1c	57	0c	e3	06	NMEA_GPS_POSITI...
0.0033625	f801	80	FF	2	8	09f80180	89	33	b1	1c	57	0c	e3	06	NMEA_GPS_POSITI...
0.0033734	f801	80	FF	2	8	09f80180	89	33	b1	1c	57	0c	e3	06	NMEA_GPS_POSITI...
0.0033937	f801	80	FF	2	8	09f80180	4c	31	b1	1c	75	e7	e2	06	NMEA_GPS_POSITI...
0.0034125	f801	80	FF	2	8	09f80180	4c	31	b1	1c	75	e7	e2	06	NMEA_GPS_POSITI...
0.0034234	f801	80	FF	2	8	09f80180	4c	31	b1	1c	75	e7	e2	06	NMEA_GPS_POSITI...
0.0034437	f801	80	FF	2	8	09f80180	4c	31	b1	1c	75	e7	e2	06	NMEA_GPS_POSITI...
0.0034625	f801	80	FF	2	8	09f80180	4c	31	b1	1c	75	e7	e2	06	NMEA_GPS_POSITI...
0.0034734	f801	80	FF	2	8	09f80180	4c	31	b1	1c	75	e7	e2	06	NMEA_GPS_POSITI...
0.0034937	f801	80	FF	2	8	09f80180	e7	07	b1	1c	6e	e2	e2	06	NMEA_GPS_POSITI...

Figure 9. Sample captured data fromour PGN analyzer device

The GUI software of personal computer is written in object oriented Pascal only runs under the Windows operational system, shown in Fig.10.

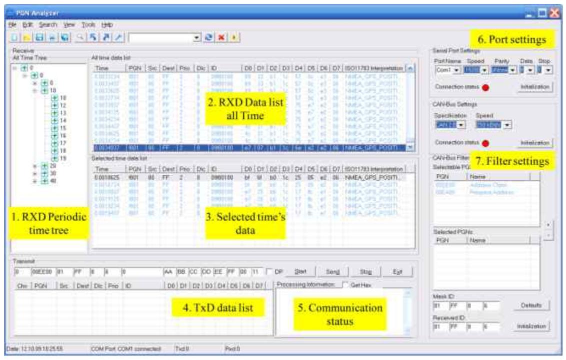

Figure 10. GUI of the PGN Analyzer Transplant of Embedded Web Server

The several embedded web servers are being intensively studied in the world, we develop GoAhead web server for GUI of smart or mobile devices. The reasons of our choice of GoAhead are followings:

- Small memory footprint
- Configurable security model
- Supporting the generation of dynamic Web page content
- Support for devices that do not have a file system
- Portability across a wide range of platforms and CPU architectures
- Integration of the source code into very customized devices

Figure.11 is shows the system diagram of embedded web server and STM32F10x ARM Cortex-M3 development board.

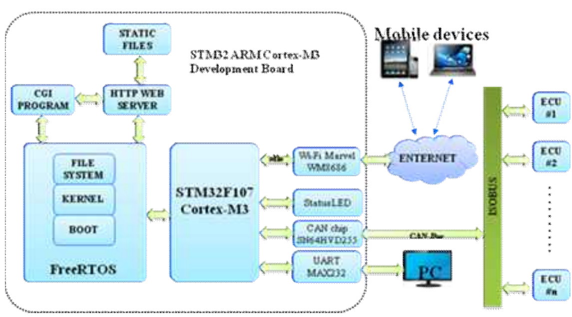

Figure 11. The system diagram of embedded web server

First of all, briefly mention about general procedure of transplantation of embedded software. It consists of three main parts: first one is bootLoader which is the code that firstly run when power on, second one is kernel code which determines process scheduling, inter-process communication, memory management, network and file interface, last one is file system that manages the logical file, including the provision of file operation. Either case code has to be written in pc then generated binary code using the cross-compiler [23]. After that binary code has to be downloaded to the embedded board. To add new application to the embedded system we have to transplant executable file to the file system image of embedded system. Embedded web server for the embedded devices provide network interface, to realize the remote management and control, which is an important technology of networked embedded system [1]. As mentioned before, to control any device by embedded web server we used common gateway interface (CGI) application program [25]-[27]. The main role of CGI application is to transmit the corresponding implementation result to the client browser after completing the relevant operations and the operations to the bottom hardware to let the users see the results of the implementation of operation intuitively.

To transplant web server to the embedded device we follow next steps:

- Download web server source code from web site
- Decompress the downloaded source code
- Create make file
- Check and fix cross-compiler version and path
- Create executable file of Web server
- Create cgi.c code for the your usage
- Compile and create executable file of cgi_app
- Copy created executable files to /system/bin/ director of kernel
- Create html web page for controlling
- Copy created html files to /system/www/ director of kernel
- Recompile or create system image
- Download system image to embedded board
- Reboot embedded board
- Configure ip address and load web server in browser and run it.

The web based GUI of wireless analyzer is written in HTML5. The main interfaces for the user are shown in the Fig 12.

Figure 12. Web based GUI of the PGN Analyzer

Ⅶ. Conclusions and Future Works

In this paper we present the hardware and software development of wireless ISO11783 parameter group number (PGN) analyzer device that is implemented in STM32F107VC Cortex-M3 development board with the Wi-Fi module. In programming of ISO11783 PGN analyzer, we focused on both of firmware and GUI on the monitoring computer and smart devices. The main role of the firmware programming is capturing CAN packet and converting to RS232 serial data format or receiving RS232 data from computer, convert it into CAN data and send. GUI of PGN analyzer receives RS232 data and converting to CAN packets in order to monitor. Those converted CAN packets are sent to some of hidden application programs using pipe programming technique. We used two virtual pipes for parsing and interpreting CAN packets. Finally parsed and interpreted data is shown on GUI of PGN analyzer in ISO11783 standard form. All converting, parsing and interpreting procedures are simultaneously made in two development boards, final displaying GUIs are different. GUIs are written in Delphi programming language and HTML5. Hence our web based application is written in HTML5 which has a good opportunity to support other mobile devices. Recently advances in wireless sensor networking (WSN) technology have led to the development of low cost, low power consumptions, multifunctional sensor nodes. With these advances, near future our research focused on wireless networks in ISOBUS has emerged. Fig.13 is shown development environments of our system.

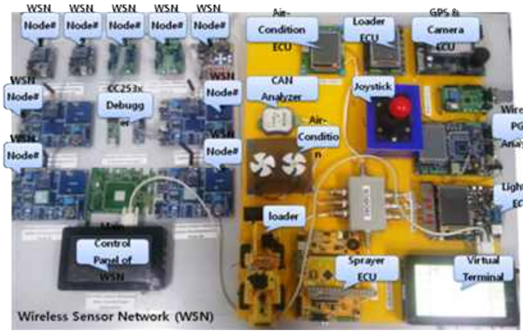

Figure 13. A Development of Environment for ISOBUS and Wireless Sensor Networks

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