A Context-aware Embedded System for Intelligent Vehicles and Smart Roads

S. Cai, M. Becherif, M. Bakhouya, M. Wack
Universite de Technologie de Belfort-Montbeliard
Belfort, 90010 Cedex, FRANCE
{shichao.cai}@utbm.fr

ABSTRACT

Inter-Vehicles Networks (IVNs) have emerged as a new environment for intelligent transportation applications. Usually, some mortal accidents are mainly caused by human errors, because it is difficult for a driver to be aware of road context. An embedded system to collect important context information like the ABS triggering and warn drivers in order to improve the safety of driving is required. In this paper, a context-aware embedded system was designed and implemented to deploy context-aware applications. This system uses a diagnostic interface to plug into the vehicle existing network (i.e. CAN bus system) and extract relevant information messages. This information should be shared with surrounding vehicles via wireless communication technologies by warning their drivers about an unexpected event. A real experimental test was conducted and some preliminary results are reported to first shed more light on the effectiveness of the proposed solution.

Categories and Subject Descriptors

J.7 [**Computer Applications**]: Computers in other systems

General Terms

Design, Experimentation, Performance

Keywords

Pervasive computing, Embedded system, Context-aware applications, Vehicular applications

1. INTRODUCTION

The growing pervasion of computing in Intelligent Vehicles and Smart Roads (IVSR) has brought the term context to focus within a variety of ITS applications. Context is any information that can be used to characterize the situation of an entity. In IVSR, context means the driving situation consisting of the road and all objects within it, i.e., vehicles, drivers, and the road. Furthermore, the expansion usage of wireless communication technologies, considerable research efforts have done in the area of inter-vehicle communications [4]. The objective is to increase the driver safety and comfort by relaying required information about the context from one vehicle to another. However, information coming from only one vehicle may be not credible and reliable to trigger a right alert action. A smart system should be developed to allow vehicles within a geographical area to be involved by communicating their context in order to either confirm or reject emergency situation. Involving multiple vehicles in exchanging context information will increase the confidence of a global current context [6].

To achieve this objective, a context-aware information system (CAIS) enriched by prevention functionalities to improve driver awareness should be deployed within vehicles. A driver experiencing a potentially dangerous situation will be detected by CAIS, which communicates this information in order to inform in advance drivers approaching that they may also experience similar conditions. For example, once the system is notified that the ABS (Anti-Lock Braking System) of the vehicle is activated to indicate a potentially dangerous situation such as incident or bad road conditions (e.g., icy road, strong rainfall or snow), it will share this information and other drivers will be informed to take preventive actions before getting into the same dangerous situation [3]. Another important scenario concerns exchanging information between vehicles to prevent traffic jams from growing to fast. For example, a driver having a vehicle in the front that embeds a fast traffic detection sensors can send the traffic state and drivers of follower or nearby vehicles can take preventive actions to avoid the congested areas.

In this paper, an embedded system was designed and implemented to deploy context-aware applications. This system uses a diagnostic interface to plug into the vehicle existing network (i.e. CAN bus) and extract relevant information messages. Wireless communication modules, mainly ZigBee and GPS/GPRS, are integrated in the system to communicate with other surrounding vehicles as well as emergency/control center. A working scenario was tested and concerns the in-vehicle ABS activation. Vehicles receiving this information increases their knowledge state and may warn their drivers by informing them that the road is slippery or there exists snow or gravel on the road. Hence, the embedded system is able to connect into the existing CAN bus system of light-duty vehicles and decode exchanged messages in order to collect some context information about the

UPC workshop in conjunction with ICPS 2010 July 13-15, 2010, Berlin, Germany

vehicle internal state. Furthermore, this information should not remain in the local vehicle, but should sent to external entities (to the infrastructure via V2I[1] communication or to the other surrounding vehicles via V2V[2]) communication. This effort is a part of our work in the EU FP7 project, ASSET (Advanced Safety and Driver Support for Essential Road Transport)[3], with the main objective is to develop context-aware applications.

The remainder of this paper is as follows. Section 2 presents the related work and background. In section 3, the architecture of the context-aware information system is presented. Section 4 presents diagnostic interface we have developed. In section 5, the experimental study together with some preliminary results are presented. Conclusions and future work are presented in section 6.

2. RELATED WORK AND BACKGROUND

Context awareness originated as a term from pervasive computing which sought to deal with linking changes in the environment with computer systems. More precisely, in pervasive computing, mobile computing technologies can be used to enhance people's interactions during unexpected contexts acoording to the classification presented in [7, 8, 1]. Interactions between users are based on geographic proximity and context-awareness and can occur in a shared local, such as in the office, in the elevator, at the grocery store, in the class, in the library, in the pool area, in the gym, on the road, etc. In IVSR, there are two major types of driver's context: the internal context and the external context. The internal context includes two important parts: the state of the driver (e.g., drunk, sleepy, etc.) and his driving attitude (e.g., tired, instantaneous breaking, etc.), and the state of the vehicle (e.g., ABS activation, engine temperature, oil level, etc). The external context refers to the situation or the environment such as the road state or the driving rules.

The modern vehicle is no longer a single assemblage of components operating independently of each other. There are more and more electronic components being used in vehicles in order to be more safe and comfortable as well as to satisfy the government's requirements for improved emission control and reduced fuel consumption. Examples of such components include engine management, active suspension, ABS, gear control, lighting control, air conditioning, airbags and central locking. The increasing number of components and their complexity requires a communication interface to exchange between them. Therefore, CAN becomes the most efficient way to enable vehicle's electronic components to communicate with each other.

CAN is a serial communication network that uses Non Return to Zero (NRZ) encoding (with bit-stuffing) for data communication on a differential two wire bus CAN-High and CAN-Low (CAN H and CAN L). Almost every new passenger car manufactured in Europe is equipped with at least one CAN network. An example of the distributed control architecture of the Volvo XC90 is given by [11]. Bosch developed the CAN, which has since then been standardized internationally (ISO 11898) 1993 and has been "cast in silicon" by several semiconductor manufacturers [5]. It is widely used in the automotive to make vehicle's electronic components interact. CAN networks are easily to be configurable overall system and possible to diagnose centrally. This subject has been the focus of a lot of research and development. For example, [13] designs and applies a CAN system to meet the need of real-time control for traction control system (TCS) of 2WD vehicle. [15] developed a network control system of CAN and applied it to an electronic control and detection system for a dry hybrid belt continuously variable transmission (A-CVT). In [2, 12, 14], authors have studied features of CAN bus and designed many applications.

The vehicle's existing CAN bus provides numerous important information, such as information on Airbag, on the trigger of ABS, about the engine, etc. These information can be exploited and used to develop context-aware application to increase road safety. However, in light-duty vehicles, the existing CAN bus normally is a private and a close bus. Every automobile manufacturer has its own CAN bus system, but identifiers of frames or messages exchanged between in-vehicle components cannot be directly decoded because components identifiers are hidden by vehicles manufacturers. Hence, information from the vehicle CAN bus cannot be directly accessible through this system.

In this paper, a context-aware information system is presented. The system is able to interact with CAN bus system, extract relevant information and send it to the infrastructure or to other vehicles. In other words, the system could extract context information and aware the driver about dangerous situation by offering a support for inexperienced drivers in harsh or unknown environment. As proof of concept, we focus only on internal context by collecting some relevant information from in-vehicle CAN bus. In the best of our knowledge, a little work have been done to use of the CAN system to develop context-aware applications in intelligent vehicles and smart roads.

3. EMBEDDED SYSTEM ARCHITECTURE

The architecture of the system is composed of a diagnostic interface, an embedded computer, a wireless communication and GPS component, and a touch screen (see Figure 1). The diagnostic interface is needed to plug into the vehicle's existing CAN bus. The embedded computer is used to gather the CAN bus frames, decode, and analyze their content. Wireless communications are realized by the terminologies ZigBee and GPRS: ZigBee is used for the wireless communication between vehicles (V2V), and the GPS/GPRS module for wireless communication with an infrastructure (V2I) since it offers the vehicle's position and support a long-distance transmission [4].

For V2V communication, XBee-PRO 868 modules are used and connected to the laptop PC by using the serial communication RS232 or the USB. AGPS receiver, Navibe GM720 has been used and can track up 20 satellites and update data position every 0.1 second [9]. A program for our wireless communications has been developed that allows the reception of data from the USB GPS receiver, the periodical data transmission through the XBee-PRO 868 modules, and recording data received. A touch screen is integrated into the system for interacting with the driver. The NI TPC-2106 Touch Panel is used and is working under Windows CE and programmed with LabVIEW.

On-Board Diagnostics, called OBD, is used to connect the laptop PC to the vehicle's existing CAN bus, as shown in Figure 2. It's worth to noting that most modern vehicles

[1]Vehicle to Infrastructure
[2]Vehicle to Vehicle
[3]http://www.project-asset.com/

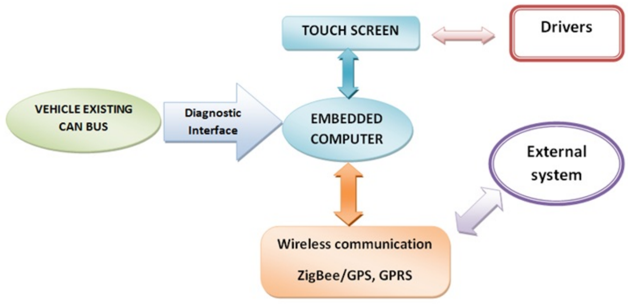

Figure 1: Block diagram of designed system

have the OBD and the OBD-II standard that specifies the type of diagnostic connector and its pin out (shown on the left of Figure 2). CAN bus is used in the OBD-II vehicle diagnostics standard, but it is mandatory for all cars and light trucks sold in the United States since 1996. The EOBD standard is mandatory for all petrol vehicles sold in the European Union since 2001 and all diesel vehicles since 2004 [10].

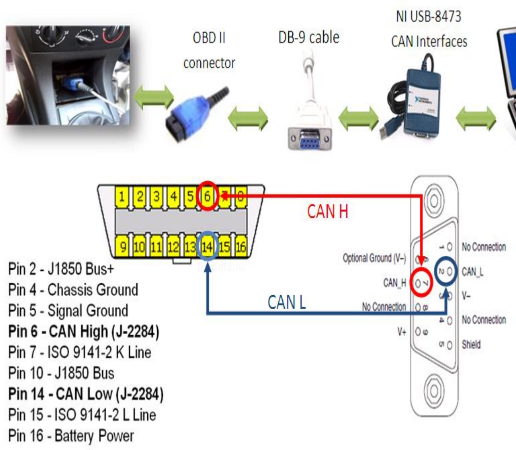

Figure 2: Design of the Diagnostic Interface

From laptop side, a connector USB-CAN (also called Spy Can) is used to read messages transmitted in the vehicle CAN. NI USB-8473 CAN Interface meets requirements and provides Hi-Speed USB interface for connecting PC to CAN networks and devices. It support CAN 2.0A (11-bit) and extended CAN 2.0B (29-bit) arbitration ID. It integrates Philips SJA1000 CAN controller and ISO 11898 physical layer Philips TJA1041 high-speed CAN transceiver. This USB-CAN interface is shown on the right side of Figure 2 with its pin out. To join together two ends, a DB nine support cable is used. So the pin 2 of NI USB CAN connector is connected to the pin 14 of ODB II connector as the line CAN L (L for Low), the other is the line CAN H (H for High). Thus, the laptop PC can gather information from the vehicle's CAN. Note that there are several CAN Bus in the vehicle e.g. the security CAN bus and the comfort CAN Bus. The vehicle's existing CAN bus, which we connected with OBD II connector, is the one concern the safety.

4. INTERNAL CONTEXT DECODING

The diagnostic interface, we have developed, is used to extract CAN frames and decode them. For this purpose, the laptop has been programmed with LabVIEW for receiving and saving the frames coming from the vehicle CAN bus. Figure 3 shows the output of the developed LabVIEW program, which displays the received CAN frames. Other information like the time, identifiers, the frame type, the data length and content of data are also displayed. A baud rate of 500kb/s is needed in order to receive frames correctly. This value was obtained through many tests. Follow the extended frame format of CAN network (with 29 identifier bits), the LabVIEW program helps us automatically separating the CAN frame into 4 parts: identifiers, the frame type, the data length, and content of data.

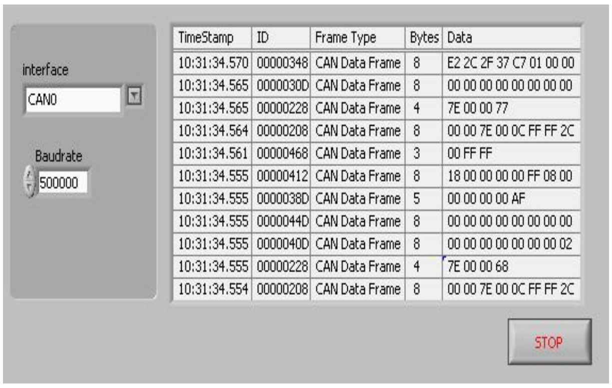

Figure 3: The received frame

The next step is to identify the CAN Bus frames (i.e., finding identifiers), filter, and collect interesting frames representing the internal context information about the state of the vehicle. It is worth to notice that identifiers are hidden information by automotive companies and difficult even impossible to get them from the car manufacturers. This is a key point of our work and quite a complicated task. The decoding was successfully done after many trials for finding a change in the data of frame according to each identifier. Every independent operation would change some frame data. It was therefore necessary to repeat some actions (e.g., switch on lights crossing) to identify changes in bit-level of the frame. After many trials, important identifiers and frames data have been found out and decoded. Table 1 shows some decoding identifiers. Thus, with this method, the existing vehicle CAN's frames were decoded, the vehicle CAN bus became now more transparent.

ID	Byte	Modified Bit	Description
432	6	3	Driver not fasten belt
208	0	3	Handbrake
412	0	3	Reverse gear
412	0	4	Brake
50D	1	6	ABS

Table 1: Identifiers table

Figure 4 shows some information about the vehicle internal context obtained by this method and the LabVIEW program. In this program, it is shown that the task to collect such information like the ABS triggering, the engine speed and its fuel temperature, some types of lights (left signal, fog light), brake, etc, have been identified. Figure 5 shows the diagram of our program.

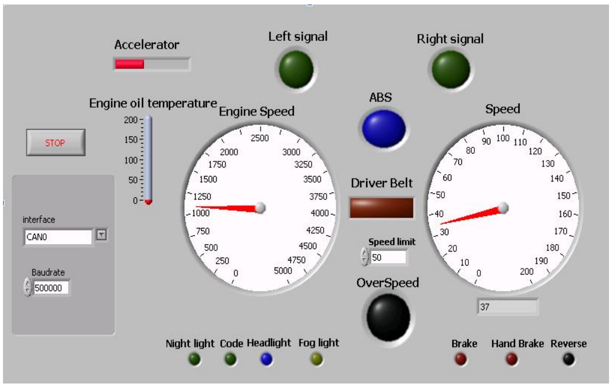

Figure 4: Context information about the vehicle from the vehicle CAN bus

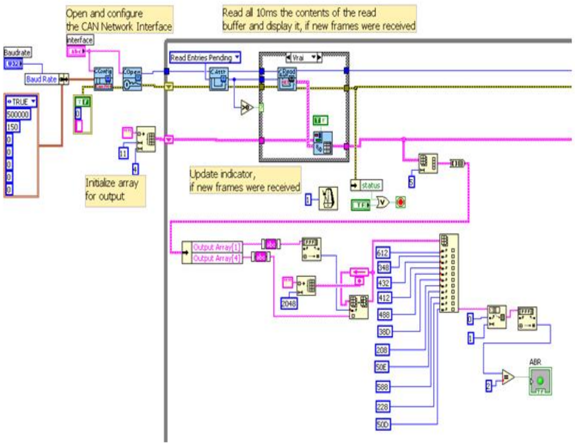

Figure 5: Diagrams of the LabVIEW program

5. THE EXPERIMENTAL STUDY

In the experimental study we have conducted, a functionality of ABS activation alert has been realized and tested. The test scenario together with the system architecture are illustrated in Figure 6 and composed of a laptop computer which is connected to the vehicle existent CAN bus by ODBII connector, a Zigbee emitter/receiver, and a GPS receiver.

The test scenario consists of two vehicles (vehicle 1 and vehicle 2). The vehicle 1 triggers its ABS during the travel and information of the ABS activation events was extracted from the CAN bus via our diagnostic interface. The developed LabVIEW program allows storing the different information to determine if some information are crucial for the safety driving and to decide to display those information to the driver on the touch screen or to send them through wireless devices to the vehicle 2 or to the infrastructure (e.g. emergency or control center). The control center can monitor vehicles position, their speed, the ABS activation, etc. By using this system, vehicles within geographical area should be involved by communicating their context in order to either confirm or reject emergency situation. Involving multiple vehicles in exchanging context information will increase the confidence of a global current context. For example, if the control center receives several messages of ABS triggering, then it will call the corresponding service to handle the problem before some drivers getting in dangerous situation.

Several tests were conducted and realized in the city and on a highway segment with different vehicles speed and vehicle distances. When ABS of vehicle 1 is triggered, the driver will discover this information on the touch screen and in the same time, this information is transmitted successfully to other neighboring vehicles (e.g., vehicle 2) by a ZigBee wireless communication module. Vehicle 2 which equipped with a Laptop, LabVIEW and ZigBee module received correctly the information about the triggering of the first vehicle ABS triggering. Furthermore, this information was also delivered to a server of an infrastructure by a GPRS wireless communication.

Figure 7: ABS activation alert test using a ZigBee communication

The scenario considered has been tested in real environnement. The figure 7 shows the ABS warning in the second vehicle. It was noticed that the signal reception quality is not affected by the speed variation of both vehicles but is only affected by the relative vehicle distance. According to the specification of the used ZigBee module, the maximum distance for receiving signal is around 300m. Results presented in Figure 8 illustrate the relation between the signal level and the distance between the two vehicles in the city. When the distance between the two vehicles grows, the signal level decreases. We have also noticed that the transmission succeeds when the distance between the two mobile nodes is below or equals 300m.

Figure 9 shows the relation between the signal level and the distance between the two vehicles on the highway. As there are less obstacles on the highway, the communication range is higher (between 750m and 1Km). For security applications, this fact is very useful, which means that on the highway users could be informed sooner, mainly in case of an accident. This is very useful, as driving speeds are much higher on the highway and therefore drivers must be notified earlier if they need to change or adapt their driving to a novel situation (accident, traffic jam, emergency, etc.).

6. CONCLUSIONS AND FUTURE WORK

The CAN is most widely used in the light-duty automotive and industrial market segments. Typical applications for CAN are motor vehicles, utility vehicles, and industrial automation. It provides a lot of information about the vehicle, which are collected from different sensors. But in the automotive industry, every automobile company has its own

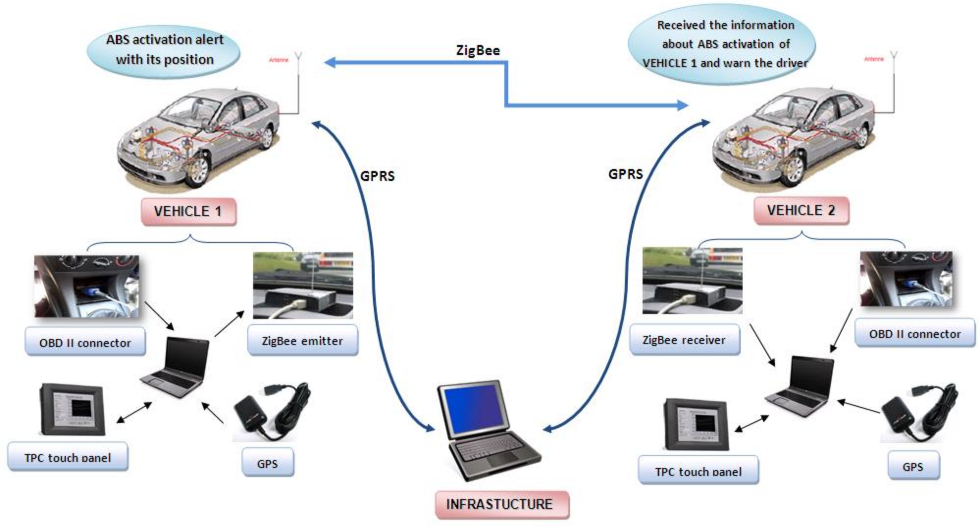

Figure 6: ABS activation alert experimental system and the test scenario

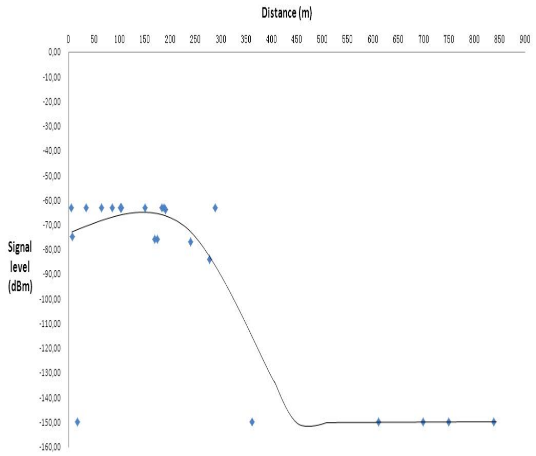

Figure 8: Signal level VS distance in urban

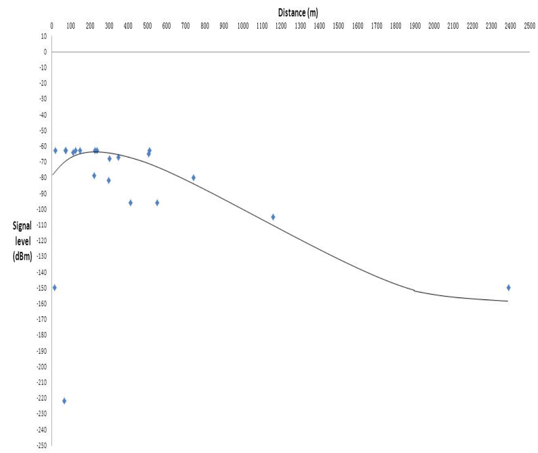

Figure 9: Signal level VS distance on the highway

CAN bus system, their CAN bus is a private and close bus, the frame identifier of the CAN bus system is secret. Therefore, no communication with the existing CAN bus can be easily established. In this paper, a context aware embedded system was introduced to extract internal information about the vehicle context. The system is interconnected to the vehicle existing CAN system and decode the CAN information messages. The system use also wireless communication modules, mainly ZigBee and GPS/GPRS, to share relevant information. A real experimental test was conducted and some preliminary results are reported and show that extracting internal vehicle context is required to develop context-aware applications. Additional experiments together with extracting more contextual information is our ongoing work.

7. ACKNOWLEDGEMENTS

This work is supported by the EU project ASSET (Advanced Safety and Driver Support for Essential Road Transport, 2008-2011).

8. REFERENCES

[1] M. Bakhouya and J. Gaber. Approaches for ubiquitous computing. In *Wireless Ad hoc and Sensor networks Edited by: H. Labiod*, pages 111–142, London, UK: ISTE Publishing Knowledge / John Wiley and Sons Inc, 2008.

[2] L. Chaari, N. Masmoudi, and L. Kamoun. Electronic control in electric vehicle based on can network. In *IEEE International Conference on Systems, Man and Cybernetics*, page 4 pp. vol.7, 6-9 Oct. 2002.

[3] K. Dar, M. Bakhouya, J. Gaber, and M. Wack. Towards a decentralized architecture for information dessemination in inter-vehicles networks. In *AICCSA proceeding, to appear*, 2010.

[4] K. Dar, M. Bakhouya, J. Gaber, M. Wack, and P. Lorenz. Wireless communication technologies for its applications. In *IEEE Communicaion Magazine*, volume 48, pages 156–162, 2010.

[5] esd gmbh Hannover. Controller area network. Technical report, esd electronic system design gmbh,

esd gmbh Vahrenwalder Str. 205 D-30165 Hannover, 1999.

[6] S. Fuchs, S. Rass, and B. Lamprecht. Context-awareness and collaborative driving for intelligent vehicles and smart roads. In *GIIS proceedings*, 2007.

[7] J. Gaber. New paradigms for ubiquitous and pervasive applications. In *Proc. of First Workshop on Software Engineering Challenges for Ubiquitous Computing*, 2006.

[8] J. Gaber. Spontaneous emergence model for pervasive environments. In *In SUPE workshop, IEEE GlobeCOM*, pages 1–6, 2007.

[9] http://www.buygpsnow.com/navibe-gm720-water-proof-usb-mouse-gps-receiver-sirf-star-iii-waas-enabled 779.aspx.

[10] http://www.obddiag.net. Building adapter for vehicle on-board diagnostic, accessed 2009-09-09.

[11] K. H. Johansson, M. Torngren, and L. Nielsen. Vehicle applications of controller area network. 2005.

[12] A. Marino and J. Schmalzel. Controller area network for in-vehicle law enforcement applications. In *IEEE SAS'07 Sensors Applications Symposium*.

[13] D. Song, J. Li, Z. Ma, Y. Li, J. Zhao, and W. Liu. Application of can in vehicle traction control system. In *IEEE International Conference on Vehicular Electronics and Safety*.

[14] X. Wang, H. Chen, and H. Ding. The application of controller area network on vehicle. In *(IVEC '99) Proceedings of the IEEE Vehicle Electronics Conference*, pages 455 – 458 vol.1, 6-9 Sept. 1999.

[15] Y. Zhou, X. Wang, and M. Zhou. The research and realization for passenger car can bus. In *the 1st International Forum on Strategic Technology*, pages 244 – 247, 18-20 Oct. 2006.