Pervasive Computing applied to Cars

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SAE BRASIL
Sociedade de Engenheiros da Mobilidade

FILIADA À
SAE International

Congresso 2008
SAE BRASIL

**XVII Congresso e Exposição Internacionais
da Tecnologia da Mobilidade**
São Paulo, Brasil
07 a 09 de outubro de 2008

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ABSTRACT

This paper presents an architecture called PeSoV using new emerging technologies to increase the security, reliability and connectivity of motorized vehicles. Many people die because of car accidents caused by lack of attention and imprudence of car drivers. Some technologies like the standard IEEE 1609, Zigbee and a network of ranging sensors can be used as tools to help the driver to avoid accidents. PeSoV is composed of three subsystems: a car health management subsystem responsible to care about the good function of the car; a car-car communication subsystem responsible to allow the communication between cars; and a collision predict subsystem that will warn the driver in case of an possible collision.

INTRODUCTION

In the end of the century 19th the modern car started to take its shape. Since that time, the automobile was always dependent of a human driver, and like everything that needs a person, it is susceptible to human fails. In the year of 2006, 822 USA citizens died in Iraq war [1], but 42 thousand people died in USA because of car accidents. 75% of the deaths were vehicle occupants, 13% of these people were pedestrians and 12% were motorcyclists [2]. Most of these accidents happened because the driver was not paying attention to the environment around him, and the human mind is not fast enough to avoid some kinds of obstacles. These deaths could be avoided or at least reduced by a computer driver.

Communication between cars and other facilities on the road was not conceived as something easy. It is until the time that IEEE has established the family of standards 1609. This family of standards encompasses a bundle of standards for vehicle communications from vehicle-to-vehicle to vehicle-to-roadside signs while providing other standards that handles security issues, networking, and data

transmission issues. Such standards are adopted in the proposed system in this paper that serves as an overview of what we can do with vehicles with these set of standards from increasing safety to smoothing traffic problems.

The best model that can take opportunity of these standards in vehicles is Ubiquitous Computing. For its philosophy of seamless integration of technology and computing in daily life [3], pervasive computing fit as the best model for inventing and developing systems for cars that help increase safety margins and handle traffic problems while minimizing road accidents. We will adapt the pervasive computing paradigm in such proposed system as a mean to seamlessly enable cars to be intelligent in monitoring and tracking their own health condition and act on it; to be able to communicate with other cars on the road for information; to be able to discover the road ahead. In other words, according to the proposed system with the aid of IEEE 1609 family of standards, cars became like a network of computers in which a car is like a computer node on a network that is able to communicate with other nodes. Not only this, each car's internal parts are treated as a network of mechanical parts similar to a network of computers in which a car's mechanical parts can communicate and synchronize matters among each other.

This paper is organized by stating some other related work in the next section; subsequently, the proposed system details shall be discussed in its three subsystems; and finally, challenges and future research directions ended by conclusions are discussed.

RELATED WORKS

Almost all papers related to autonomous driving and obstacle detection are related to the DARPA challenge. DARPA challenged research teams to build an autonomous ground vehicle (AGV) to drive across 132 miles of unknown terrain without any human intervention.

One of the most relevant works used in paper was the results obtained by one of the teams that finished the race in 2006 [4]. This work explains how sensors and algorithms are used to detect obstacles and redefine car's path. In their approach, they used sensors enough to provide information to the car finds its path in a desert. Because in this paper the car will not be drove by a computer and the scenario will be in cities between other cars, some more sensors were add, like a back collision prediction sensor and few ultrasonic sensors to help the driver during the parking procedure. In he DARPA challenge, the cars have no drivers. So the competing teams use two or more cameras to detect the road and work together with the sensors to avoid obstacles. The PeSoV proposal does not contemplate an automatic pilot due the high processor power needed and complex algorithms to be used. So, in PeSoV project, stereo cameras were not used.

Other important work is related to the use of Zigbee sensors forming an intranet of wireless devices inside the vehicle [5]. This work shows the communication issues when using wireless Zigbee sensors inside a car, verifying different scenarios: with the engine on and off, with and without the driver and with the car moving. The results were based on Zigbee boards placed on different places of the car and quantifying the packets lost, the strength of signal, etc. They results were used as base of this paper. In PeSoV, the same structure of sensors was used, with the difference that actuators were added to allow the car to fix itself when possible.

OVERALL SYSTEM DESCRIPTION

The basic concept behind PeSoV is to make cars similar to a computer network and to treat a car's internal mechanical parts as a network as well. This conceptual consideration helps opening the horizon to our imagination when developing systems for cars and we can start thinking of making cars more efficient as computers; like the object-oriented paradigm has helped opening the horizon to developers to better imagine advanced functionalities for their systems. On the broader level of the system, vehicles shall be able to communicate among each other and share different information seamlessly. Moreover, vehicles are able to communicate with roadside signs designated for transmitting special type of data to vehicles. Such communications are now made possible with the existence of IEEE 1609 family of standards WAVE (Wireless Access in Vehicular Environment). Namely, IEEE standard 1609.3 is used for vehicle-to-vehicle and vehicle-to-roadside signs wireless communication. Along with this standard for wireless access in vehicles, standard 1609.2 is used for security services. This mode of communication is present in the schematic Fig.1.

On the internal level of the system, a vehicle's mechanical parts will be communicating together in a

network of mechanical parts and will exchange information about each other for possible synchronization activities. When a vehicle's mechanical parts share information about each other, it will be possible to conduct synchronization between parts involved in one operation. For example, the brakes oil container and the brakes part itself and we can as well synchronize the tires together for air adjustment and so on. With this technique each mechanical part will be holding information about itself and other parts involved with it; this will make maintenance easier and efficient while reducing road accidents and sudden breakdowns. The standard to be used in the mechanical parts network that will be discussed in the next subsection is the Zigbee standard. We will leave the full description of such standard for the next subsection. The schematic presentation of this communication between mechanical parts is shown in Fig.2.

Figure 1 - Overall External Communication

Figure 2 - Internal Mechanical Communication

In the following subsections, it will be discussed the three subsystems constituting the entire system.

CAR HEALTH MANAGEMENT SUBSYSTEM – Zigbee is a wireless communication standard focusing in low power consumption. The main application for this standard is sensors and actuators communication. So, for this application, it is not necessary long range and neither high bandwidth. It took its name from bees' formation,

zigzagging during the flight and creating a communication network between them, a MESH network.

It was based on IEEE 802.15.4 standard for low-rate WPAN (wireless personal area network). Zigbee has three frequency band, they are 2.4GHz worldwide ISM band, 915MHz US ISM band and 868MHz Europe ISM band. The bandwidth for each frequency bands are 240Kbps, 40Kbps and 20Kbps respectively.

Zigbee defines 3 types of devices with different uses and specifications:

1) Coordinator: This device is capable to connect to any Zigbee device. This is the most sophisticated type in the standard. It is responsible to manage other devices and centralize their information, maintaining the network knowledge. For this reason, it needs more processor power and memory than the other Zigbee devices. This device is main powered is most of the cases.

2) Full Function Device (FFD): It can connect in any Zigbee device and can be used as a network coordinator. This device is normally main powered as well and it is normally used as zigbee router, connecting to other devices and including them in the network.

3) Reduced Function Device (RFD): This kind of Zigbee device doesn't receive incoming connections. So it is always in the edge of the network. Due the small processing power and memory necessary to implement its protocol, the Zigbee sensors are often implemented as a RFD Zigbee device, main powered, battery assisted or passive.

This technology is very useful for cars monitoring, allowing sensors and actuators to be installed without cables. In PeSoV these Zigbee devices will be applied to verify the car's health, diagnosing problems and, when possible, fixing them automatically. The coordinator element will be the navigation computer embedded in the car, installed in the front panel. A LCD screen will connected to this device to present the car status in real-time, and the detected problems as well, and it will allow the driver to act over the detected problems.

Due the high concentration of metal around and interferences sources, two FFD routers will be installed. The first FFD router will be installed in the front part of the car and other in the back. The front router will route the connections of the engine related sensors. The back router will manage the connections of the back tires, fuel tank and external temperature. Both routers will connect to the coordinator located in the car panel.

The sensors used are pressure sensors for the tires, radiator water level and temperature, windshield water

level, car internal and external temperature, engine temperature and engine oil level. They will be connected to Zigbee sensor nodes board to the analog to digital conversion and transmit it wirelessly.

The tires will be connected through pipes, and each tire will have a zigbee valve. These valves will be commanded to distribute the pressure between the tires. If one tire has low pressure, other tire will supply pressured air to equalize the pressure. If the coordinator detects an air leaking in one tire, the driver will be warned. Depending on the distance of the next gas station, the driver can choose to divide the pressure between the tires during the leakage to keep all of them partially full.

The same feature will be replicated between the radiator water and the windshield water. If the radiator becomes without water, a pipe with a water pump connected in both reservoirs can transfer the windshield water to the radiator.

CAR COMMUNICATION SUBSYSTEM – Communication among cars as depicted in Fig.1 will provide different functionalities for the system. Cars within a connected area range will be considered as a network of cars. We will use two types of connectivity in this subsystem: Wireless Internet connectivity (normally as like as the laptop connects to a WiFi hotspot). This type of connectivity is necessary for the download programs functionality of this subsystem. Besides, it will be used IEEE 1609.3 standard extension to Bluetooth. This type of connectivity is necessary for the communication between cars. As we are adopting IEEE 1609.3 standard, the network of vehicles will be of range 100m up to 1000m as a maximum which is a fair enough range of wireless communication for the system purpose [6]. In the following paragraphs, it is discussed the different functionalities for cars communication.

Firstly, there is a download capability between the car and WiFi hot spots on the road. Cars shall be able through a wireless network card to access WiFi hot spots to download gadgets or firmware to update the whole software system of the car. This actually makes car maintenance more efficient since car brand manufacturers can simply make the new versions of the car software firm available in established transfer stations. For example, Volvo may establish a small station with Antenna specialized just to allow them update their cars. This is one of the flexibility provided by the system. However, we have a serious special case here. In the first point, we are making the assumption that the driver is stopping with his car at a WiFi hotspot, but what if the driver would like to download things off the internet while moving. This is very crucial and challenging aspect because the car is moving so this means that the signal may get interrupted and it means that the WiFi range would exceed in a short time due to the car relative fast speed.

Nevertheless, the solution to such problem is facilitated by the use of 802.11n standard. The 802.11n standard creates several connections to the same access point and it has a high transfer rate of 700 MB per second. This will reduce the transmit time enormously.

Secondly, cars will be able to exchange information and transmit data among each other along the road, and also cars will be able to communicate with 1609 roadside signs that can transmit plenty of useful information to cars. The application software that will handle those two functionalities of the system is basically consisting of software responsible for organizing the ample of information received by cars and is responsible for retrieving that information whenever needed.

Regarding the classification software, Cars on the road will be receiving multiple types of information: weather, road, numbers, news...etc. It is very efficient and neat to have software organizing such data in order to best benefit the driver rather than dumping large amount of data. The categories of data shall be presented as a graphical user interface GUI. How this classification software will work will depend on how basically the data is acquired. Is it acquired through sensors or is it acquired through a third party device. In case the data is acquired through sensors, this is easy; we can make the software categorize the data acquired to the type of sensor. For example, a temperature sensor data will of course classify as Weather data and so on. In case the data is acquired through third party device; for example, a roadside established station that transmits weather data to drivers on a travel road, this is still made easy by the identification of the device itself. If the device is a weather device, then, the data will be classified by the software as weather data.

For the information retrieval software, As we are in an opened network of cars, a car will be collecting different data. The question is which one is to be referenced when the driver wishes to query for example information about the weather in the destination. It can be implemented a stack-based retrieval mechanism; this is to have the last acquired piece of information as the referenced one. The last weather information acquired pushed on top of the stack shall be popped from the stack and displayed to the driver. This will guarantee having the freshest information acquired.

We have a great advantage in using IEEE 1609 family of standards. As you can see, the software is relieved from many things; making it simple and sharp focusing on the work at hand. We are not worrying about managing multiple communications (That is, a car can be exchanging information with 5 cars at the same time as shown from the figure). Standard 1609.4 (multi-channel operation) and standard 1609.1 (resource management and simultaneous data streams management) handle that for us. We are not worrying about security. Standard 1609.2 (security

management) handles that for us. However, we an extra anti-virus can be used internally on the car software system.

COLLISION PREDICT SUBSYSTEM – To create an environment to allow the car automatically detects obstacles it will be necessary several sensors. This environment will alert the driver about the possibility of collision, and it can even break the car or change its direction if the car supports drive-by-wire. Based on the knowledge shared by the DARPA project competitors, here will be used 3 kinds of sensors:

1) Radio Detection and Ranging (Radar): This sensor use radio waves to detect long distance objects in a very narrow scanning angle. It normally has 80 m of range and conic 12 degrees of scanning angle.

2) Light Detection and Ranging (Lidar): A Lidar has the same principle of the radar, but it uses light beams besides radio waves. This kind of sensor has medium range, normally 50 meters, but has a wider scanning angle (180 degrees). This scanning area is a plane, so the sensor can be positioned to scan horizontally or vertically.

3) Ultrasonic sensor: This sensor measure the distance based on reflected sound waves. It has a very close range of 4 meters normally.

For the application of this paper, it will be used: one radar, five lidars and 16 ultrasonic sensors, seen in Fig.3.

Figure 3 - Different sensors of PeSoV, aerial view

The radar in the front will be used to detect far objects, like other vehicles. The radar will be installed with the beam parallel to the ground.

One lidars installed in the front of the car will be aligned to scan vertically, detecting holes and obstacles in the road, bridges and tunnels as well. The other three lidars will be used to detect the elevation of the road and the height of the obstacles. The first of them will be aligned horizontally and parallel with the ground. The second will be installed with scanning plane crossing the ground aligned lidar 30 meters in front of the car. The last one will be installed to cross the ground lidar 50 meters far, as show in

Fig. 4. The fifth lidar will be installed in the back of the car, aligned horizontally parallel to the ground. This lidar will detect incoming vehicles checking from behind to warn the driver for back collision.

Figure 4 - Different sensors of PeSoV, side view

Finally, the ultrasonic sensors will be installed around the car to avoid small collisions during car maneuvers in parking lots, city and drive-through places. Four ultrasonic sensors will be installed in the front bumper and more four in the back bumper. Each side of the car will have other 3 sensors, and there are two more sensors in the ceiling of the car.

All these sensors will be connected directly to the car embedded computer. The data sent by the sensors will be compared and processed according to a collision detection algorithm. In case of collision detection, a warning voice message will be played to the driver and presented in the panel. This system will permit to detect front collision up to 50 meters, giving time to the driver to try to change the car direction. In case of eminent collision detected, the embedded computer can act over the air-bag, brakes and sit-belts to increase the chance of survive of the driver and passengers of the car.

CHALLENGES

The fundamental challenge of such types of systems made for the purpose of being deployed on vehicles is the efficiency of data transmission. This challenge is due to the fact that vehicles, especially new brands, have relatively high speed. For this challenge, there are two issues that have to be considered when dealing with such system. Firstly, the system performance regarding processing time shall be done in a timely manner. For example, the third subsystem responsible for discovering any road obstacles should be able to process the information in a timely manner and take the appropriate action quickly so that it takes effect before the vehicle basically reaches the obstacles. This is very challenging since cars have high speed capacity and when driving on a free way. Secondly, data transmission from other cars or from roadside signs must be handled efficiently because cars will be having high speed relative to the rate of data transmission. In other words, the challenge to this type of systems for vehicles is that we are dealing with a moving object and fast moving one. Thus, optimizing

the processing time and finding ways to increase the throughput of data transmission is a key issue for the success of such systems.

FUTURE RESEARCH DIRECTIONS

Enhancing on such type of system is not a matter of enhancing the system itself as it is a matter of improving research in this direction, namely research for acquainting vehicles with computers aiming at making cars more efficient and intelligent on the road. New deep research directions need to be undertaken more seriously by research scientists. The major concerns by car vendors are directed to increasing the luxury of cars and enhancing its mechanical capabilities. However, we need a research concern regarding safety and directed to exploiting means to include computing into vehicles that will increase the efficiency of cars. Research scientists shall need to consider vehicles as similar to computer but with mechanical parts instead of electronic chips; just as we did in modeling the PeSoV system discussed in this paper. When research scientists treat cars or think of cars as like as computers, they can research topics related to cars more efficiently and abstractly.

CONCLUSION

We can go ahead and classify problems related to roads and driving into two broad categories: the road and the vehicle itself. Many problems and accidents are caused by malfunctioning cars. When cars have health management system working internally inside the car, awareness of possible problems as early as possible will be increased. This will enable drivers to avoid many road problems ranging from car broke to accidents. When cars are able to communicate among each other, drivers shall avoid accidents caused by lack of knowledge about road conditions. Drivers will be able to acquire data along the way as they drive. Also, cars will be more intelligent in updating themselves and this is very easy when a car's system becomes fully software-oriented due to the great flexibility and potentials of software. When cars are able to discover the road for us and perform a road look ahead, drivers will be able to avoid sudden obstacles and possible road surprises that contribute to a great number of road accidents. On the road, drivers are not the only ones who are fully responsible for safety, organization, and efficiency; it is the cars as well that act as the drivers' partners. Long ago, cars are considered passive machines, but when we make cars more intelligent by making them software-oriented, cars will become an intelligent partner to drivers that can share responsibility.

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