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On Vehicle Data Acquisition System

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Abstract— **The goal of this paper is to present a vehicle data acquisition system. This system is a part of the Car Transport Safety project that is aimed at modern methods in the vehicle transportation systems. The goal of the project is to reduce hazardous situations on the roads by analyzing behavior of the driver and identifying the degradation of driver's abilities. The goal of the vehicle data acquisition system is to create a publicly available data archive taken from the operation of a real car under various real conditions of the driver and the road. The data is collected from a vehicle's communication bus and from an image acquisition system. Data is processed with the aim to analyze it and reveal changes in a driver's abilities and to eventually alarm the driver or passenger(s).**

I. Introduction

In the Czech Republic the problems of vehicle traffic safety has been a subject of discussion for the last two decades. Vehicle traffic safety was first of all political discourse; however, after our entry into European Union structures, it has led to important social problems with serious economic impact. Our country is copying the situation that has already happened in economically highly-developed countries [1] as well as the situation in the similar countries [2]. A typical solution of traffic safety is based on improving and building new infrastructure, but building new highways and motorways (or repairing the existing ones) is very expensive. For example, the typical cost of a new 2-lane highway per 1 kilometer in the Czech Republic is about 9 million EUR [3]. And the correlation between the quality of the roads (i.e. the density of the highways) and traffic safety is not evident. From the traffic safety point of view, society has never invested so much and received so little.

Another solution is based on electronic systems [4], [5]. There are several electronic systems in place on the highways and roads, e.g. safety and traffic warning information boards, remote controlled traffic signs, etc. All these systems work almost autonomously. Other roadside systems known from the highways in Germany will be implemented in other countries soon; however, as a result of non-existent unified information and telecommunication environment, the added value of these systems is once again minimal or speculative.

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Statistical data from the last decade shows that the situation on the roads is serious. Car crash statistics show that there were nearly 75,000 accidents on the roads in the Czech Republic in 2010 [6]. Ninety percent of them were caused by car drivers who killed nearly 700 people and injured 24,000. About 2 people die every day in vehicle crashes in the Czech Republic – one death every 11 hours. Motor vehicle crashes were the leading cause of death for children and teenagers. While statistics are improving, 14 percent of fatal accidents involved alcohol-impaired drivers.

While the absolute number of accidents has been decreasing in the last decade (in 2001, 185,000 accidents and in 2010, 75,000 accidents), the number of killed people per 100 accidents is almost the same or even higher (for last two years). This trend is evident from Figure 1.

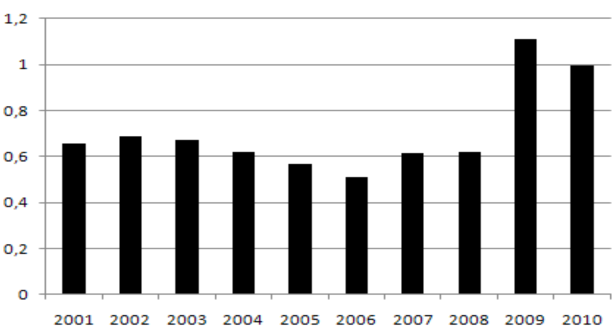

Fig. 1. Number of causalities per 100 car accidents for the last decade in the Czech Republic.

The country has invested a lot of resources to improve road infrastructure and to decrease financial impact and human losses in car crashes, but the result is not sufficient. An important aspect of this failure is based on the distribution of the cause of accident. Figure 2 shows how different car driver failures contribute to fatal car accidents in the Czech Republic.

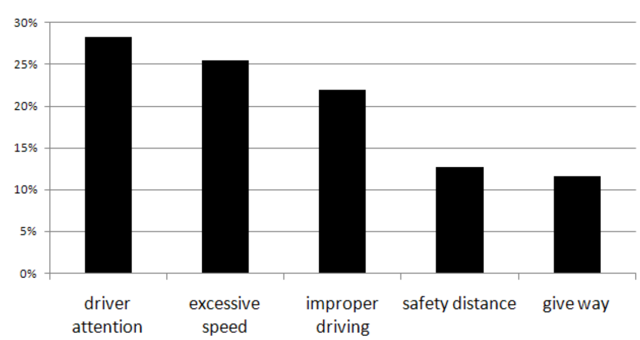

Fig. 2. Distribution of the accident cause in the Czech Republic in 2011.

Driver attention contributes to the total cause of accident by 28 %. It is twice more than failing to give the right of way or not keeping a safe travelling distance.

The goal of this Vehicle Data Acquisition system is to provide sufficient information from the driver's behavior with the aim to decrease the number of drivers with low concentration, usually due to drowsiness or fatigue. It can significantly increase traffic safety with minimizing the amounts of resources (mainly in improving road infrastructure and complex vehicle electronic systems).

Many previous works are focused on systems for recording vehicle data and driver information. Toledo and Lotan have introduced an in-vehicle data recorder system in order to record, identify and classify various maneuvers the vehicle performs [8]. Acquiring data from a vehicle is a real-time process with many requirements. Huixin and Hous presented a multi-channel storing system. This system is based on FPGA architecture and is suitable for real-time recording in-vehicle data, including image acquisition system [9]. Perez at al. presented an advanced in-vehicle data recorder Argos [7]. This is a complex system that allows recording many kinds of data such the speed, the point of gaze or up to nine simultaneous video images.

The Vehicle Data Acquisition System is a compact system that is based on standard HW components like personal computer or CAN/USB interface. To build the system no special hardware or software components like FPGA or microcontrollers are necessary. Data storages are flexible external SSD drivers that can be easily transferred out of the vehicle for data processing purposes.

The Vehicle Data Acquisition system consists of an in-vehicle communication data acquisition and of a driver image acquisition system. The purpose of the in-vehicle system is to provide all available information from the vehicle internal data bus during the ride. The aim is to create a publicly available data archive. This archive includes data that is taken from the operation of the real car under various real conditions of the driver and the road. Data can be processed with the aim to analyze it and reveal changes in drivers' abilities. The purpose of the driver image acquisition system is to support data from the in-vehicle system by the information acquired from a machine vision system.

II. In-Vehicle Communication Acquisition System

The goal is to create a publicly available archive of data collected during the operation of real car in various real road and driver conditions. The data is collected from the vehicle communication bus. The data is technically available in modern vehicles; however, creating an archive and making it available enables to apply data mining techniques to reveal static and dynamic changes in the data with respect to expected changes in drivers' abilities and to other research teams to use data from a real vehicle driven by real drivers.

Our experiments are based on the Czech car Skoda Octavia II. This model uses an in-vehicle communication system that is based on the CAN bus [10]. Skoda Octavia II uses 5 different CAN busses:

- KI - a data bus located between the instrumental panel and the vehicle Gateway.
- INFOTAINMENT – a data bus located between entertainment devices (radio, amplifier, CD changer, etc.).
- ENGINE – a data bus located between different parts of the engine (drive, ABS, transmission, wheel, etc.).
- COMFORT – a data bus located between comfort devices (air conditioner, doors controller, central control unit, navigation panel, etc.).
- K LINE: a diagnostic bus.

From the driver's attention point of view, the most important is the Engine bus where all important messages about the state of the engine, wheel, and transmission are available. The advantage of this car is that all the above-mentioned CAN buses are available in one point – the Gateway.

The Gateway is normally connected to the bus by a cable that is available under the steering wheel. When the Gateway is disconnected from the cable, a T-tap device can be plugged between the Gateway and the cable (Figure 3) and all the CAN busses can be wiretapped without influencing the original signals. It is important to make the T-tap device as small as possible and to properly terminate all CAN lines that are wiretapped.

Wiretapped signals are processed in a CAN Interface device that is a gateway between the original CAN bus and a USB High-Speed communication bus. This interface is based on a CANview USB gateway. The CANview interface provides fast data exchange with a standard PC through its USB interface. The communication speed on the CAN side can be up to 1 Mbps and on the USB side up to 12 Mbps. The connection to the device is established over a virtual serial COM supporting the high speeds of the USB interface. CANview is located in robust aluminum housing for easy and safe deployment in the car environment. The device is powered via the USB port and does not require a separate power adapter. The CAN side and the USB side are electrically isolated which makes it easy to connect it with a PC. CANview is equipped with a 128 KB SRAM memory buffer where CAN messages can be stored if the USB interface is not processed for a short time.

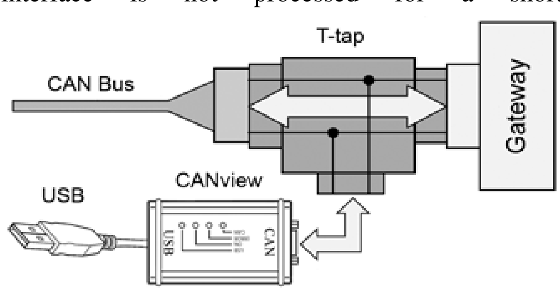

Fig. 3. Gateway with the T-tap device and USB CAN Interface [11].

III. IMAGE ACQUISITION SYSTEM

The driver's face is recorded during the ride by a high-speed and high-resolution camera. The board camera MT9P031 by Aptina Imaging has been chosen as a convenient device for the image acquisition task [12]. The camera is equipped with a CMOS sensor of a 2592 by 1944 px physical resolution and a 1/2.5'' optical format; the camera is shown in Figure 4. For the purpose of the image analysis, the 800 by 600 pixels resolution is chosen because of higher frames per second provided by the sensor. If the 24 bpp color depth is considered, one image from the camera corresponds to the 11.52 Mb data in a raw data format (800x600x24). The camera can be connected to a PC either by a USB High-Speed interface with the theoretical speed of 480 Mbps or by a Gigabit Ethernet (1000 Base-X) interface with a speed of 1000 Mbps. The theoretical number of transferred frames per second is approximately 42 for the USB interface (480 Mbps divided by 11.52 Mb); however, practical experiments show that the average speed of the USB High-Speed interface is about 250 Mbps for data transfer and the typical number of transferred frames per second is approximately 21. For the Gigabit Ethernet, doubled real frame per second transfer can be achieved.

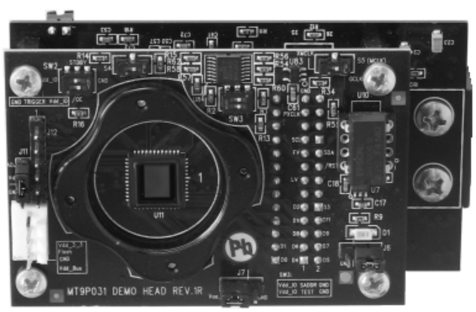

Fig. 4. Board camera MT9P031

A machine vision system is responsible for an exposure algorithm, the driver's face segmentation, and the driver eye detection and tracking. The robust and efficient image acquisition technique with an auto-exposure algorithm was designed in order to achieve information about driver vigilance [13].

IV. DATA STORAGE

In order to connect both data acquisition systems (in-vehicle communication and image acquisition) into one data store, a vehicle telematics computer VTC6100 has been used. This computer is a standard PC with wide interface connectivity, good computational power (Atom N270 CPU at 1.6 GHz), and very low power consumption. This CPU supports Hyper-Threading Technology that enables thread-level parallelism on each processor. It results in more efficient use of processor resources and improves performance on the multi-threaded software. The CPU can deliver about 3300 MIPS and 2.1 GFLOPS which is sufficient not only for data acquisition but also for basic data processing. VTC6100 has a fanless design with a rugged aluminum chassis, a wide range of DC input from 6 V to 36 V, a 128 MB internal SSD disk, and 2 GB RAM. The hardware architecture of the Vehicle Data Acquisition System is shown in Figure 5.

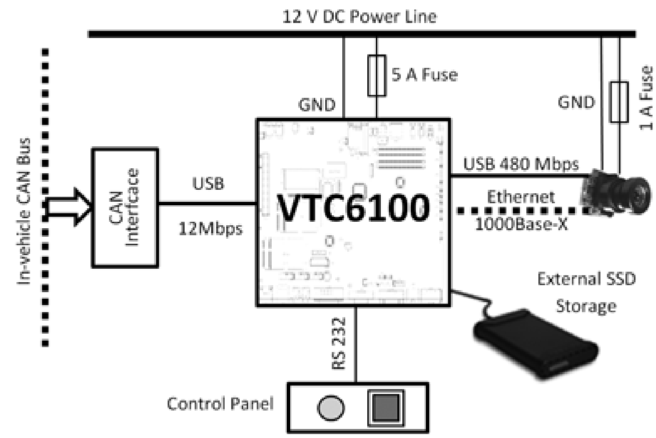

Fig. 5. Vehicle Data Acquisition System hadware architecture

The computer is powered from the main car fuse box (Label A in Figure 6) through a 5 A fuse (Figure 6) and the camera is powered either by a USB cable (if Ethernet is used as a data bus) or from another fuse in the main car fuse box. The CAN Interface is powered from the USB cable and the communication speed between the computer and the interface is 12 Mbps.

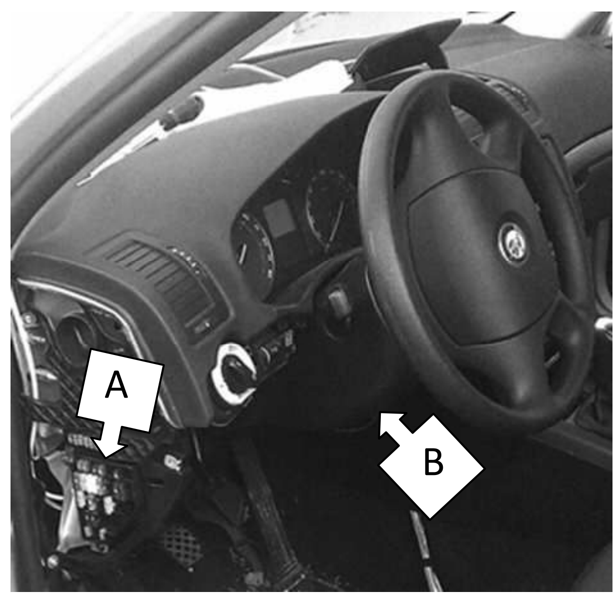

Fig. 6. A - Fuse box from where the computer and the camer are powered, B – position of the Gateway with CAN Interface module under the steering wheel.

Communication speed on the CAN bus will be discussed later. The camera can be connected either by a USB High-Speed (480 Mbps) interface or by Gigabit Ethernet (1000 Base-X).

A 256 MB SSD drive is used as an external data store. This drive is connected to the computer by a High-Speed

USB interface. The drive includes both data from the in-vehicle communication acquisition system and image acquisition system. Moreover, it contains a configuration file with the predefined parameters and a log file. Before the ride, the driver connects the drive to the computer and after the ride, the drive is disconnected and acquired data can be easily transferred from the car into the publicly-accessed data archive.

The computer is situated in the luggage compartment of the car. It is screwed on the back side of the left passenger seat, so it can be easily accessible by reclining it. Placement of the computer is shown in Figure 7.

In order to control the power off sequence of the computer and to indicate the state of the data acquisition system, a control panel is connected to the computer via an RS 232 interface. The control panel is a small box including an LED indicator and a button. The control panel is situated in the middle panel above the ash tray. The LED indicator provides a blinking signal with a 1 s period, informing the driver that the vehicle data acquisition system is working properly. If any subsystem is not working properly, the period of the signal is increased. The button is used when the driver wants to stop the data acquisition system and to safely remove the external drive from the computer. The external drive is configured as a fast remove device. It reduces the transfer speed but significantly improves the data consistency if the USB connection is lost. Whenever the button on the control panel is pressed, the external drive is safely removed from the PC and the PC is eventually switched off.

Fig. 7. Placement of the VTC6100 vehicle telematics computer in the luggage compartment.

V. SW EQUIPMENT

Data acquisition software must comply with several requirements. The most important requirement is time consistency. The CAN bus is a time deterministic system with high speed communication. The Engine bus has a fixed communication speed of 500 kbps and the typical number of messages is in the range of [1300, 2200] frames per second (frame rate). The number of frames per second depends mainly on the model of the car. The in-communication system has been tested on three different models of the Skoda Octavia II and the frame rate depends mainly on the year of the production and the motorcar appointments. The length of the CAN frame can be in the range of 1 to 8 bytes. The average length of the CAN frame on the Engine bus is 7 bytes. If the average value of the frame rate is considered, then the dataflow between the Engine bus and the CAN Interface is 12.250 kBps. Dataflow between the CAN Interface and the PC is greater due to synchronization marks and commands; it is another 10 bytes per CAN message. Total dataflow is 29.75 kBps which is 0.238 Mbps. Because the maximum speed of the USB interface between the CAN Interface and the computer is 12 Mbps, the utilization is about 2 %.

The CAN Interface is equipped with a 128 KB of static RAM memory. This memory is used as a buffer between the CAN interface and USB interface. If the dataflow of 29.75 kBps is considered, a buffer can theoretically store a record up to 4.4 seconds long. Practical utilization of the buffer is only 50 %; thus, only 2.2 seconds can be saved in the interface and later transferred into the computer. A bounded response property of the system states that a desired reaction of the software to a read operation occurs within a time interval of [0, 2.2] s. With representing the timer interrupt at time and representing a completed read operation at time , the desired property can be expressed by the formula:

(1)

In other words, the control software running on the computer must ensure that the maximum delay between two subsequent read operations from the virtual COM port must not exceed 2.2 seconds. If the delay is greater, the time consistency condition will not be satisfied and measured data will be lost, incomplete, or incorrect.

The Windows XP operating system runs in the vehicle computer and there is no guarantee that the application satisfies this condition at all times because property (1) can be falsified in bounded time. For that reason, Windows XP was extended by the RTX real-time extension. RTX is a real-time extension based on the Win32 Application Interface (API) [14]. It provides precise control of IRQs, I/O, RTC, and shared memory. It operates in Ring 0 with the highest performance and sustained interrupt rates of 30 KHz with an average IST latency of less than one microsecond. Another advantage of this real-time extension is its close cooperation with the Windows operating system. It makes it possible to create an outstanding graphical user interface (GUI) without any additional costs or effort because this GUI is created under standard Windows API and, with the real-time extension core, is connected by a shared memory mechanism.

The real-time part of the control software was modeled and checked in UPPAAL. A simplified model of the system is shown in Figure 8.

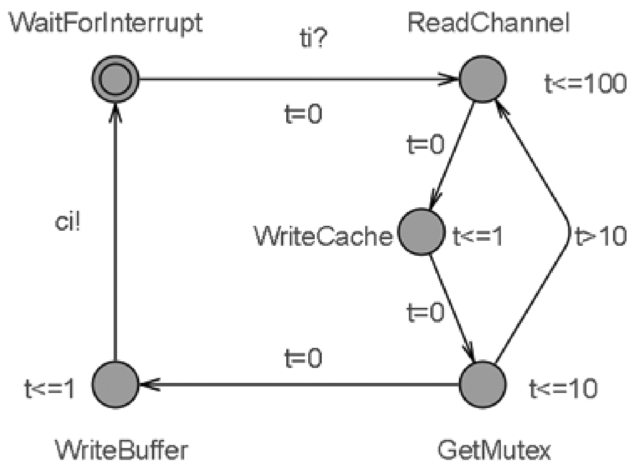

Fig. 8. UPPAAL model od the real-time part of the software.

The Model assumes a cache memory between the USB communication buffer that is used for a virtual COM port and output buffer for writing operations onto the external drive. Anytime the timer interrupt occurs (channel *ti*), the application reads data from the virtual COM port and transfers them into the stack memory that represents the cache memory. As soon as data is stored, the application tries to get access to the output buffer via a mutex operation. When the mutex is accessed, the local cache memory is written into the external SSD drive and the interrupt request is confirmed by channel *ci*. Because RTX provides real-time response for the running application, the model in Figure 8 can be implemented in it and property (1) is always satisfied.

VI. EXPERIMENTS

Messages on the Engine CAN bus can be separated into two different groups. The first group is the messages with the highest priority and highest frame rate; the second group are the messages with the low priority and low frame rate. Data was acquired from a 30-minute ride in city traffic. The messages with the highest frame rate have a period of 0.02 second. After 30 minutes of measurements, 90,000 messages should be expected in the measurement file. Due to a fluctuation of the time on the CAN bus and the vehicle computer time, the real record includes 90,035 messages. That means that the stability of the measurement is better than 0.04 %. It proves that the software solution fulfills property (1) in the long-term interval. Figure 9 shows messages belonging into the high rate group.

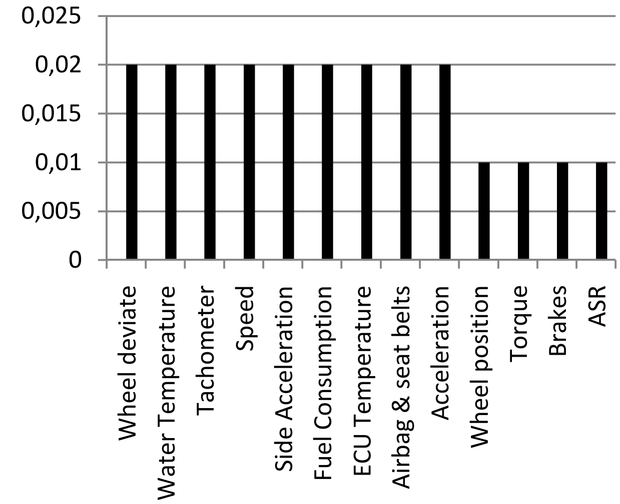

Fig. 9. High rate and high priority messages on Engine CAN bus.

The vertical axis of the graph in Figure 9 is the rate of the message in seconds. It is obvious that the most important values like the tachometer, speed of the car, steering wheel position, or acceleration are the highest rate.

Figure 10 shows messages belonging into the low rate group. Their period is either 1 second or 500 milliseconds. Even if the period is much greater in comparison with high speed messages, the output record includes 1,800 messages about power of the engine or oil temperature during the 30-minute ride. They can also play an important role in the data mining process.

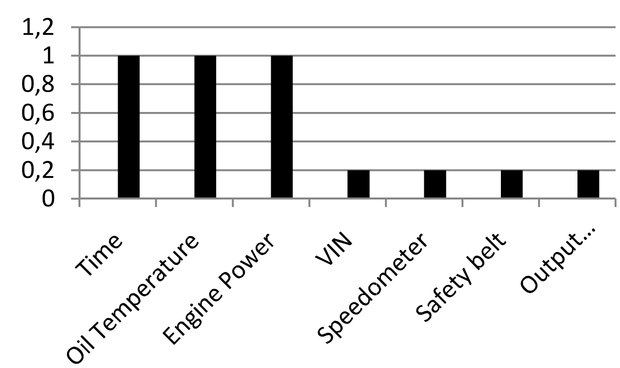

Fig. 10. Low rate and low priority messages on Engine CAN bus.

VII. CONCLUSION

The experiments proved that this vehicle data acquisition system is able to acquire data from the Engine bus and the camera in a real-time fashion. Acquired data is publicly available at the site http://project-bay.eu/vehicle-dataset.

The project is presently continuing in the phase of data mining in order to recognize important features from the Engine bus, to analyze it, and reveal changes in drivers' abilities online.

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