

Integration of passive driver-assistance systems with on-board vehicle systems

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Abstract. Implementation in OIAS such functions as driver's state monitoring and high-precision calculation of the current navigation coordinates of the vehicle, modularity of the OIAS construction and the possible increase in the functionality through integration with other on-board systems has a promising development future. The development of intelligent transport systems and their components allows setting and solving fundamentally new tasks for the safety of human-to-machine transport systems, and the automatic analysis of heterogeneous information flows provides a synergistic effect. The analysis of cross-modal information exchange in human-machine transport systems, from uniform methodological points of view, will allow us, with an accuracy acceptable for solving applied problems, to form in real time an integrated assessment of the state of the basic components of the human-to-machine system and the dynamics in changing situation-centered environment, including the external environment, in their interrelations.

1. Introduction

Domestic driver assistance systems (ADAS) are being implemented in the Republic of Belarus and in the Russian Federation within the framework of science-and-technology programs at different levels. These are supported by relevant funds, targeted enterprises and performed by companies proactively. A sufficient number of current developments is intended for production of passive ADAS oriented to its use on domestic trucks. Such systems alert a driver only on several potentially dangerous cases (giving a visual and sound alarm message) and they do not affect a vehicle's dynamics, working automatically. As a rule, such systems use information obtained from cameras (vehicle monitoring in a track or related tasks), ultrasound sensors (blind spots monitoring), radars (ACC – adaptive cruise control systems), navigation modules for location identification, etc. installed on a vehicle unit. There are many mass-produced systems, for instance, driver's vigilance monitoring systems such as DVMS or VIGITON that monitor driver's psychophysiological parameters to interpret automatically a driver's current functional state and his ability to perform current activity algorithms to drive a car [1,2]. For instance, Mobileye systems of 5th and 6th series are advanced driver assistance systems having a built-in camera and EyeQ chips family to process obtained images; the systems alert a driver on several potentially dangerous cases and give the following warnings and notifications (namely, visual and sound alarm message): a warning of a dangerous frontal approach (FCW and UFCW), of potential front collision with a vehicle driving (standing) in front of; a pedestrian collision warning (PCW); lane departure warning (LDW); a warning of keeping a distance between the cars and of a dangerous approach with a forward vehicle



(HMW), etc. Moreover, the following articles may be referred to this group: speed limit information systems (SLI) that detect and classify different signs of a speed mode notifying a driver of exceeding of permissible speed limit indicated on the sign; traffic sign recognition systems (TSR) that detect and classify different road signs and notify of them the driver. In case of using the Mobileye systems, the driver has to perform all management tasks on his own and keep control over the vehicle, track car's conditions, fulfill all recommendations in terms of safe driving. In the User's Manual, the Manufacturer specifies, "it cannot guarantee and does not guarantee 100% detection of vehicles, pedestrians, road signs or traffic lanes and does not guarantee giving any sound and visual warning notifications related to it." Aside from that, recognition and responsiveness of the Mobileye systems may be adversely affected by road, weather and other conditions" [3]. However, 27 OEM Suppliers of the ADAS implement in their systems Mobileye components, EyeQ chips (6th generation is used nowadays) and the software.

As it is known, works in such direction including production of active ADA are carried out by large corporations developing components and/or safety shields: BOSCH (Germany), Knor-Bremse (Germany), WABCO (USA), etc. according to the market analysis performed by Semicast Research (figure 1), Continental company took a top position in an area of electronic components for automotive ADAS systems in 2015 [4].

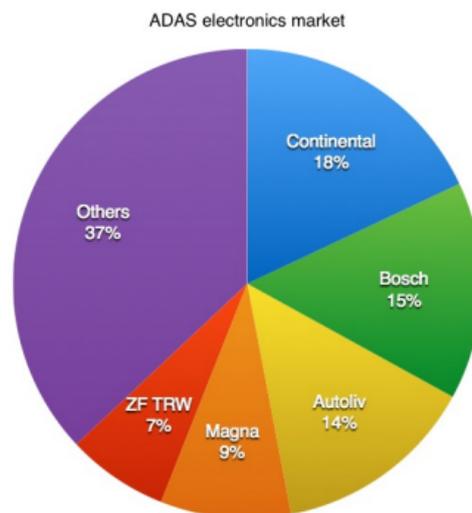


Figure 1. Analysis of the electronics suppliers sector in ADAS segment by Semicast.

2. Problem Statement

To develop a basic structure of an onboard information analysis system (OIAS) and a basic software architecture designed to create a vehicle float body for commercial vehicles. The software shall embody the following main functions: vehicle's location identification accurate to the nearest centimeters, first, to support ADAS in terms of vehicle monitoring in a track, if a traffic lane and a road border are not recognized by optical methods; communication maintenance with dispatching offices and emergency services; transfer of information, including obtained in an automatic mode, on system «human-to-machine» dynamics (current state of the major systems, units and aggregates, driver's state, warning on emergency cases, emergency call in case of an accident or if a driver has fallen unconscious or is dead), communication between passive ADAS and active safety systems or its integration to coordinate their joint operation in real-time mode in terms of accident prevention or mitigation.

3. Results

An information and analytical system with the indicated functions is being developed at the Institute jointly with the partners having the expertise relevant to the area under consideration, within the

framework of the Scientific and Technical Undertaking of the Union State “Avtoelektronika”: the Limited Liability Company “NTLab-sistemy” included into the group of companies “NTLab” (Republic of Belarus, <http://www.ntlab.com>) develops and produces very-large-scale integration circuits (VLSI circuits), plug-in modules, as well as portable hardware and software packages, including navigation sets for usage in automotive vehicles. The company develops the products based on specialized VLSI circuits of in-house design; the Open Joint-Stock Company “Ekran” (Republic of Belarus, <http://www.ekranbel.by>), a developer and supplier of production active safety systems, on-board monitoring systems and their spare parts for CIS machine-building enterprises; the Closed Joint-Stock Company «Neurocom» (Russian Federation, <http://www.neurocom.ru>), creation and development of a monitoring methodology for tracking the functional state of operators in the «human-to-machine» systems and further development based on it, mastering the production and supply of a production range of production systems for railway and automotive transport.

Figure 2 depicts the VLSI circuits structure and its plugging-in by joint usage with other intelligent on-board systems on board of a motor vehicle (MV).

The on-board module for detection of driver’s dangerous states (developed by the Closed Joint-Stock Company «Neurocom») is connected to the system via CAN data bus. Module’s application enhances OIAS functional abilities significantly and specifies it as a prevention safety system that enables to prevent accident occurrence because of driver’s relaxation, unconsciousness or death. The module is unique due to the fact that the following features are used in its construction: a specialized chip set, a robust algorithm to recover an useful signal from noise, original algorithms for automatic interpretation of the driver’s functional state, short-range telemetering measurement to transfer information to the stationary part of the system. In total, it enables a high interpretation reliability of dynamics in a driver’s vigilance level complied with requirements specified for active safety systems. As prototype for the module under development, we may consider DVMS or VIGITON, which use monitoring and automatic analysis of electrodermal arousal parameters (the main criterium for automatic interpretation of the current dynamics in the driver’s relaxation level, the used method has the lowest, among the known ones, probability of dangerous failure ($p - 0,0001$), principles of building a system of safety monitoring of the operator’s (as a human being) state have been applied [1].

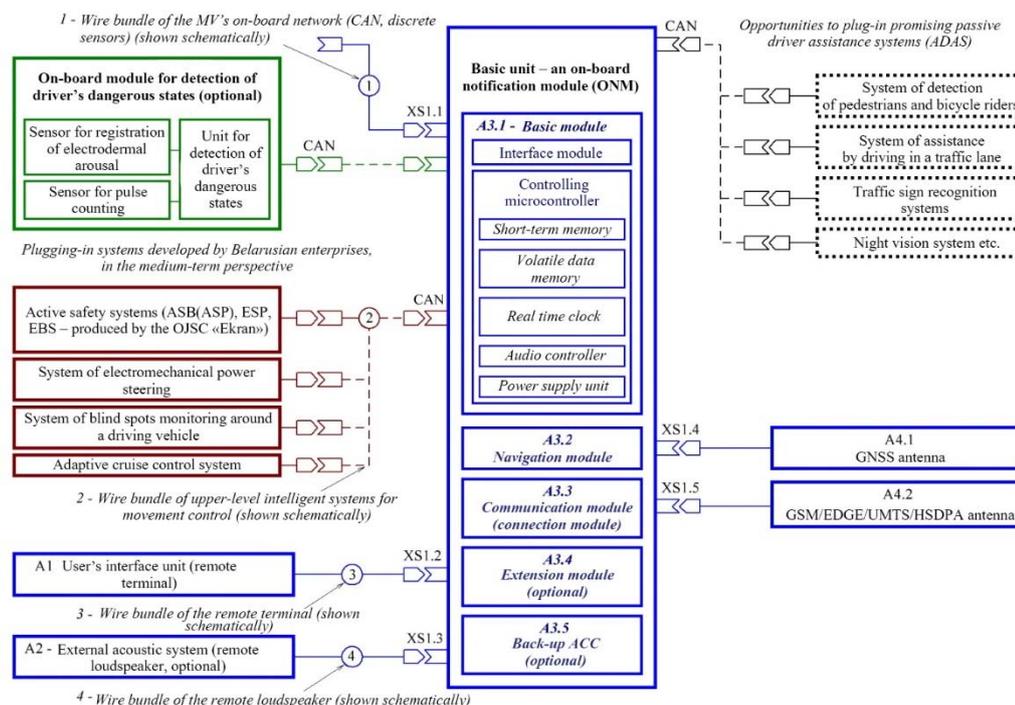


Figure 2. Structure of OIAS and its connection on MV's board.

The technical specification to the on-board module, namely the definitions of the driver's dangerous states (deep relaxation, unconsciousness, death), include a probability of a dangerous error of the used registration method (an error of the 2nd class) in rate of no more than $4 \cdot 10^{-4}$ and a probability flow of dangerous failures causing car accidents in rate of no lower than 10^{-9} .

Navigation module. To improve the accuracy and reliability of the navigation module, the use of jointly processed signals of the operating global navigation satellite systems (GNSS) such as GLONASS (in the frequency ranges of L1, L2), GPS (in the frequency ranges of L1, L2), GALILEO (in the frequency ranges of E1B, E1C, E5a, E5b) and BEIDOU (in the frequency range of B1-C) is provided. To further improving the accuracy of the coordinates determination, it is possible to use RTK (Real Time Kinematic) technology, which allows, due to simultaneous signals processing in real time obtained from GNSS and signals of correcting stations, gaining centimeter accuracy of determining the coordinates. The ability to integrate GNSS signal combining with information from sensors of the microelectromechanical systems and the odometer sensor of the vehicle's path allows the use of the "Dead reckoning" technology, which will reduce the error in calculating navigation parameters, and will also allow estimating the coordinates when GNSS signals are inaccessible, in specified time spans. The module supports automatic monitoring of the integrity (reliability) of navigation calculations and the elimination of inauthentic measurements, the implementation of robust algorithms of differential correction (RTK mode) and algorithms for combining GNSS data and inertial sensors (accelerometers) of in-house design, determination of navigation parameters in WGS-84 or PZ- 90 reference systems (by confidence coefficient of 0.95).

Figure 2 depicts the systems already being developed or planned in the near future in the Republic of Belarus (the electromechanical power steering system, the system of blind spots monitoring around a driving vehicle, ECP brake system and the adaptive cruise control system in the future). Mass production of such systems on board of vehicles is to expect in the short-term perspective. Plugging-in these systems is assumed to be performed via CAN data bus that may be implemented as a part of hardware taking into consideration the developed system.

There is also a significant potential associated with the use of promising passive ADAS. This includes systems of detection of pedestrians and bicycle riders, a system of assistance by driving in a traffic lane, a traffic sign recognition system and night vision system, etc. The operation of these systems is based on the rapidly developing systems of technical vision or (in a number of developments in terms blind spots monitoring, assistance while parking) scanning of space by ultrasonic sensors.

The basic module contains the necessary hardware features and a set of interfaces that provides the implementation of basic functions and technological modes.

The extension module supports additional functions related to interaction with other intelligent systems on board of a vehicle.

The software has a multi-level modular hierarchical structure. Individual modules operate asynchronously with respect to each other, which allows implementing the multi-tasking mode of operation in real time. The file structure used allows maximum isolation of the levels code and modules. The architecture of the basic software is shown in Figure 3.

Description of the levels of the basic software project. BASE level: at the BASE level, there is a module for software implementation of the operating modes of the system and a module of debug interface. The module for software implementation of the operating modes consists of subprograms ensuring the system's operability at the logical level. The module of the debug interface provides access to the variables of the software implementation module at the hardware-independent level. BASE level modules can directly access the hardware-dependent functions of the controller that have atomic access via the HAL level.

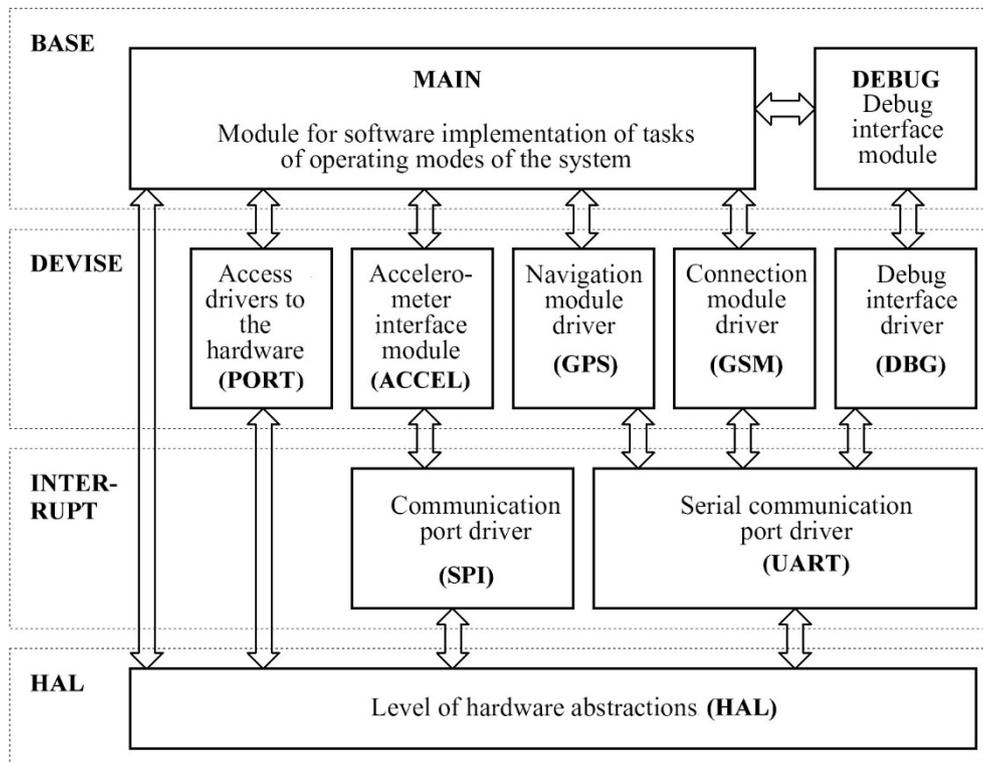


Figure 3. Architecture of the basic software.

DEVICE level: at DEVICE level, there are modules of external device drivers that provide information exchange at the level of protocols specific for each device: active safety systems, driver's functional state monitoring, ADAS, navigation, communications, etc.

The debug interface driver **DEBUG** provides access to the variables of the software implementation module at the protocol level. Access drivers to the **PORT** hardware allow calling hardware-dependent controller functions that require processing at the protocol level (generation of time delays, input of the state of controls with debounce filtering, etc.). The **INTERRUPT** level provides secure joint access to subprogram's data operating in the user mode and to the subprograms running in the core mode (hardware interrupt handlers). The **HAL** level ensures the independence of the **BASE**, **DEVICE** and **INTERRUPT** software codes from the implementation of the hardware platform used.

Conclusion

Implementation in OIAS such functions as driver's state monitoring high-precision calculation of the current navigation coordinates of the vehicle where components, algorithms and software developed in the Union State are used, modularity of the OIAS construction and the possible increase in the functionality through integration with other on-board systems has a promising development future.

The development of intelligent transport systems (ITS) and their components allows us to set and solve fundamentally new tasks for the safety of human-to-machine transport systems, and the automatic analysis of heterogeneous information flows provides a synergistic effect.

Based on the results obtained, the task is to develop a concept of cross-modal (intersensory) interaction in the human-to-machine transport systems. The cross-modal interaction in human-to-machine transport systems is the interaction of hierarchically arranged multi-functional on-board monitoring and control systems (vehicle's and driver's technical components) between themselves and external systems (primarily ITS, dispatching and emergency services) with a targeted function to improve the efficiency of human-to-machine systems. The analysis of cross-modal information

exchange in human-machine transport systems, from uniform methodological points of view, will allow us, with an accuracy acceptable for solving applied problems, to form in real time an integrated assessment of the state of the basic components of the human-to-machine system and the dynamics in changing situation-centered environment, including the external environment, in their interrelations.

Definition

Cross-modal interaction in human-to-machine systems is the transformation, synchronization and analysis of heterogeneous information flows in CAN, MOST, FlexRay data buses, in the future, vehicle Ethernet or its analog and V2V, V2I and V2P (P2V) protocols, in real time scale.

The purpose of the cross-modal interaction analysis is to obtain an integrated assessment (synthesis of the integrated assessment criteria) and automatic generation of control commands for the efficient functioning of vehicles with the support of the intelligent transport systems in real time, and maintenance of human-machine systems in accordance with the actual state.

Reference List

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