Classification of tablesemantically binary relevant information for drivers in highly automated vehicles

V V Savchenko and V V Litarovich
The State Scientific Institution “The Joint Institute of Mechanical Engineering of the National Academy of Sciences of Belarus”, Minsk, Republic of Belarus

E-mail: uus@tut.by

Abstract. The search for ways to solve the problem of transfer control to the driver in highly automated vehicles, involves the development of new methods and adaptation of known under the solution of the problem. The development of the method of monitoring the perception of semantically binary relevant information by the driver implies the identification of sources of significant information and classification of semantically relevant information for drivers coming from ADAS, ITS and the dashboard. Determination the driver's time to response to the relevant information and the subsequent analysis will allow in real time, during the execution of the algorithms of the activity on the management of the highly automated vehicle, without using the additional equipment, to monitor and update the particular driver’s database containing quantitative values that characterize a number of its professionally important qualities, in automatic mode, with the use of cloud servers. The obtained results are focused on the solution of the problem control transfer to the driver in highly automated vehicles, when the vehicle's onboard systems cannot support further “unmanned” mode of control and the vehicle is not within a specific operational design domain.

1. Introduction
In accordance with the UNECE Resolution (ECE/TRANC/WP.1/165) on the introduction into practice of highly automated and fully automated vehicles in traffic conditions, “highly automated vehicle” means a vehicle equipped with an automated driving system. This automated driving system operates “within a specific operational design domain” for some or all trips without the need for human intervention as a fallback to road safety; “operational design domain” means the ambient and geographical conditions, time of day, and road, infrastructure, weather, and other conditions for which the automated driving system is specifically designed to operate.

In the work [1], to solve the problem of the control transfer to the driver in highly automated vehicles when the vehicle’s onboard systems cannot support “unmanned” mode of control further, being at the level of exploratory research today [2], a method is introduced to monitor the perception of semantically binary relevant information by the driver in highly automated vehicles taking into account the circulating information flows in the vehicle’s onboard systems, the driver’s response to semantically binary relevant information, which is based on the earlier works [3-6], the dynamics of a particular driver’s professionally important qualities in the context of solving the problem of transferring control to the driver in highly automated vehicles, when the vehicle's onboard systems cannot support “unmanned” control mode further, i.e. do not correspond to the operational design domain. The current main problems of functioning safety of highly automated and unmanned vehicles are considered. The
structure of the top-level system for transferring control to the driver in highly automated vehicles is presented (figure 1).

Figure 1. Structure of the top-level system for transferring control to the driver in highly automated vehicles.

For implementation of perception monitoring method of the semantically binary relevant information by the driver in the highly automated vehicles, it is necessary to identify the sources and to classify such information.

2. Semantically binary relevant information sources for drivers
Relevant information falls into three categories [6]:
- Warning information is informative, contains information about the general situation (including emergency) and recommendations for action, preserving the ability of the driver to choose the final decision.
- Prescribing information is commanding and requires or permits execution of strictly defined actions.
- Prohibiting information is of an emergency nature, imposes strict restrictions on the performance or prohibition of certain actions, indicates a component unavailability or malfunction.

In highly automated vehicles semantically binary information for the driver is: warning of ADAS about changing situational circumstances and/or a particular driver’s wrong actions in the current situation (crossing the road marking lines without turning on the direction indicator, attempt to change lines when another car is in the dead area of visibility, the sudden emergence of a pedestrian or cyclist, overspeeding, etc.), other relevant information about the vehicle systems operation presented on information boards (panels), in some cases duplicated by an audio signal.

It is also cross-modal relevant information for drivers “circulating” in a communication platform C-V2X for the “connected” vehicles, for example, “transmitted” via V2I protocols (interaction vehicle-to-infrastructure), for example, traffic light sign change, adverse weather conditions warning, etc., according to protocols V2V (interaction vehicle-to-vehicle), for example, an accident along the route of the vehicle, warning of the overtaking danger, “problems” with the road carpet, etc.

3. Semantically binary relevant information classification for drivers
In general, the semantically binary relevant information is an informational message to the driver that can have a different modality, being significant in specific traffic conditions and directing the driver to the immediate implementation of appropriate algorithms activities (“here and now”) or posing requirements to perform important specific actions in the short term. In ADAS, the driver can be informed in three ways: visual, audio and tactile. To classify semantically binary relevant information for drivers coming from ADAS, the following systems were analyzed: FCW – Forward Collision Warning; UFCW – Urban Forward Collision Warning; PCW – Pedestrian Collision Warning; LDW – Line Departure Warning; HMW – Headway Monitoring and Warning; SLI – Speed Limit Indicator; TSR – Traffic Sign Recognition; TLR – Traffic Light Recognition; BSM – Blind Spot Monitoring; DM – Driver Monitoring (monitoring the driver’s attention); RCTA – Rear Cross Traffic Alert; LKAS – Line Keeping Assist System; LCA – Lane Change Assist; PD – Pedestrian Detection; APA – Advanced Parking Assist; NV – Night Vision.

Visual information provision for the driver of the vehicle is carried out using special icons displayed on the vehicle’s digital display or a specially installed system; information reflected on the vehicle’s digital display; highlighting of indicators that are located on the side mirrors or on the rear-view mirror; information display on the vehicle’s windshield in the driver’s field of visibility. Audio information provision of the driver is carried out using embedded audio systems (often with a signal tone and frequency change), tactile information provision of the driver is performed using a vibration mechanism installed in the steering wheel or under the driver's seat of the vehicle.

Table 1 presents the above mentioned systems and the signal modality to inform the driver of the vehicle.

Table 1 shows that all systems provide visual information to the driver of the vehicle. Audio information is not provided in the SLI and TSR, and in TLR, LCA and NV, the availability of informing depends on the manufacturers of the systems, all the other systems provide audio information. Tactile information is not provided in TSR, TLR, DM, RCTA, PD, APA and NV, in DSM and LCA, availability of informing depends on the manufacturer of the system, all the rest provide tactile information.

Semantically binary relevant messages are messages that come from all presented systems, to one degree or another, as well as always messages that have audio and/or tactile information to the driver of the vehicle. Since all systems except NV (there is no data on the system), have a CAN-bus, it is possible to register the information emergence time to analyze it subsequently, for example, to determine the
driver’s time to respond to the relevant information, which makes it possible in real-time during the execution of algorithms for controlling of highly automated vehicle without the use of additional equipment, to monitor and update the specific driver’s database containing quantitative values characterizing a number of his professionally important qualities in automatic mode.

| ADAS | Informat the driver of the vehicle | visual | audio | tactile |
|------|-----------------------------------|--------|-------|--------|
| FCW  | +                                 | +      | +     |        |
| UFCW | +                                 | +      | +     |        |
| PCW  | +                                 | +      | +     |        |
| LDW  | +                                 | +      | +     |        |
| HMW  | +                                 | +      | +     |        |
| SLI  | +                                 | –      | –     | +      |
| TSR  | +                                 | –      | –     |        |
| TLR  | +                                 | +/-    | –     |        |
| BSM  | +                                 | +      | +/-   |        |
| DM   | +                                 | +      | –     |        |
| RCTA | +                                 | +      | –     |        |
| LKAS | +                                 | +      |        |
| LCA  | +                                 | +/-    | +/-   |        |
| PD   | +                                 | +      | –     |        |
| APA  | +                                 | +      | –     |        |
| NV   | +                                 | +/-    | –     |        |

4. Systems that are part of ITS and inform the driver of the vehicle

ITS, providing information to the driver: RWIS – Road Weather Information System; ATIS – Advanced Traveler Information Systems; ATMS – Advanced Traffic Management System, collects statistical data on vehicle traffic, aimed at unloading and redistribution of traffic flows based on the collected data analysis; the ATMS consists of several subsystems of narrow focus, which monitor the traffic of certain areas of the road network and provide information to the driver of the vehicle. ATMS subsystems:

- **BTM – Bridge/Tunnel Management.** The system controls road traffic on bridges and tunnels and includes:
  - **HWWS – High Wind Warning System.** High Wind Warning Systems monitor wind speed and direction and inform the driver when wind conditions pose a potential hazard. High wind warnings are typically part of traffic management systems on bridges. Typically, wind warnings are divided into different levels according to pre-set thresholds for various parameters, including wind speed, direction, and stability. Depending on the conditions, response plans are executed, ranging from spreading warning messages for approaching traffic to complete closure of the bridge in severe conditions. As the impact of high winds varies depending on the vehicle’s size, warning messages often target specific vehicle types, primarily alerting the most exposed vehicles and advising drivers to reduce vehicle speed to minimize potential hazards. Depending on the conditions, the response plan may include restricting access only of small vehicles to the bridge and eventually close the bridge completely. Depending on the subsystems involved in the traffic management system on the bridge, warning messages may be distributed through the media, HAR and/or DMS [7];
  - **OOD – Overheight/Overweight Detection of the vehicle.** Overheight detection systems include the installation of devices on the track prior to the object emergence with a height restriction. The aim is to detect the excess, and alert the driver so that he can choose a different route. These devices can range from a simple mechanical device, such as chains suspended over the road...
surface, to more sophisticated electronic overheight detection systems. The devices are used in conjunction with road signs (both static and dynamic) to inform the driver of a vehicle exceeding the permissible clearance and to redirect him to the appropriate route. With regard to the detection of overweight, all commercial vehicles must be weighed at commercial vehicle inspection stations located at specific points throughout the road network or using specialized equipment Weigh-in-Motion (WIM) [7]. WIM can be used on selected sites located in front of stations to verify and confirm that the weight and dimensions of the commercial vehicle are within acceptable limits. WIM is an effective sorting tool that helps inspectors identify problem vehicles while at the same time allowing the relevant vehicles to pass through the inspection site unhindered.

- **SWZ – Smart Work Zones.** Applications that inform the driver in construction work areas. Technologies and systems that are used to inform [7]:
  - **RI/MS – Roadway Information/Monitoring Systems.** The system is intended for monitoring and informing in repair areas. One or more vehicle detectors located in the working areas are used. They are often used together with portable variable message signs (PVMS) to inform drivers about the reduction of speed down the route, creating an autonomous system that automatically generates messages for PVMS;
  - **MC – Merge Control.** Several ITS products have been developed for merge control, which provide a smooth traffic flow leading to the work area by creating a dynamically impassable zone in front of the construction site, which reduces conflicts, reduces collisions and reduces "road rage". Trailer-mounted portable signs usually consist of flashing lights and a "DO NOT PASS WHEN FLASHING" sign. The system purpose is to merge the car flow at an early stage to prevent "backups" of car flows that may occur when merging at the last minute.

  Table 2 presents the above mentioned systems and the modality of signals for informing the driver of the vehicle.

| ITS           | Informing the driver of the vehicle | visual | audio |
|---------------|-------------------------------------|--------|-------|
| RWIS          |                                     | +      | +     |
| ATIS          |                                     | +      | +     |
| ATMS          |                                     | +      | +     |
| BTM           | HWWS                                | +      | +     |
|               | OOD                                 | +      | –     |
| SWZ           | RI/MS                               | +      | –     |
|               | MC                                  | +      | –     |

Table 2 shows that all systems of this class provide visual information to the driver of the vehicle, audio information provision is carried out in all systems except the OOD, RI/MS and MC subsystems. Semantically binary relevant information would constitute as information that is critical to the driver at a given time and/or in the given situational circumstances:

- **RWIS –** bad weather icons that are reflected on the vehicle display, and discrete audio signals.
- **ATIS –** information is displayed on vehicle information systems (warning of adverse conditions such as sharp turns, wet road surface, etc.).
- **ATMS –** information is provided by the vehicle's navigation systems and RDMS.
- **HWWS –** information is provided using DMS.
- **OOD –** information is provided by dynamic and static road signs and specialized height control devices.
- **SWZ –** information is provided using PVMS, Queue Warning, and WZIA.
• RI/MS – information is provided using PVMS.
• MC – information is provided by signs that include flashing lights and an explanatory inscription to them.

5. **Informing the driver using the potential of the communication platform C-V2X**

Informing the driver is provided mainly in two ways – visual and audio, and only in some cases – tactile impact. Informing the driver using C-V2X, main subsystems:

- **V2V** – vehicle-to-vehicle interaction. It is designed to provide communication between the vehicles, the transmitted information using V2V contains the following data: speed, direction, braking status, vehicle location, etc. The range of V2V messages reaches more than 300 meters, which makes it possible to detect dangerous situations that cannot be observed due to traffic density, terrain or weather conditions. Informing the driver is carried out by special icons on the onboard computer of the vehicle, audio signals, and the tactile information provision to the driver is being developed, presumably on the steering wheel [8].

- **V2I** – vehicle-to-infrastructure interaction. V2I allows vehicles to exchange information with components that support the highway system. Such components include RFID readers, cameras, traffic lights, lane signs, street lights, signs and parking meters. V2I communication is wireless and bidirectional: data from infrastructure components can be delivered to the vehicle via a special network and vice versa. In ITS, V2I sensors can collect infrastructure data and provide travelers with real-time information on issues such as road conditions, traffic jams, accidents, construction areas and parking availability [9]. Similarly, traffic control systems can use data from infrastructure and vehicles to set variable speed limits and adjust the phase and timing of traffic lights (SPaT – Signal Phase and Timing) to increase fuel economy and speed of traffic flow. Information provision of the driver of the vehicle is carried out using special icons displayed on the vehicle’s onboard computer or monitor, audio signals, tactile effects (vibration on the pedal or steering wheel) [10].

- **V2P** – vehicle-to-pedestrian interaction. V2P makes it possible to exchange location information between a vehicle and a pedestrian. Information provision of the driver of the vehicle is carried out using the display of pedestrian icons and action icons, for example, the system developed by Honda based on V2P can recognize some pedestrian actions (talking on the phone, texting, listening to music with headphones) when a dangerous approach, the inscription “WARNING” is displayed on the vehicle's onboard computer or on the HUD (Head-Up Display), and emergency braking is performed. The icon display is duplicated by short audio signals [11].

Table 3 presents the above mentioned systems and the modality of signals for informing the driver of the vehicle.

| C-V2X | Visual | Audio | Tactile |
|-------|--------|-------|---------|
| V2V   | +      | +     | +/-     |
| V2I   | +      | +     | +       |
| V2P   | +      | +     | -       |

Table 3 shows that all technologies provide visual and audio information to the driver of the vehicle. Provision of tactile information is performed in V2I, and it is under development for V2V. All types of alerts of vehicle driver are semantically binary relevant information.

6. **Informing the driver of the vehicle from the dashboard**

Informing the driver of the vehicle from the dashboard (indicator panel) can be carried out in two ways – visual and audio. The information is provided to the driver using the indicator panel.
Informing the driver is carried out by the following devices: speedometer, tachometer, odometer, fuel level indicator, engine coolant temperature gage, econometer, indicator lights, alarms reflected on the LCD display.

Table 4 presents the above mentioned devices and the modality of signals for informing the driver of the vehicle.

| Dashboard | Informing the driver of the vehicle visual | Informing the driver of the vehicle audio |
|-----------|------------------------------------------|------------------------------------------|
| Speedometer | +                                       | –                                        |
| Tachometer  | +                                       | –                                        |
| Odometer    | +                                       | –                                        |
| Fuel level indicator | + | – |
| Engine coolant temperature gage | + | – |
| Econometer  | +                                       | –                                        |
| Indicator lights | + | +/– |
| LCD display | +                                       | –                                        |

The information coming from all instrument panel components is semantically binary relevant information to one degree or another. As a rule, indicator lights marked in red are duplicated by an audio signal.

Table 4 shows that visual information provision of the driver is carried out by all presented devices. Audio signal duplication is provided for the indicator lights that carry out the alarm, for the fault of the brake system, the oil pressure in the engine lubrication system.

7. Conclusion
To develop the perception monitoring method of semantically binary relevant information by the driver in highly automated vehicles and the subsequent problem solution of control transfer to the driver in highly automated vehicles, when onboard vehicle systems cannot support further “unmanned” control mode, the classification of semantically binary relevant information for the drivers coming from ADAS, ITS and dashboard is presented. In general, semantically binary relevant information is information message to the driver, it can be of different modalities, significant in specific traffic conditions and prescribing the driver to immediately perform the relevant algorithms of activity (“here and now”) or imposing requirements for the implementation of important specific actions in the short term. Determining the driver’s time to respond to the relevant information and its subsequent analysis allows in real time, during the execution of algorithms for the management of highly automated vehicle, without using the additional equipment, to monitor and update the particular driver’s database containing quantitative values characterizing a number of his professionally important qualities in automatic mode, for which cloud services are used.

References
[1] Savchenko V V 2019 Problem of transferring control to the driver in highly automated vehicles: method of monitoring the perception of semantically binary relevant information by the driver Mechanics of machines, mechanisms and materials 2(47) pp 14–9
[2] Effects of adaptive cruise control and highly automated driving on workload and situation awareness: a review of the empirical evidence Information on https://www.vdi-wissensforum.de/news/effects-of-adaptive-cruise-control-and-highly-automated-driving/
[3] Savchenko V V 1991 Methods and means of improving the efficiency functioning of ergatic system operators (abstract of the thesis SPb) p 16
[4] Savchenko V V 1992 Methods and means of improving the efficiency of ergatic system operators (control of the level of waking, control of the perception of relevant information by the
operator, algorithms of increasing the efficiency of operators of precision production (Minsk: Institute of Technical Cybernetics of the Academy of Sciences of Belarus)

[5] Man'shin G G, Savchenko V V and Shunevich N N 1994 *Operator functional state control device* (Patent RU 2020871)

[6] Savchenko V V 2005 Methods and means of improving the efficiency functioning of operators of human-machine transport systems *Vesti National Academy of Sciences of Belarus* 2 pp 29–37

[7] *Advanced Traffic Management Systems. Ontario Traffic Manual* 2007 B 19 p 148

[8] Vehicle-to-Vehicle Communication Information on https://www.nhtsa.gov/technology-innovation/vehicle-vehicle-communication

[9] Vehicle-to-Infrastructure (V2I or v2i) Information on https://whatis.techtarget.com/definition/vehicle-to-infrastructure-V2I-or-V2X

[10] *Definition of necessary vehicle and infrastructure systems for Automated Driving* 2011 (European Commission) p 111

[11] Honda V2P Overview Information on https://www.qualcomm.com/videos/honda-v2p-overview