DRIVER ASSISTANCE SYSTEMS IN VEHICLES USING AUGMENTED REALITY – BENEFITS AND CHALLENGES

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Abstract: *The issues related to road safety and the complexity of the driving task present a continuously increasing burden for the driver. In order to support this task, the existing on-board systems in vehicles primarily display visual messages, forcing drivers to move their eyes from the road. This paper presents a survey of studies related to perception and cognitive attention of drivers when this information is presented on the windshield (Head-Up Displays). Past research has suggested that this technology is considered as a possible solution for reducing the time and frequency of drivers moving their eyes of traffic. However, this technology brings its own challenges that are discussed in this paper. Augmented Reality concept is also presented because this solution adds new challenges to the technology as the risk of occlusion of real objects that are relevant to the traffic as well as phenomena like perception tunneling and cognitive capture.*

Keywords: DRIVER ASSISTANCE SYSTEMS, HEAD-UP DISPLAYS, AUGMENTED REALITY, 3D VISUALIZATION, ROAD SAFETY.

1. Introduction

Driver Assistance Systems in the automotive industry have been developing for several years, with a final goal to improve the safety of the driver and the passengers, but also to improve the performance, efficiency and comfort through ICT. The activity of operating a motor vehicle is highly complex. Partially, that is because of the high time limitations needed for the human to notice, percept, process information before making a decision, and act appropriately. This activity is happening in an environment of traffic filled with unpredictable situations. In such an environment, displaying appropriate information, like step-by-step navigation instructions, information about the road conditions, accidents or work on road, distance to the vehicle in front, danger from rockslides and similar information can be highly useful as information in support of the decision making and preparation for appropriate action. Issues of the ergonomic design aspect for these solutions are focused on determining the most appropriate ways for ensuring efficient and effective cooperation between human and the system in context of that that the driving activity is of primary importance. The efficiency, or on the contrary, the negative effects of the aspect of road safety while using these systems is mainly depended of the compatibility of their interfaces, the way of dialog, surrounding and functional ability of the drivers [1].

The European Commission in its document the European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems presents the framework recommendations and principles that need to be fulfilled when developing these components, as well as the basic safety aspects that need to be followed. The document lists the key European directives and international standards that provide the framework for the manufacturers and suppliers of such equipment to be able to plan their development and implementation [2]. Geham (2005) states that in order to increase safety of the driver and passengers it is more important for the vehicles through the systems for active safety to avoid accidents compared to the minimizing effects of the accidents through the systems for passive safety. The systems for driver assistance aim to increase the safety and/or comfort and to assist the driver to focus on the driving activity.

Regarding the perception, it has been concluded before long time that the driving performance are in tight correlation with the ability for visual perception and visual strategy. Lot of authors agree to the fact that the perceptive visual channel is of paramount importance for the driving activity [3,4]. It is estimated that up to 90% of the needed information for seamless completion of this task are communicated through the visual channel. The existing systems in vehicles are mainly presenting visual messages: in a form of text messages, pictograms and/or graphic maps on displays integrated in the dashboard. When the driver needs to operate these systems, he has to move his view from the road for several seconds. The probability for an accident increases with the duration of the time the driver is not watching on the road [3, 4, 5]. Studies determine that the key duration of sight of the road while driving is 2 seconds [6]. In wider perspective, any integrated display in the vehicle can be assessed as visual cost that can be quantified in a number of occurrences and duration in order to get an information from the system [7].

Because there is a void or distance between the physical spaces (for example the road and the vehicle interior) and the virtual ICT spaces (for example the integrated display in the vehicle), the user has to spend time and cognitive effort to adjust from one space to the other. This void is referred as cognitive distance between the physical and the computer world [6]. Two separate components exist that consist the cognitive distance. The first component is the cognitive effort needed in order for the driver to move his/her attention from the physical to the computer environment and to locate the appropriate information in that space: moving the view from the road to the display. The second component is the needed effort to return back from the computer environment to the physical world and to implement the gained information in the current activity like using the systems for GPS navigation, glance from the ICT map to the road and the real environment and making a decision regarding the maneuvering and driving of the vehicle. The increased effort for completion of each of the components that make the cognitive distance result in increased total result of the cognitive distance. Going into details, if the user has to switch between spaces often the effect of the cognitive distance is even bigger. This is significant for people with cognitive disabilities, people that complete activities that are in tight regard to the time duration, or activities that have big cognitive load. This is especially important for older drivers that often have weak cognitive system as result of their age [6].

In this regard, the concern of the human factor is how to define criteria for efficient recommendations for support in the design of the systems for driver assistance in vehicles with displaying visual messages without the need to distract the attention of the driver from the driving activity [8]. This should also take into consideration the major road safety issues knowing that the number of systems implemented in vehicles is getting bigger each year [9, 10].

2. Head-Up Displays and Augmented Reality in Automotive Industry

The way information is displayed on the windshield of vehicles or the Head Up Display (HUD) can be one of the solutions for presenting information from the driver assistance system because they are already proven concept for reducing the time and frequency of sight off road while driving [11]. The HUD system is defined as see-through display that presents data without the need of the user to change the usual viewpoint.

Augmented reality (AR) is a concept in which the presented information to the windshield of the vehicle correspond to the elements in the physical world or the real objects in the traffic environment. This concept presents information at the right place where the need for that information origins. With that the number of glances off road in order for the driver to obtain visual information is reduced.

Historically, the HUD systems have been first introduced in fighter jets where the information were shown in the field of view of the pilot. In the automotive industry, for the first time they are introduced by General Motors in 1988 in Oldsmobile Cutlass Supreme. Although, the HUD systems are not a new concept, their sales is not according the expectations. That is mainly due different issues with the technology, like the used light sources and optical solutions. Today, there is a significant increase in the demand for these systems from the car manufacturers following the constant improvements in the used ICT.

Only 2% of the vehicles sold in 2012 had a HUD system. Nevertheless, it is expected that by 2020 this percent will reach up to 9. Japan has the highest percentage of vehicles with HUD system in 2010, but it is expected that Europe will become leader in this segment by 2020 [35]. In further, the HUD technology in combination with AR offers potential to overcome the existing issues for displaying visual information for drivers compared to the traditional displays.

One of the key advantages that is expected to be achieved from the increased focal distance of the HUD systems is the reduction of the need to adjust when switching the views and the reduced need for additional adjustment of the driver’s eye focus when returning the view to the road. It is expected that the biggest benefit from this feature will be to the older drivers [6], because they have limited range of adoption and they will not have to glance through the lower part of the view field of their glasses in order to read out an information from the dashboard [15].

In addition to that, HUD gains much more attention because it reduces the time needed for adaption of the driver’s focus [12], it increases the time of sight on road by reducing the time needed to look at the dashboard and the other systems in the vehicle interior [13, 14].

The time needed for driver’s reaction in an emergency is shorter when using these systems compared to the traditional displays. In addition, the speed control is more consistent [4, 6]. These systems enable the driver to spend more time on scanning the traffic, faster response times in unpredictable situations in the traffic, earlier detection of danger, lower mental stress for the drivers, easier use for beginners in traffic [17], lower number of mistakes, shorter times compared to the use of traditional systems for information displaying in vehicles [18] as well as increased understanding of the surrounding of the vehicle especially in conditions of bad visibility [16]. Altogether, bigger number of drivers feel safer when driving a vehicle equipped with HUD system [19].

The advantages in aspect of better understanding of the situation in the traffic can influence on the probability of the driver to successfully notice an event in critical time [15]. Therefore, it is expected that in the future the HUD systems will become important equipment for most part of the drivers.

However, these systems are also criticized, for example the measured times for scanning of the traffic are valid only in situations with lower load of obligations for the driver and they cannot be generalized for all conditions [15]. Furthermore, these systems can have negative effect if the information projected on the windshield occludes some of the real objects form the traffic scene [20]. This effect is in conjunction to the level of filling up of the field of view as result of the information displayed by the system and the contrast between the displayed information and the real environment in the background [15].

Some of the shortcomings of the previously described system can be overcame with the concept of augmented reality (AR). AR is enriching the three-dimensional world by adding computer generated virtual objects into the user surrounding [28]. This concept has recently been further developed in the context of the automotive industry, enabling registration of the projected information on to the windshield and the real world that the user is looking at [16, 29]. The combination of object or locations and the appropriate information allow condensation of information and enrichment of the perception. This way of information presentation uses new, implicit schemes of presentation that present a lower mental load for the user while interpretation. Especially the information regarding the spatial relations to the surrounding of the vehicle have the capacity to be transferred in AR.

A decade ago, researchers have started investigating and evaluating the concepts for visualization based on AR using mobile platforms or driving simulators based on projectors [30, 31, 32]. The fact that information can be related to the location of the object of interest introduces new possibilities for fast and efficient presentation of information. In the same time, it generated new challenges.

Compared to the HUD systems, the presentation of information in AR has several shortcomings like for example the risk of occlusion of objects of interest in the traffic scene, and the phenomena like perception tunnel and cognitive capture.

In the next part of the paper several displays based on HUD-AR are presented and their functions are analyzed from the aspect of operating a vehicle.

3. Analysis of the existing systems for driver assistance based on the HUD-AR technology

Having in mind the advantages of the systems and in order to test the effects, different types of HUD-AR displays have been analyzed from the aspect of several of their functions for driver assistance.

3.1. Lane Departure

While testing the AR systems that present safe corridor for lane departure when driving in order to provide the driver with the ability to safely overtake a vehicle in front of, the researchers have noticed a significant improvement in two positive aspects: bigger number of the drivers used the braking pedal to lower the speed, which in general is a positive indicator from the aspect of safety; all drivers operated the vehicle and braked in a similar way, according the instructions of the desired path. Nevertheless, the behavior of the drivers in adverse situations have not been investigated, that is when the vehicle is in the dead spot or when overtaken by a faster vehicle. Furthermore, this study shows that in situations of lane departure, AAR systems have the tendency to make the drivers glance at the side rear view mirror later compared to the drivers not using such a system, because the visual attention of the driver is firstly occupied by the AR display on the road (Figure 1.). After they interpret this AR information, the drivers checked the side mirror to prepare for lane departure.

Fig. 1 *Driver Assistance System for lane departure*

(Source: http://cdn.bmwblog.com/wp-content/uploads/head-up-display-augumented-reality-04.jpg).

Keeping the desired path of the vehicle while driving can be especially difficult for unexperienced drivers and/or in bad weather conditions when the visibility is lower. The concept of augmented reality enables outlining of the road edge with a virtual element assisting the driver in the task of maneuvering the vehicle (Figure 2, Figure 3). By displaying a path for driving in augmented reality, the maintaining of the vehicle in the desired path of motion can be achieved while lowering the deviations from the desired trajectory [19].

Fig. 2 *Driver Assistance System for lane keeping*

(Source: http://continental-head-up-display.com/ar-hud/#arhudfeatures).

Fig. 3 *Driver Assistance System for lane keeping*

(Source: http://www.wired.com/2010/03/gm-next-gen-heads-up-display).

3.2. Detection of critical events on the road

Drivers must be careful on the vehicles around them, the dangers on the road, the desired path, pedestrians and traffic signs and all of that while driving the vehicle, controlling its speed and direction. All these tasks increase the physical and the mental workload, which is especially dangerous for older drivers and drivers with lower reflexes. Hence, an alarm that would warn the driver for an eminent danger on the road can assist in minimizing the workload of the driver and decrease the number of accidents. The fact that a critical event can be presented on the windshield can assist the driver in detecting the dangerous events (Figure 4, Figure 5). Compared to traditional systems for driver assistance, HUD-AR systems lower the time needed for detection of an event up to 100ms [34].

Fig. 4 *Driver Assistance System for obstacle detection on the road*

(Source: http://continental-head-up-display.com/ar-hud/#arhudfeatures).

Fig. 5 *Driver Assistance System for critical events detection*

(Source: http://continental-head-up-display.com/ar-hud/#arhudfeatures).

3.3. Night Vision

The systems for displaying information with AR can significantly improve the visualization in dark, emphasizing the location of pedestrians and other obstacles on the road, enabling drivers to efficiently transfer information that is instantly understandable [32, 35].

Night vision systems are known from time ago and for the first time were used in the military industry. In the automotive industry, this type of systems was introduced for the first time in a serial production model by Mercedes-Benz in 2011. This system shows an image on display placed in the instrument panel of the vehicle. That means that the driver needs to move the eyes from the road, to interpret the image on the display, to return the view on the road and to implement the information gained from the system. The systems for night vision using AR present the very same information but this time directly on the windshield and with that significantly lowering the workload of the driver and decreasing the time needed for processing of the information and taking action (Figure 6).

Fig. 6 *Driver Assistance System for night vision*

(Source: http://w-info.blogspot.mk/2013/05/hud-head-up-displays-windshield.html).

3.4. Navigation

The concept for projecting navigational instructions and guiding through space directly on the windshield using HUD or AR has been researched for several years now. The main goal of the researchers is to investigate if this way of informing the driver makes the decision making process easier for the driver that is navigating through different traffic conditions and complex road infrastructures. The use of navigation systems based on GPS that presents information on display results in divided attention, meaning the driver needs to focus the view at the display with navigational instructions and the road ahead at the same time. In addition, a significant cognitive effort is needed to interpret the computer-generated streets on the navigational system and connecting them to the real streets in 3D perspective of the driver.

Fig. 7 *Driver Assistance System for navigation*

(Source: https://www.the4cast.com/2013/09/pioneer-launches-navgate-head-display-hud-future-satellite-navigation).

Projecting information in AR can be used to minimize the issue of visual distraction. The distraction and the cognitive effort can be mitigated through overlapping the navigational information with the real world directly on the windshield. In that way, the system assists the driver and enables him/her to focus the attention only on one location and easily interpret virtual information in efficient navigational instructions.

Some navigation solution based on AR [36], use the complete surface of the windshield to project navigational information like the destination or the distance to it in combination with the heading of movement that the driver needs to follow.

Some researchers develop similar system for driver assistance where instead of standard navigational instruction the solution uses so called virtual cable. This solution uses a volumetric display to create a 3D image and overlay it to the view of the real world through the windshield.

Fig. 8 *Driver Assistance System for navigation*

(Source: http://www.ohgizmo.com/2007/12/17/virtual-cable-provides-better-in-car-navigation).

However, because the virtual image of the AR is by definition connected to the reality or the road infrastructure, the potential for anticipation with this type of display while navigating through space is less efficient compared to the existing displays of the navigation devices. They inform the driver for the next steps necessary to undertake much earlier than the AR based devices that provide this information after the location is in the field of view of the driver. To overcome this problem, some researches [6] develop device based on AR that allows anticipation of the next steps even when the appropriate infrastructure is still not in the field of view of the driver. In this original concept, the AR information is overlapped in the upper portion of the real street and continues with the display of the streets that come ahead and what the driver needs to follow even they are still not in the driver’s field of view (Figure 8).

While testing this device, the authors have notices that older drivers liked the fact that AR allows them to see at the same time the navigational instructions and the real street. They have also mentioned that this enables them to easily notice the pedestrians crossing the streets. As expected, AR reduces separation of the attention and the cognitive load for older drivers that have difficulties using the navigation devices and most of them have lower cognitive functions.

Fig. 9 *Driver Assistance System for navigation*

(Source: Seung Jun Kim, Anind K. Dey [6]).

However, it was noticed that in cases when the visualization informs before time about the needed activities like the needed turn in a street, some drivers made mistakes and turned earlier, before they have arrived at the appropriate intersection. Other drivers have commented that when the visualization have instructed them to drive straight (by presenting a lighted path moving upward on the windshield) they thought that they can continue to drive straight no matter the real condition of the traffic scene and the signals at the traffic lights.

4. Conclusion

Besides the fact that the HUD systems are present since the 80s, they are still not a usual way of displaying visual information in the automotive industry. Studies have shown that HUD displays have bigger potential, but they have lower acceptance level from drivers. One of the possible reasons for that why HUD systems are still not well established is the fact that so far the focus was on their development as technology, and not on adjusting to the needs of their use by drivers. The design principals of the classic 2D displays are not applicable any more in full for this way of presentation, because of the different habits of movement of the visualized objects. Further research is needed in the area of determining the combination of design principals that provide best results for a certain driving activity especially for HUD and AR.

Based on that perspective, the review presented in this paper shows that HUD-AR visual displays have great potential from the aspect of driver assistance in the way of increasing the perception and decreasing the work load, but with caution to the design principles and implementation of information to the windshield. In addition, it is necessary to make additional studies in real conditions and not with the use of driving simulator in order to get better understanding of the acceptance level of the driver for the HUD systems and to get understanding of that where drivers like to receive the information.

Further research should be conducted on the aspect of human factors in order to fully understand the ways of optimization of the huge technological advantages of the HUD-AR concept in the automotive industry with a final goal to increase the road safety.

Understanding the challenges that these systems are bringing and their effect to the road safety in the everyday use in traffic should become part of the capacities of the other stakeholders (police, departments for motor vehicles, insurance experts, prosecutors and others) involved in the process of keeping the roads safe.

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