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ADAPTING ADAS TO TRAFFIC STATES

AN APPROACH OF HUMAN-CENTRED AUTOMATION

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ABSTRACT

Field studies show that different traffic states lead to specific errors of the drivers' when entering the freeway. In order to adapt Advanced Driver Assistance Systems (ADAS) functions to these traffic states these have to be measured in real-time from a moving car. Two methods were developed to this aim and evaluated in field studies. It is shown that the detection rate of traffic states is sufficient for an adaptation of ADAS. In a simulator study different traffic states were then examined to derive concepts for adaptive ADAS. These will in future experiments be evaluated.

KEYWORDS

Advanced driver assistance systems (ADAS), human-centred automation, adaptive automation, traffic state

DRIVER ASSISTANCE SYSTEM MANAGER (ADAS MANAGER)

The German Helmholtz Association uses an "Impuls- und Vernetzungsfond" (further information: www.helmholtz.de/de/Wir_ueber_uns/Profil/Impuls-_und_Vernetzungsfonds.html) to support the collaboration between Helmholtz Centres and German universities. From this fond, 65 Virtual Institutes (VI) were introduced since 2003. One of the first was the VI 'Human-Centered Automation in Traffic'. From the Helmholtz Association the Institute for Transportation Research (IFS) at the German Aerospace Center (DLR) participates. The Center for Traffic Sciences (IZVW) at Julius-Maximilians University of Würzburg and the Institut für Kraftfahrwesen (ika) at the RWTH Aachen are university partners. The primary goal of the VI is to research jointly in order to increase traffic safety and efficiency. A human-centred research approach is used to improve the development of ADAS for cars. This approach is demonstrated by using the task of entering the freeway.

The first step of the joint research of the VI was to define a common framework for the adaptation of ADAS with regard to the needs of the drivers and to select a relevant ADAS function with which to examine this approach. The concept of an ‘ADAS-Manager’ uses traffic states on the one hand and driver states on the other hand as an input (see Figure 1). Both traffic and driver states are supposed to be closely related to specific driving errors which may be counteracted or be prevented by a special ADAS functionality, a special feedback to the driver (ADAS strategy) and a certain technical characteristic of the assistance function. For example, when drivers enter the traffic at very low traffic densities, a lane change assistance function is selected which warns the drivers acoustically if another vehicle happens to drive right beside him if he starts to merge on the highway. In contrast, if the traffic density is very high, an ADAS function is selected which presents visual hints of which gap to select in traffic and which also watches for preceding car, keeping a safe distance towards them by means of changing vehicle speed autonomously. Depending on characteristics of the driver (e.g. inexperienced novice driver or experienced driver) different distances may be chosen (adaptation of ADAS parameters). Overall, the aim of the ADAS manager is to assist the driver in a way which is most adequate to the situation and the driver’s state and thus effectively prevents errors of the driver.

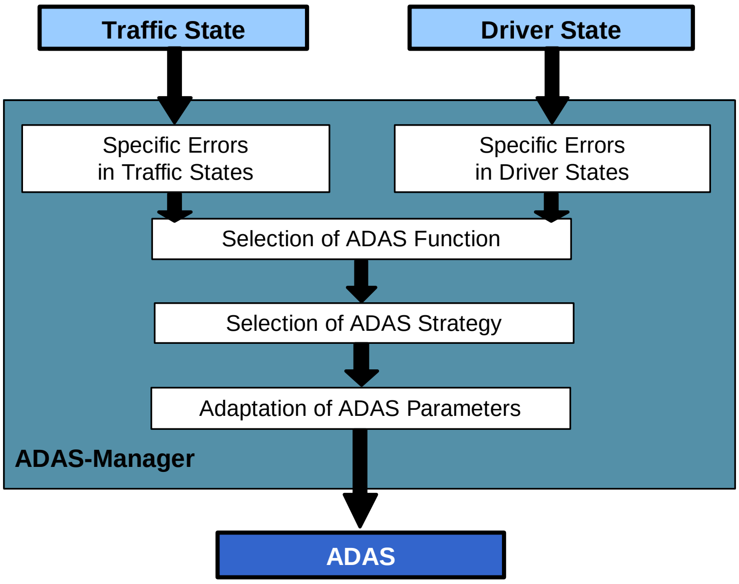

Figure 1 - Concept of the ADAS-Manager

The first step to develop an ADAS manager is thus to examine errors depending on the characteristics of the situation or the driver. Within the VI a field study was done by the DLR using the DLR ViewCar [1, 2]. It could be shown that different kinds of critical situations occurred when entering a freeway [3, 4]. On the one hand, critical situations were found when selecting a gap in flowing traffic and entering it safely. On the other hand, keeping a safe distance towards preceding cars presented problems for the drivers under certain circumstances. By analysing video and data recordings of the merging process it was shown that errors were found most often at either very low or very high levels of traffic flow. However, the reasons may be different: Drivers seem to neglect to watch oncoming traffic at very low flows and are overtaxed at very high flows. This interpretation is supported by accident studies showing that different types of crashes occur at different levels of traffic flow [5]. Thus, this study supported the notion of a correlation between traffic states and specific errors of the drivers. With this starting point, investigations were done with two aims: (1) In order to adapt the ADAS to the different states, these have to be measured from within the moving vehicle. Two different approaches to achieve this were examined by the DLR and the ika. The results are presented in the next section. (2) In parallel, the IZVW conducted a driving simulator study were traffic states were systematically varied and driver errors were examined. The results of these study are presented in a further section.

MEASURING TRAFFIC STATES FROM A MOVING VEHICLE

The adaptation of ADAS functionality with regard to traffic flow requires an on-line estimation of the traffic flow level. DLR and ika both developed methods to achieve this with different sensor configurations. The DLR uses an IBEO laser-scanner with a range of 210 degrees as shown in Figure 2. As a measure of traffic density, the percentage of the scanning range in which other vehicles are present is computed. This is shown by the darker areas in Figure 2. For the computation the information about the position of the different lanes provided by a video-based lane recognition system is additionally used. Finally, the mean speed of all vehicles detected (including the DLR ViewCar) is used. Both measures (density and speed) are combined to estimate the level of traffic flow.

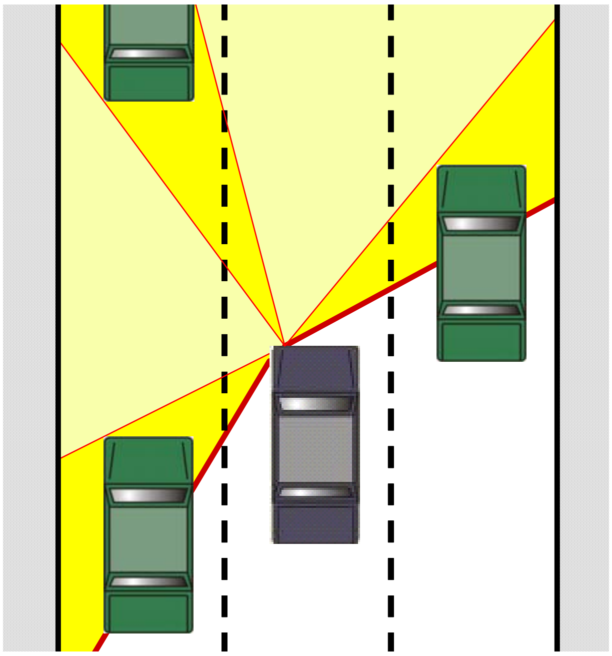

Figure 2 - Detecting traffic flow using the IBEO laser-scanner in the DLR ViewCar

Comparisons with a video rating of levels of traffic flow show a very good correlation. Thus, this method yields a very good real-time measure of the current level of traffic flow. This method was afterwards improved and refined (see [6] at this conference). Additionally, a very high correlation to subjective ratings of drivers in their vehicles could be shown (see [7] at this conference) indicating that this is a valid parameter reflecting one aspect of traffic which is also relevant for the drivers.

However, a large amount of sensor information is needed for this method. The ika examined the possibility to provide a similar estimation using only a radar-sensor which is, e.g. being used in an ACC (adaptive cruise control) system and thus readily available in modern cars. The radar gives information about the presence and distance of preceding cars. Additionally, the speed of the own car is used to estimate the level of traffic flow. By comparing the results with measurements from stationary sensors at a freeway in the proximity of Cologne it was shown that a quite good estimation is possible even with this simple sensor configuration. However, this method requires an averaging of measurements so that reliable estimates may only be given for periods of about one minute. This is sufficient to use when driving on a freeway where traffic flow does not change very frequently. However, for use for an ADAS at ramps this estimation is only useful when other cars at the freeway transmit this information to the car entering the freeway by, e.g., means of car-to-car-communication.

Overall, both methods enable to develop a demonstration for an adaptive ADAS when entering a freeway. With the DLR method this is possible from within a car. However, a laser scanner is required. The ika approach can be used when information from local traffic flows at the ramp are provided via Car2Car or Infrastructur2Car information. The question remains of how to select and adapt ADAS functions and strategy to the different traffic states. In order to answer this question, the IZVW conducted a driving simulator experiment which is described in the next section.

TRAFFIC STATES AND ERRORS IN THE DRIVING SIMULATOR

In order to systematically examine the effect of different traffic states on driving errors when merging on a freeway, an experimental approach was chosen. The ika provided a literature review to define different levels of traffic flow [8-10]. These were implemented in the PELOPS traffic simulation of the ika and could thus be systematically varied at simulated ramps of a freeway. The results of this traffic simulation were transferred to the motion-based driving simulator of the IZVW. The behaviour and subjective evaluation of n = 44 subjects entering the freeway at 7 different traffic states were recorded and analysed. Two different conditions were constructed. In the first, the different vehicles were well coordinated resulting in a homogeneous traffic density. In the second situation, one vehicle was entered which differed from the others and thus resulted in a dynamic traffic situation. Figure 3 gives the most relevant results.

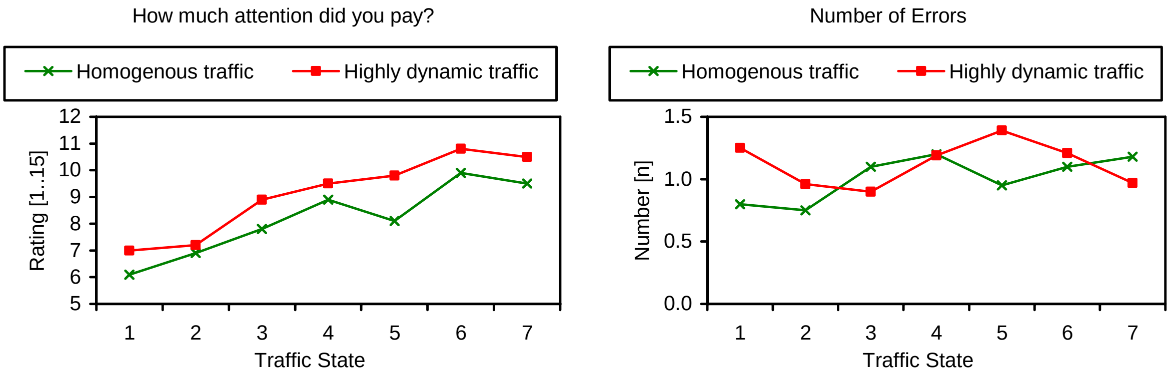

Figure 3 – Attention and number of errors at different traffic states

The traffic states 1-7 presented in Figure 3 correspond to an increasing traffic density. At the left part of the Figure the subjective ratings of the drivers directly after each merging manoeuvre are presented. In both homogenous and highly dynamic traffic situations, drivers indicate that they had to pay more and more attention with increasing traffic density. Only at the largest density (level 7) the attention remained constant or even decreased a little. In this traffic state, traffic becomes slower and nears a standstill so that the difficulty of the situation decreases somewhat. The number of errors (right part of Figure 3) presents a somewhat different picture. With the homogenous traffic states, a first maximum of errors is already reached at levels 3 and 4 and a second maximum at level 7. Thus, the largest demand for ADAS is at levels 3 and 4 as subjectively drivers think that they do not require maximum attention but their errors increase. In this situation, expert ratings indicate that an ADAS should support achieving an adequate speed and finding a gap suited for entering the freeway.

Additionally, when the traffic is highly dynamic, a maximum error rate is already found at traffic state 1 where drivers think that not much attention is required. In these situations the drivers do not expect that other vehicles appear and misjudge the speed and behaviour of these vehicles. In these situations, blind-spot detection systems could be valuable to prevent accidents.

In a similar manner, a detailed analysis of the different errors in the other traffic states provide more indication about which kind of assistance is required in the different situations and also about how to assist, e.g. how to achieve an adequate speed (by automatically accelerating or braking, or visually indicating the required speed on a head-up display etc.). Thus, requirements for an ADAS manager for merging on the highway which adapts the assistance to the traffic states are defined.

NEXT STEPS

The VI “Human Automation in Traffic” has used field studies and simulator experiments to show that different traffic states lead to specific errors in certain driving situations which require different ADAS functionalities and interaction strategies to adequately support the driver. Methods were developed to measure these traffic states from single vehicles in moving traffic. Thus, it is possible to adapt ADAS to these states. The simulator experiments combined with expert ratings provided concepts how to support the drivers in different traffic states. Additional evidence was gathered by the DLR in field studies where low and medium traffic densities were compared (see [7] at this conference). Additionally, in a driving simulator study the DLR examined how the drivers perceive these different states in order to gain more information about how to best assist them [6, 7]. The next step will be to implement an adaptive ADAS in the driving simulator of the DLR and also in a real car (DLR FASCar) in order to evaluate the effects of this ADAS manager on driving behaviour and safety. Overall, the results presented in this paper show that this human-centred approach to the development of ADAS provides interesting insights in what kind of support the drivers really need. This may also contribute to increasing the acceptance and thus market penetration of these systems.

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