Adaptive Interfaces in Driving

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Abstract. The automotive domain is an excellent domain for investigating augmented cognition methods, and one of the domains that can provide the applications. We developed, applied and tested indirect (or derived) measures to estimate driver state risks, validated by direct state-sensing methods, with major European vehicle manufacturers, suppliers and research institutes in the project AIDE (Adaptive Integrated Driver-vehicle InterfacE). The project developed an interface with the driver that integrates different advanced driver assistant systems and in-vehicle information systems and adapted the interface to different driver or traffic conditions. This paper presents an overview of the AIDE project and will then focus on the adaptation aspect of AIDE. Information presented to the driver could be adapted on basis of environmental conditions (weather and traffic), and on basis of assessed workload, distraction, and physical condition of the driver. The adaptation of how information is presented to the driver or the timing of when information is presented to the driver is of importance. Adapting information, however, also results in systems that are less transparent to the driver.

Keywords: In-car services, workload, adaptive user interface, central management.

1 Introduction

A major research effort on augmented cognition takes place in the defense domain, aiming at systems that support or extend the limited human information processes for operations in high-demand situations [1]. To augment cognition in dynamic conditions, the momentary human state is often sensed via (psycho)physiological measurements, such as EEG and heart rate [2]. New non-obtrusive methods can be used, such as camera sensors and microphones to assess emotion out of, respectively, facial expressions and voice [3]. In general, we propose to use a mixture of methods, including measures of human, task and context [4]

In our view, the automotive domain is an excellent domain for investigating augmented cognition methods, and one of the domains that can provide the applications. First, the human is in a constrained (relatively fixed, "indoor") position, sitting in an environment that can be relatively easily enriched with driver-state sensing technology. Second, the driver's tasks is rather well-defined, and can be tracked well, and

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context factors can be easily assessed via both current sensor technology (e.g., slippery road) and data acquisition via wireless networks (e.g., traffic density and weather). These domain and task characteristics allow for high-levels of automation to support safety and comfort, but the human task performance will remain a crucial factor of the overall driver-car performance. Third, there seems to be a real need for AugCog technology. Drivers can access more and more services in the car, for example for navigation, traffic information, news and communication. Furthermore, the car itself provides more and more information that should support drivers' tasks, such as speed limit warnings and parking guidance "beeps". The consequences of providing in-car traffic management information (like route information) in combination with infotainment services (like news headlines) can be negative; distraction or high workload could adversely affect the interaction between the driver and the in-car system (e.g. [5], [6]). Overload means that the driver is unable to process all relevant information necessary to perform the primary driving task. This may lead to increased error rates and delayed detection of other traffic participants and, hence, to reduced safety [7].

A recent study showed that 93% of observed crashes related to 'inattention' [8]. Within traffic research detection of 'inattention' (eyes not on the road) plays an important role. The 'eyes not on the road' can be caused by many things such as distraction, drowsiness, intoxication, workload, etc. It is not an easy task to detect 'inattention'. Clearly drowsiness can be detected through EEG signals but no driver will step into a car and puts an EEG cap on. So alternative measures needed to be developed. A lot of research effort was put into developing such measures. However still none provided a detection good enough to develop an in-vehicle system. The number of accidents is the measure for traffic safety. Although they happen on a daily basis accidents are fortunately still quite rare. So also with respect to the traffic safety alternative measures or indicators are needed. In traffic research, objective measures were developed that relate to the lateral part (e.g., how does a driver keeps its lane) and the longitudinal part of the driving task (e.g., car following). Of some of these measures it could be shown that there was a correlation between the measurement (e.g., speed) and traffic safety [9]. Other measures such as the duration until a driver crosses a line marking given the same speed and acceleration (time-to-line crossing) or the time-to-collision have also shown to be related to traffic safety. Subjective questionnaires were developed to indicate workload experienced by the driver. However under normal driving conditions it is unwise to fill out a questionnaire to assess the workload of the driver. So objective measures were used that a related to the steering behaviour of the driver (such as steering reversal rate). An extended list of measures that are commonly used in traffic research was generated by the AIDE project (e.g., [6]).

The importance of measuring the status of the driver (workload, distraction, etc) while driving lies in the possibility to warn a driver for potential hazardous situations and for adapting the interface to the driver. A driver that is distracted will need an earlier warning of a system in order to avoid a possible collision then a driver who is not distracted. However adapting the HMI to the driver requires storing some data of that driver. So adapting the HMI brings along privacy issues (e.g., who has access to the stored data). Also the introduction of driver support systems brings along other problems then just technical or HMI related. For example, an adaptive cruise control (ACC) can not only maintain a certain speed but also a certain distance to a leading vehicle. If that vehicle drives slower then the ACC vehicle then the ACC vehicle has to slow down too. However this deceleration is limited. If the leading vehicle suddenly brakes harsh then the ACC might technically able to cope but this cannot be guaranteed for all kind of situations. To avoid such legal issues on who is the blame in case of an accident when there are driver assistance systems on board, it is always stated that the driver is responsible, meaning should always stay in the loop with respect to the driving task.

To address all appplication constraints of AugCog technology, the AIDE project developed, applied and tested alternative (or derived) measures to estimate driver state risks. In this approach, the direct state-sensing methods (like eye-tracking and hear rate) are used to validate these measures.

2 The AIDE Project

Within Europe in 2007 about 43000 people died as the consequence of a traffic accident and about 1.7 million people were injured. Human error is the main contributing factor in accidents. To assist drivers in their task Advanced Driver Assistance Systems (ADAS such as forward collision warning systems, lane departure warning systems, vision enhancement systems) have been developed that offer great potential for improving road safety. These systems can warn the driver with respect to (potential) dangerous situations but can also to a certain extent take over part of the driving task. In-vehicle information systems only inform the driver and are most of the time not directly related to the driving task (e.g., mobile phone, fleet management, but also route navigation). Although these systems have benefits either with respect to driving safety or comfort there is huge risk that if the systems work in isolation the workload of the driver may increase thereby compromising traffic safety. Integration and adaptation of the systems are important tools to have the benefits of these systems without having the side effects. The AIDE project (Adaptive Integrated Driver-vehicle interfacE; IST-1-507674-IP) wanted to generate the knowledge and develop methodologies and human-machine interface technologies required for safe and efficient integration of ADAS, IVIS and nomad devices into the driving environment. The objectives of AIDE are

- to maximize the efficiency, and hence the safety benefits, of advanced driver assistance systems,
- to minimize the level of workload and distraction imposed by in-vehicle information systems and nomad devices and
- to enable the potential benefits of new in-vehicle technologies and nomad devices in terms of mobility and comfort.

To reach the objectives an integrated HMI was developed and tested in which the following components was developed

– Multimodal HMI I/O devices shared by different ADAS and IVIS (e.g. head-up displays, speech input/output, seats vibrators, haptic input devices, directional sound output)
– A centralised intelligence for resolving conflicts between systems (e.g. by means of information prioritisation and scheduling).

- Seamless integration of nomadic devices into the on-board driver-vehicle interface.
- Adaptivity of the integrated HMI to the current driver state/driving context. The adaptive interface should also be re-configurable for the different drivers' characteristics, needs and preferences. This requires techniques for real-time monitoring of the state of the driver-vehicle-interface system.

To illustrate best what AIDE aimed at is the vision that was laid down in the AIDE proposal:

> "Maria starts the car and drives through the city centre towards the motorway that leads to the small seaside town where she lives. When the car starts moving, all functions not suitable for use while driving are disabled. It is rush hour and the streets are crowded with other vehicles, pedestrians and bicyclists.
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> By means of using information gathered from on-board sensors combined with a satellite-based positioning system, the car knows that the driving situation is demanding and adapts the driver-vehicle interface so that Maria can concentrate on the driving. Thus, the information given through the interface is reduced to a minimum and all non-critical information is put on hold until later. Moreover, irrelevant safety systems, e.g. lateral control support, are disabled.
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> When Maria stops at a traffic light a voice message is given informing her that the road ahead is blocked and suggests an alternative route. This message was judged by to be sufficiently important to be let through despite the overall demanding driving context, but the system waited to present it until the workload was temporary reduced at the traffic light.
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> After driving for a few minutes on the highway, Maria starts thinking about a complex lawsuit that she has been assigned the responsibility for at work. The vehicle detects the increased cognitive activity from changes in her eye-movement patterns (detected by the cameras in the dashboard). After a while, the vehicle in front of hers brakes for a traffic queue. This is detected by the collision avoidance system, which alerts Maria of the potential danger using a flashing light combined with a slight seat vibration. She gets the alert well in time to be able to avoid the danger. However, since Maria was cognitively distracted, the warning was given earlier and the intensity of the warning was stronger than would have been the case if Maria had been fully attentive."[1]

Clearly not everything can not yet be implemented but for example adjusting the HMI based on "satellite-based positioning system" can easily be achieved. Within AIDE three different prototypes were developed: One truck and two cars.

An example: Adapting a forward collision warning system

This paper focuses on the adaptivity aspect of the AIDE project and more precisely on the acceptance of an adaptive system.[2] In AIDE a large number of experiments were performed with respect to the different aspects of the AIDE system. Three closely

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[1] Taken from the AIDE website http://www.aide-eu.org/index.html

[2] For more information on the AIDE project the interested reader is referred to the AIDE IP website (http://www.aide-eu.org/index.html) or you can contact Rino Brouwer at rino.brouwer@tno.nl

related experiments were performed by ITS Leeds (UK), VTI (Sweden) and TNO. In these experiments the effects of a Forward Collision Warning system were investigated. A Forward Collision Warning (FCW) is an on-board electronic safety device that continuously monitors traffic obstacles in front of the host vehicle and warns the driver when a risk of collision is imminent. The benefits of an FCW in reducing the number and severity of front-to-back collisions or 'shunts' have been reported (e.g, [10]). The effects of the system on driving behavior and on acceptance of the system were investigated in three driving simulator experiments (see Figure 1). In the experiment performed by ITS Leeds the FCW was adapted to the driver, in the experiment of VTI it adapted to the road friction, and in the experiment by TNO to distraction.

Fig. 1. The driving simulators used in the experiments. Top left, the TNO simulator; bottom left, the (old) ITS Leeds simulator; right the moving base driving simulator at VTI.

In all three experiments participants had to drive a route of 40 km in which a leading vehicle could sometimes suddenly brake in which the FCW could give a warning. In all experiment driving with an adapted FCW was compared to driving without an adapted FCW. As stated at ITS Leeds the system was adapted to individual differences. For drivers with a short reaction time the system warned later then for drivers with a longer reaction time. At VTI the FCWwas adapted whether the roads was slippery or not. In case of a slippery road the system warned earlier than on a dry road. At TNO the FCW warned earlier when the driver was distracted which was achieved by letting the driver perform a secondary task (for more detailed information on these experiments see [11]).

User acceptance was assessed by using the Van der Laan scale [12], giving a rating for satisfaction and usefulness of each FCW type. This scale consist of nine questions which reflect the underlying scale satisfaction and usefulness. (see Table 1).

Table 1. The questions in the van der Laan scale

Useful	|__| __| __| __| __|	Useless
Pleasant	|__| __| __| __| __|	Unpleasant
Bad	|__| __| __| __| __|	Good
Nice	|__| __| __| __| __|	Annoying
Effective	|__| __| __| __| __|	Superfluous
Irritating	|__| __| __| __| __|	Likeable
Assisting	|__| __| __| __| __|	Worthless
Undesirable	|__| __| __| __| __|	Desirable
Raising Alertness	|__| __| __| __| __|	Sleep-inducing

The results for the three experiments showed that only the adaptive FCW in the experiment of Leeds was rated more positively then the non-adaptive FCW. In both experiments of VTI and TNO the non-adaptive system was rated more positively. Although there are some differences between the three experiments an important difference was that in the experiment of ITS Leeds the system was adapted to individual differences while at VTI and TNO the system was adapted to circumstances (slippery roads or distraction). The adaptation of the system to a driver's preference is more likely to be noticed by the driver then a system that adapts to circumstances. Although the road may look slippery it may not be clear to the driver that the system warns earlier because of less friction. And although the driver has to perform a secondary task and is distracted (at least that is assumed) the driving task might still be manageable together with the secondary task. So it may not clear to the driver why the system warns earlier. In both the friction and the distraction experiment the driver may only perceive that a warning is given earlier but not why.

3 Conclusions

This paper presented an approach to realize "Augemented Cognition" in a car by adaptive in-car information and service presentations. According to this approach critical user states are assessed via context information, and validated in high-fidelity driver simulators. Via sensing the driver behaviour, information provision and environmental conditions, the actual critical states can be detected, and the in-car interfaces can be changed to establish adequate load levels. The most important developments in this area are the Advanced Driver Assistance Systems (ADAS) and In Vehicle Information Systems (IVIS) [11].

The AIDE project showed that information presented to the driver could be adapted on basis of environmental conditions (weather and traffic), and on basis of assessed workload, distraction, and physical condition of the driver [13]. The adaptation of how information is presented to the driver or the timing of when information is presented to the driver proved to be of importance. Adapting information, however, also proved to result in systems that are less transparent to the driver. Tests in the driver simulators showed that the rationale of adaptation, such as assumed distraction, is not always clear for the drivers, resulting in less acceptance. Actually, the drivers may have to learn that the circumtances and own state bring about a safety risk, and feedback on this aspect might help to improve the acceptance. In other words, the adaptive interface should explain its behaviour (e.g., during a training session). Furthermore, the experiments showed that personalization can be beneficial on this aspect.

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