DESIGN AND DEVELOPMENT OF AN ADAPTIVE INTEGRATED DRIVER-VEHICLE INTERFACE: OVERVIEW OF THE AIDE PROJECT

Angelos Amditis[1]
Luisa Andreone[2]
Aris Polychronopoulos[1]
Johan Engström[3]

[1]*Institute of Communications and Computer Systems*
9, Iroon Polytecnhiou St.
Tel: +30 210 7722398 - Fax: +30 210 7722291
E-mail: aamditis@mail.ntua.gr
[2]*Centro Ricerche Fiat*
[3]*Volvo Technology Corporation*

Abstract: This paper presents the sub-project 3 of the AIDE (Adaptive Integrated Driver-vehicle Interface) Integrated Project; AIDE is a pan European project co-funded by the European Commission, coordinated by Volvo Technology and managed by a core group with the participation of both the industry (Bosch, CRF, PSA, and BMW) and the academia (ICCS, TNO, Joint Research Centre). The main objective of the SP3 and the paper is the design and development of an innovative adaptive integrated human-machine interface for driver assistance, information and nomad systems. To address this objective different modules are described which monitor in real time the driver, the environment and the vehicle and to which the HMI is adapted. The information data flow, the communications and the interaction is ensured by a dedicated centralized module, namely the Interaction and Communication Assistant (ICA), which is considered as the main innovation and is described in details in the paper.

Keywords: Intelligent systems, Adaptivity, Human Machine Interactions, driver-environment-vehicle supervision, real time systems

1. INTRODUCTION

Today, a wide range of new in-vehicle technologies are being introduced in the market, including Advanced Driver Assistance Systems (ADAS) and In-vehicle Information Systems (IVIS). Moreover, the in-vehicle use of portable computing devices (or nomad devices) is increasing rapidly. These new technologies have great potential for enhancing road safety, as well as enhancing the quality of life and work, e.g. by providing in-vehicle access to new information and communication resources. However, the safety benefits of ADAS may be significantly reduced, or even cancelled, by unexpected behavioural responses to the technologies, e.g. system over-reliance and safety margin compensation. Moreover, IVIS and nomad devices may induce dangerous levels of workload and distraction. The general goal of the AIDE Integrated Project (IP), which is presented hereafter, is 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. In order to reach this goal, the project will involve sub-projects on (1) behavioural effects and driver-vehicle-environment modelling, (2) development of a generic human-machine interface (HMI) evaluation methodology and (3) design and development of an adaptive integrated driver-vehicle interface. Moreover, a fourth sub-project contains horizontal activities such as project management, training activities, dissemination and development of HMI design guidelines and standards (Engström, *et al*, 2004).

The current paper presents the general approach employed for the design and development work in sub-project 3. This work involves the specification and design of the adaptive interface as well as the general HMI architecture. Moreover, real-time adaptivity of the HMI will be enabled by the development of techniques for real time monitoring the driver-vehicle-environment state. The work will build on, and extend, the results from previous projects in the area, e.g. GIDS (Michon, 1993), CEMVOCAS (Bellet, *et al*, 2002) and COMUNICAR (Amditis, *et al,* 2002). Current related efforts include the ongoing SAVE-IT project in the US, co-funded by the US Department of Transportation (SAVE-IT, 2002). The main output of the sub-project will be three demonstrator vehicles: a SEAT city car, a FIAT luxury car, VOLVO heavy truck and various simulators to be evaluated using the methodology developed in sub-project 2 (Engström, *et al,* 2004). Below, the general concept underlying the design and the implementation of the adaptive integrated interface is described in further detail.

2. AIDE FUNCTIONS AND COMPONENTS

Traditionally, in-vehicle systems are considered as stand-alone devices, where each function (e.g. ACC, Navigation system, radio etc.) is implemented in a separate physical component with its own HMI. However, as the number of in-vehicle functions increases this approach quickly becomes unfeasible, for economical as well as for practical and ergonomic reasons. The vehicle cockpit cannot become the cockpit of an airplane or it becomes too complex to use and too distractive. Moreover, it should not be forgotten that the majority of vehicle drivers are not trained like, for example, pilots.

Therefore, the future trend is to use a component (e.g. a display) for multiple functions (e.g. the radio, the navigation system). Conversely, a function (e.g. lane-departure warning) may utilise many different components (e.g. a lane detection sensor, a specific computer hardware, a display, the sound system etc.). Thus, in the distributed architecture functions are generally distinguished from the physical components used to implement them. The HMI-related functions include:

1. *Advanced Driver Assistance (ADA) functions:* This refers to functions intended to directly support the primary driving task, e.g. lateral control support (lane departure warning, blind spot, lane change assistance etc.), longitudinal control support (e.g. forward and rear collision warning, ACC), friction monitoring, vision enhancement, driver fatigue monitoring etc.
2. *In-vehicle Information (IVI) functions:* E.g. instrument cluster, infotainment (radio, CD, DVD, mp3, email), road and traffic information and other Telematics services etc. These functions have to satisfy the growing request of information both related to the personal information cell and to the mobility related information. In this context, one crucial and growing problem to face is the "safe use" of portable devices while driving. .
3. *Integrative and adaptive "meta functions":* This refers to functions intended to manage and integrate all functions, e.g. by means of prioritisation of the information initiated simultaneously from different systems. This may also involve the selection of the modality for presentation of information (e.g. visual, acoustic, tactile etc.). Finally, the HMI may be adapted in real time based on the current driving situation and to the individual driver. Last but not least it will be possible to personalize the HMI according to the different driver characteristics and behaviour and to the specific driving tasks.

In table 2 different use cases are presented that correspond to information and safety signals and functions and will be addressed in AIDE. It should be notices that AIDE should solve conflicts, when more than one uses cases occur at the same time. AIDE solution will be implemented using the above mentioned Meta functions.

Table 2: Cases where AIDE system addresses

Information	Turn by turn navigation
	Incoming information from navigation system
	Entering destination in the information system
	Continuous feedback about an event or status
	Active steering, fuel level
	Incoming information on road, traffic or environment
	Advise of speed limit, fog, approaching an accident
	Input or check information on vehicle system status
	Warning from vehicle status (e.g. fuel is getting empty)
	Entering a driving parameter (e.g. speed) – secondary task
Comfort and Infotainment	Access agenda
	Making a phone call
	Answering a phone call
	Writing SMS
	Reading SMS
	Writing e-mail
	Reading e-mail
	Access the web
	Control media player
	Looking or listening media player and radio
	Control radio
	Access communication radio
	Talk into the communication radio
Safety	Enhanced scenario in reduced visibility (looking into a frontal enhanced mirror)
	Looking into additional mirrors

	Incoming warning of a potential accident like (e.g. incoming warning of the car unintentionally leaving the driving lane, a vehicle in the lateral blind spot, presence of a frontal obstacle, the speed limit is overcome)

In order to implement these functions, a number of physical components may be used, where the components may be shared by several functions. These components include:

1. *Integrated HMI input/output devices:* Devices used by the driver to input or to request information to/from the different vehicle systems, exploiting auditory, haptic as well as visual sensory modalities. Examples include standard buttons and knobs, speech input and haptic control devices. Other examples include displays (standard- as well as head-up displays) the sound system (used for auditory warnings, text-to-speech output etc.), haptic feedback through the seat, pedals or the steering wheel etc. here the key is “reconfigurability and simplified use via the new concept of availability only when needed”.
2. *Sensors (and other sources of information):* This includes sensors for monitoring the driver-vehicle-environment state. The sensors may be roughly divided into (1) *on-board sensors* (e.g. steering wheel angle sensor, pedal position sensor) (2) *driver monitoring sensors* (3) Traffic and environmental *sensors (*radar, laser, IR etc.) and (4) v*ehicle dynamic state sensors (*speed sensors, accelerometers, yaw rate, pitch). Moreover, the external telematic link and the GPS receiver provide useful information.
3. *Control units:* This is the hardware and software that implement the core computations for the functions and it is the intelligent manager of the human vehicle communication dialogue
4. *The vehicle data bus:* The onboard network connecting the different components, e.g. CAN and MOST.

In the context of HMI design, this type of distributed architecture has many advantages, including:

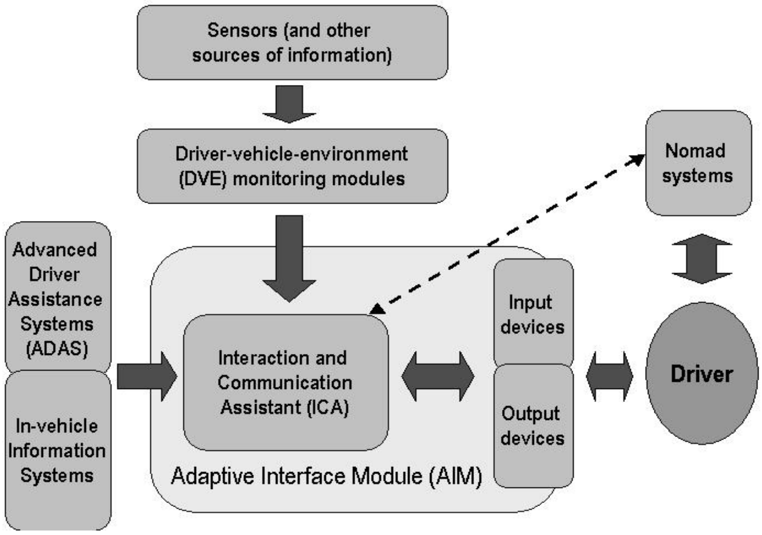
- Reduced number of HMI components (simplification of use, reduction of the time to learn, cost reduction, design simplification)
- Possibilities for more efficient driver-vehicle interaction, e.g. by means of integrated HMI solutions exploiting multiple sensory interaction modalities.
- Possibilities to develop and use an intelligent communication agent for managing the information exchange.
- Possibilities for adaptation of the driver-vehicle interface to the individual driver preferences and needs and/or to the driving tasks, the environment and the traffic situation, etc.

The development of an integrated, distributed, HMI architecture for enabling these possibilities is a major sub-goal of the AIDE sub-project 3. Figure 1 illustrates, on the most general level, the envisioned AIDE HMI architecture. The detailed specification of the architecture will be part of the work in the sub-project. The key components in the AIDE system, the Interaction and Communication Assistant (ICA) and the DVE monitoring modules are further described in the following sections.

3. THE AIDE INTERACTION AND COMMUNICATION ASSISTANT

The general objective of the ICA is to manage all interactions between the driver and the various in-vehicle systems in order to:

- avoid the negative impact of the information sources on the driving task (e.g. distraction and information overload)



- avoid interference between different pieces of information

The management functions include:

- To define what type of information should be delivered, when and how
- To adapt to the driver and to the environment
- To personalize the adaptive HMI to the individual driver

The design of the ICA will be based on an overall communication and harmonization plan where the objective is to define in *which way* to give each information to the driver and to accept or to inhibit *which* input tasks (based on the input/output devices and functions defined in earlier) according to a user needs and experts' judgements, i.e. find the best relationships between input/output media and information). Moreover, defines *if*, *when* and in *which way* the information will be provided and the input tasks (digit a number, insert a destination in the navigation system, etc.) will be accepted or inhibited on the basis of the traffic and environment assessment, as well as level of activity of the driver in primary and secondary tasks. The ICA will be checking the state and the number of the available functions (ADAS, telematic functions, etc.). If a new service will be addressed in future, it will be able to accept the incoming information from this service without any amendments on its hardware. It means that ICA recognises the new function, thanks to the openness of the multimedia network, and defines which are the best way and the right time to give that information to the driver fusing it with all the other existing information. This is a "plug and easy to use" approach.

Critical HMI related points are issued by the introduction of **Nomadic devices:** Drivers have personal portable devices, like mobile phones or PDA's, which can both be used as part of the vehicle interface and at the same time distract the driver (e.g. incoming telephone call). Through short range communications like Bluetooth (or through using a docking station) the nomadic device can communicate with the vehicle, and hence be integrated as part of the AIM. The introduction and safe integration of NOMADIC devices within the car environment are of high importance since these devices are expected to act as bridges between the home, office and vehicle environment. The AIDE project will research how nomadic devices can be integrated as part of the HMI thus allowing a "regulated" use that will enable only the essential functionality when driving and all functionality when the vehicle is stopped and the essential functionality will only be allowed through channels (like vocal) that will not interfere with the driver's primary task.

4. DRIVER-VEHICLE-ENVIRONMENT MONITORING

In order to enable real-time adaptivity of the HMI, a number of driver-environment-vehicle (DVE) monitoring modules will be developed. The following such modules are envisioned (Table 2):

Table 2: The envisioned AIDE DVE monitoring modules

Functionality to which HMI should be adaptable to	Relevant module	Acronym
Driver characteristics Driving style	Driver characteristics module	DC
Driver's primary task activity: Driving task	Availability of the Driver Estimation Module	ADES
Distraction, Driver behaviour (secondary tasks)	Cockpit activity assessment module	CAA
Driver fatigue Hypo vigilance, physical ability	Driver state degradation module	DSD
Environment, Traffic	Traffic and environmental assessment	TERA

4.1Driver characteristics module (DC)

This module includes the definition of a driver set of typical profiles, the development of driver identification through smart card or facial recognition applications, the application development and the integration of correlation to the DVE monitoring modules and the Interaction and Communication Manager. The main application is based on Agent Technology. Initially, a *User's Profile Configuration Agent* will support different "types of users". The users themselves will choose his/her type, residual abilities and preferences on posture, interface elements, etc. Actions will be taken to secure user's sensitive personal information, a proper, in-vehicle interface for input of this profile by the user will be also developed (user-friendly, cost-effective). Then, a *Customisation Agent* will monitor the user's driving behaviour and preferences / actions, by keeping and processing the user's driving record, i.e. average position in the lane, average headway, typical speeding and braking pattern, preferred seating position, average use of radio and mobile phone, other services, like navigation, requested often, etc.

This Agent will help to predict user needs that are not explicitly mentioned (i.e. long reaction times) and based upon stochastic algorithms, will evolve with the user. Nevertheless, the self-built user profile will be always possible to be reviewed and changed by the user, to avoid frustration, surprise or other mistakes.

4.2. Availability of the driver estimation module (DAE)

This module will be focused on the analysis of the primary task activities (i.e. driver's actions on vehicle controls), while the Cockpit Activities Assessment Module (CAA) (cf. to the next paragraph) will consider the availability effect of a secondary task. In this task we will partly assess the driver's availability level by considering data coming from "basic" sensors, which reflect the driver's actions on vehicle controls (e.g. pedals, steering wheel, blinkers, etc) and the dynamics of the car (e.g. vehicle speed). Though improvements of existing platforms, will be required to have a more robust technology (i.e. diagnosis performances increasing, data collection and performance testing for a largest number of driving situations), tests in real driving conditions with end users have confirmed the feasibility and interest of an "availability diagnosis" for managing on-board information. Driver availability estimator algorithms will be adapted to the truck application as well.

4.3. Cockpit activity assessment module (CAAM)

This module will further develop detection of whether the driver is engaged in and/or distracted by a secondary task (as opposed to the primary driving task), e.g. operating the radio. Using a fully automatic and unobtrusive version eye and head tracking system, raw measures of driver visual behaviour will be obtained. The tracking system currently outputs 3D head position, 3D head rotation, and gaze rotation signals at 60Hz from stereo video images of the driver's face. It is expected that an embedded computer version with small, high dynamic range cameras (very robust to lighting variations), automatic initialisation and calibration of gaze, Perclos, and >60Hz sampling will be used for the vehicles. A central measurement of interest for present purposes is visual demand. Traditionally this has been quantified in terms of glance-based measures: glance frequency, average glance duration, total glance duration, and total task time, according to the standard offline video analysis method described in ISO 15007-2 and SAE J-2396. Cluster identification and vehicle/world model target association using a hierarchical classification scheme, i.e. in/off-road then larger to smaller in-vehicle targets (e.g. dash – centre console – radio – dials), will be employed. Additionally, various other basic ocular measures of visual demand may be used, e.g. fixation duration and dispersion, saccadic latency, saccadic velocity, smooth pursuits, head motion profiles, power spectrum measures, large visual angle reversal rates, saccade and fixation rates, smooth pursuit rates, scan paths

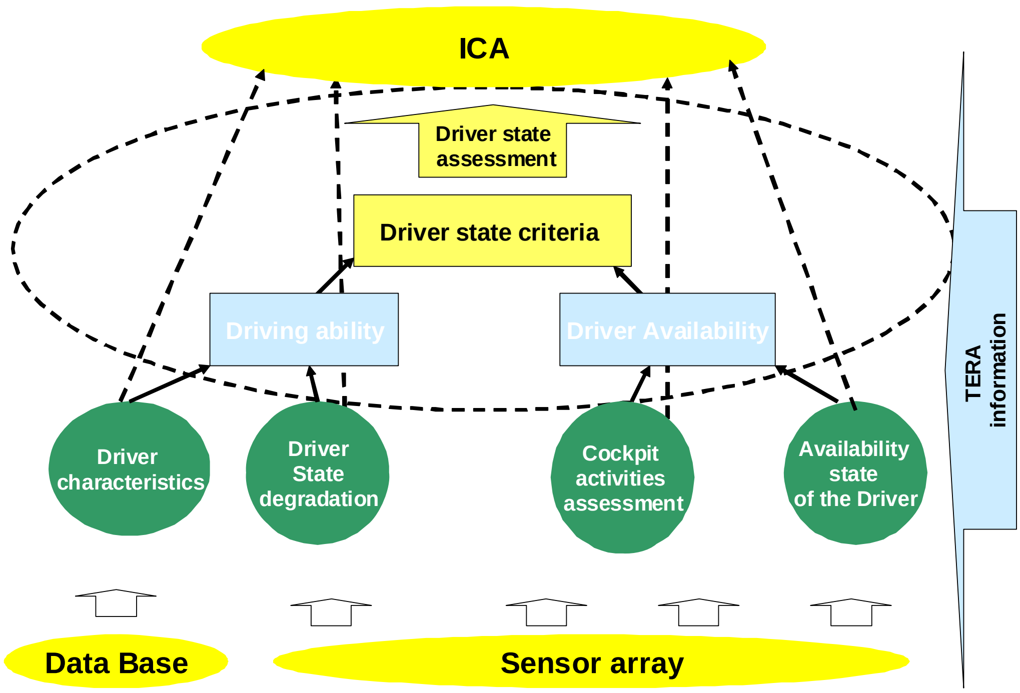


Figure 2: Real time DVE monitoring system

(e.g. mirror checking), staring (i.e. fixated gaze without blinks), etc. Scan path evaluation can be potentially applied to identify situations (manoeuvres, city/motorway driving) and driver characteristics (e.g. expert/novice driver). The current algorithms are tailored to motorway driving. These will be further verified and made more robust. Algorithms for city driving will be developed.

4.5. Driver state degradation module (DSD)

In this module, driver monitoring for fatigue and hypovigilance will be addressed. Since the development of such a monitoring system is not an Aide's objective, existing sensors/systems will be used in order to demonstrate the capability of the AIDE HMI to adapt also to the driver's state degradation.

4.6. Traffic and environment assessment module (TERA)

Traffic and Environment Risk Assessment in AIDE monitors and measures activities both inside and outside the vehicle in order to assess the level of activity and potential risk and the Driver level of attention. For example, existing sensors used by collision-warning systems and localisation measurements combined with digital maps of corresponding roadway characteristics will be evaluated so to check their usability to understand the environment outside the vehicle. Inside the vehicle, sensors to monitor the driver's attention (e.g. eye-gaze sensor) will be evaluated with the aim of handling these measurements like traffic parameters within this module (to assess traffic density for example). The role of Traffic and Environmental Risk Assessment is twofold:

a) To calculate in real time a total level of risk related to traffic and environmental parameters

b) To calculate environmental and traffic parameters according to the requirements of the other modules (mainly the Driver Situation Assessment and the Communication Administrator)

The output from these modules will form a DVE state vector that will be used by the ICA (see above) for managing all interactions between the driver and the in-vehicle systems

CONCLUSIONS

This paper presented the sub-project 3 within the AIDE integrated project, co-funded by the EC within the Sixth Framework Programme and started in March 2004. The sub-project aims at the design, development and demonstration of innovative adaptive integrated HMI concepts and technologies for in-vehicle systems (ADAS, IVIS as well as Nomad devices). The general approach underlying the work was outlined and the main AIDE functions and components were described. Future publications will describe in further detail the concepts and technologies developed in the project related to the real-time DVE supervision and to the development of the Interaction and Communication Assistant.

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