Communication and interaction strategies in automotive adaptive interfaces*

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Abstract - *Today's drivers have to cope with a growing amount of information coming from on-board information messages, Telematics and advanced driver assistance systems. The interaction between the driver and these systems is critical since it may distract the driver from the primary task of driving. The paper, addressing this problem has a twofold aim: in one hand to carry out a review of past and current initiatives on the optimization of Human Machine Interfaces (HMI) in the automotive research area; on the other hand it presents relevant results, investigates research and market trends and proposes strategies and architectures for future implementation. The COMUNICAR project is presented - the most well-know European project - as an example for past activities, while the AIDE Integrated Project and its vision is proposed as the roadmap for future activities.*

Keywords: Human Machine Interaction, Information Management, Adaptive interfaces, Driver-Vehicle-Environment modeling.

1 Introduction

Today's drivers have to cope with a growing amount of information. This is caused by several factors such as the increments in traffic density, the number of on-board and roadside sources of data, and the new additional in-vehicle equipment, such as mobile telephone and automotive displays. Moreover, errors in judgement of driver's own driving capabilities in relation to the vehicle typology and to the external environment and traffic conditions are key issues in the occurrence of road accidents. And it is in this complexity of human behaviour with respect to the vehicle and the environment that nowadays an increasing number of new in-vehicle technologies are being introduced on the market. To guarantee that driver workload is maintained within tolerable levels, most ADAS (Advanced Driver Assistant Systems) include Human Machine Interaction (HMI) user-centered design and evaluation activities during their development phase. These evaluations have provided a good basic knowledge background to understand which is the best way to give information to the drivers. However, what happens if more than one system (e.g. ADAS, telematic services, etc.) is used simultaneously?

Studies have clearly shown that drivers are able to acquire peripheral in-car information without shifting the focus of attention from the road scenario. In this case, the acquisition process is influenced by the type of information (e.g. visual, acoustical, haptic, etc.), the position and the usability of input/output devices. However, things might get worse if the driver tries to use more than one system at the same moment.

Therefore, there is a need to design and develop an on-vehicle multimedia HMI (Human Machine Interface), able to harmonize the huge volume of messages oncoming from the new and traditional functions for the driving support. Such functions could be the Advanced Driver Assistance Systems - ADAS (e.g. Adaptive Cruise Control, Lateral and Longitudinal Control, Collision Warning, Lane Departure Warning etc.), telematic services and in-vehicle information systems – IVIS - (e.g. navigation, traffic and weather information, distance diagnosis, messaging, Internet, etc.). The simultaneous information coming from these systems can be a benefit for the driver and the social environment - in terms of safety, comfort, increase of alertness - if and only if the HMI is developed taking into account the user's needs and ergonomic requirements. This information management must be done in a way that guarantees drivers and vehicles safety. At the same time, this HMI should be able to control and manage all the different input and output devices of the vehicle in order to provide an optimized interaction between the driver and the vehicle.

Consequently, in future vehicles there is a demand of a central management system that optimizes the communication and the interaction between the driver and the vehicle. The issue of the optimization of the HMI and the integration of multiple ADAS and IVIS by means of integrated and adaptive interfaces techniques is a currently hot topic in the automotive industry, and many companies are investing heavily in the area. There are also a number of previous and ongoing initiatives, both in Europe (GIDS, COMUNICAR, CEMVOCAS in [1, 2, 3]), United States (Delphi [4], Motorola [5], SAVE-IT

[6]) and Japan (Toyota). All projects address to a sub-class of the problem, estimating drivers' workload and developing static situation-dependent rules for the Interaction between the driver and the vehicle. An ambitious new initiative, AIDE Integrated Project [7], started in March 2004, under the 6th Framework Programme of the European Commission and aims at studying drivers' behaviour, developing a generic evaluation methodology and developing an adapting HMI unifying existing research approaches in the automotive area.

The development of next generation of driver vehicle interaction systems should be also focused towards the objective to obtain a safe and sustainable mobility which has the aims to reduce the number and the severity of accidents while promoting the mobility for every user. Mobility in the future should be promoted towards "intermodality" to reduce traffic congestion and to optimise travel planning, but towards this aim there is an increasing demand for on board information systems. These needs together with the demand for new on vehicle support and services and the need of the users to be connected to their own information cell (mobile phone, PDA, etc.) will unavoidably increase the number of interaction of the driver with the vehicle thus raising the potential risk of driver's distraction and fatigue which are among the main causes of road accidents.

2 First generation information management systems

The most typical example of first generation of information management systems is COMUNICAR system. COMUNICAR comes from the so-called European funded project started in January 2000 and finished in May 2003, involving a consortium of 11 partners belonging to 6 European countries. The main project objective was to design and develop a new concept of an integrated, in-vehicle multimedia HMI able to harmonise the messages coming from the ADAS, the telematic services (telephone, route guidance, etc.) and the entertainment functions (radio, CD, etc.). The developed HMI is able to choose in real time the best ways to provide messages to the driver on the basis of the environment status, the traffic conditions and the driver's level of activity in the primary task. A user centred approach ([8] – [10]) was adopted for the design and development of the COMUNICAR HMI which has been integrated into two car demonstrators. A number of tests have been conducted during all the phases of design and development of the system concluding with the field tests involving the two car demonstrators. COMUNICAR project designed and developed an on-vehicle multimedia HMI able to harmonise the huge volume of messages oncoming from the new and traditional functions for the driving support. The main objectives of the project are:

- ♦ to assess the driver needs of information;
- ♦ to define which driving support functions produce useful information for the driver and which is the best way to give the messages, taking into account the workload and the different conditions of traffic scenario;
- ♦ to design, develop and test an easy-to-use multimedia HMI using innovative interaction elements;
- ♦ to assess and implement the best ways to ensure the easier interaction between the driver and the on vehicle HMI and also to find the best way to provide information to the driver taking into account the information sources and his/her workload at the specific time;
- ♦ to promote the standardisation of the information layouts designed;

The COMUNICAR HMI is composed of an Information Management System (IMS), that manages information priorities; a network architecture that exchanges all data; a set of input/output devices included in the multimedia HMI and connected with the multimedia network; and an electronic unit, called DWE (Driver Workload Evaluator) integrated with the IMS and aimed to measure the mental workload of the driver. The IMS, which is the core of the COMUNICAR HMI, is responsible for managing information priorities, defines the information hierarchies, queues, and identifies potential conflicts proposing in real time the optimum solutions.

A user centred approach was adopted for the design and development of the COMUNICAR HMI to ensure the appropriate involvement of all users at all phases of the design and the development of the proposed system. Therefore, the developed HMI was tested in all conditions and in different environments including lab simulation, driving simulators and through on road tests to ensure that the need of integration of the different services inside the vehicle is faced in a safe and comprehensive way.

The core element of COMUNICAR HMI is the IMS. This specific module is responsible for the *selection and the management* of how, when, where and in which format to issue driver information avoiding his/her overloading, and distraction form his/her primary task-driving which could result to possible increase of traffic safety risks. In doing so it takes into account:

1. the presence of vehicle functions or other systems (from ADAS to telematic) which are potential sources of information, together with their priority and relevance, particularly in terms of safety;
2. the availability of input and output channels and the mapping between them and the different functions;
3. the driving context and environment conditions through the calculation of a risk factor;
4. the driver's workload which is estimated through the DWE

The communication model according to which the HMI concept has been conceived divides the multimedia HMI in two areas. The first one, close to the driver in terms of perception and attention capturing, should be mainly devoted to the safety and driver support functions (like collision avoidance, lane warning, ACC, etc.). The other one, located in the center of the dashboard, can be targeted to the infotainment, telematic and comfort functions (from the MP3 to the climate control). This second display, which includes a visual output and a mouse to manage the functions, could be shared between driver and frontal passenger.

The IMS receives raw data from the automotive system, the Human-Machine Interface and the external world, translates raw data into messages useful to the driver, and manages delivery of such messages. The IMS is a knowledge system built on a set of rules which encode the content of state matrices. Such matrices express the actions to be performed when a given message (e.g. an incoming call) is processed in a given state (e.g. a certain value of the total level of risk).

The matrices keep also into account car-specific system features – such as the geometry of the available displays, the functions to be provided and their classification.

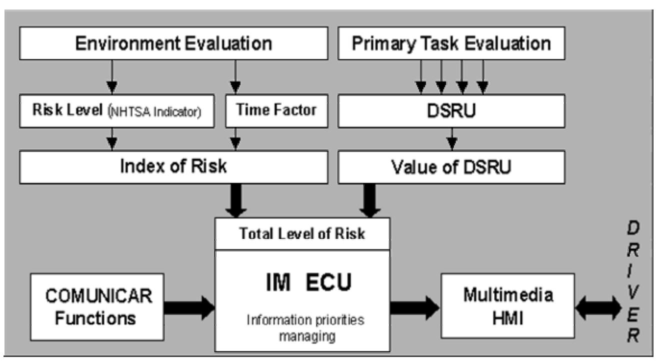

Figure 1 : The basic architecture of the COMUNICAR HMI management framework

3 A step forward

The in-vehicle information and HMI needs a communication and a harmonization plan where the objective is to define in which way to deliver each piece of information to the driver and to accept or to inhibit which input tasks (based on the input/output devices and functions) according to a user needs and experts' judgements (i.e. find the best relationships between input/output devices and the information). Moreover, this task, define 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. COMUNICAR system was the first rule-based Information Manager approach. The COMUNICAR project allowed testing positively the first "FIXED RULES" based algorithms of message prioritisation according to a driver's risk level dynamically estimated on the basis of the vehicle status and the driving manoeuvres. The novelty of future HMI initiatives lays in the possibility to develop a "FULL DYNAMIC RULE-BASED SYSTEM" which will encounter the driver and its activity level, considering the real driver's workload status, his activity both on the primary and on the secondary task, the real environment and traffic conditions with the help of intelligent agent technologies, user profiling techniques, enhanced rule-based algorithms and advanced digital maps. Given the fact that future vehicles will integrated diverse ADAS and IVIS and also aftermarket devices (e.g. Personal Digital Assistant – PDA), a system with Artificial Intelligence (AI) should monitor in real – time the driver, the vehicle and the environment in order to prioritize information and optimize the communication and the interaction. An abstract architecture of such a centralized intelligence is sketched in Figure 2.

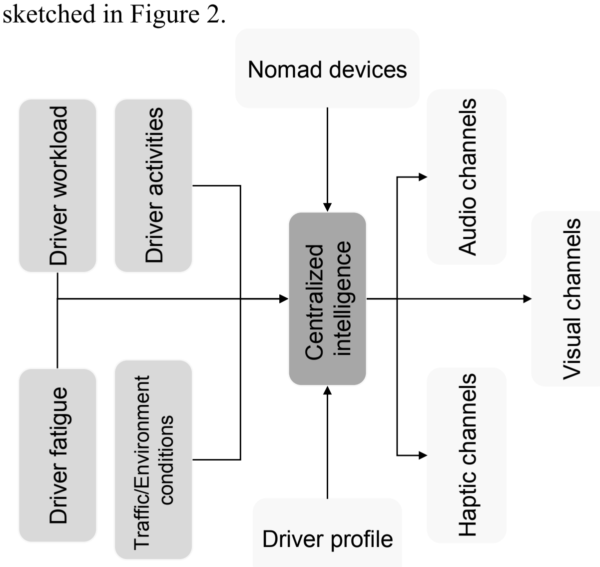

Figure 2: Abstract architecture of an AI automotive system

The design and implementation of the "safe and efficient interaction and communication" of the driver with the vehicle and with the external environment includes the definition of a number of HMI modalities, which in the future will include:

- Selected modality or modes combination (audio, visual, haptic…)
- Design of warning format for safety application or vehicle signals
- Input and Output channels (e.g. speech)
- Message and information priorities
- Graphical layout
- Dialogues (adaptation to the situation)

Within this framework a number of highly innovative characteristics and concepts can be identified as follows for future consideration:

- ♦ The simplification of vehicle cockpit via the multiple use of the same device (by reconfigurability) and the function availability only when needed
- ♦ The configurability to the context, and to driver's preferences and style
- ♦ The integration of the HMI both for ADAS, for telematic services and for a safe use of the nomad devices
- ♦ The design and development of a seamless connectivity to driver's personal information cell
- ♦ The use of new devices for novel design towards an easiness and intuitiveness of use and towards an efficient use of functions
- ♦ The enhancement of drivers' perception of the external world to improve safety avoiding distraction, lack of perception and overconfidence
- ♦ The enhancement of driver's perception of systems limits to avoid misuse or "no use" of the system
- ♦ To reduce the time to learn the use of a new system or service again avoiding misuse

Finally, it is well known, that the success of an on-board information system or, more generally, every automotive function directed to the drivers depends on the usability of the corresponding user interface. In the future and in more complex automotive environments, this should be rephrased since user interfaces will be replaced by the terms "Interaction" and "communication". The only way to improve the usability will be the adaptation of the user centred methodology adoption, based on the analysis of the user task, the identification of a solution involving the users themselves in the design phase, and an iterative design-test process until the solution developed will not reveal its full compliance with the identified usability requirements.

4 Next generation integrated systems

The general objective of the AIDE IP, the most typical example of European next generation projects, is to generate the knowledge and develop the methodologies and human machine interface technologies required for safe and efficient integration of multiple driver assistance and information functions into the driving environment. Specifically, the goal of the IP is to design, develop and validate a generic Adaptive Integrated Driver-vehicle InterfacE (AIDE) that...

- ...maximises the efficiency of individual and combined advanced driver assistance systems by means of innovative, integrated and adaptive, human-machine interface concepts that prevent negative behavioural effects (e.g. under-load, over-reliance and safety margin compensation) and maximises positive effects (e.g. enhanced situational awareness), thereby enhancing the safety benefits of these systems. AIDE should demonstrate significantly enhanced safety benefits compared to existing solutions.
- ... reduces the level of workload and distraction related to the interaction with individual and combined in-vehicle information and nomad devices, thereby reducing the number of road accidents. AIDE should demonstrate a significant reduction in the imposed workload and distraction compared to existing solutions.
- ...enables the potential benefits of new in-vehicle technologies and nomad devices in terms of mobility and comfort, without compromising safety. AIDE should demonstrate that the benefits of new in-vehicle technologies could be enjoyed without increased acciden**ts risk.**

Moreover, the concepts and technologies developed should have high product-feasibility in order to penetrate the market and contribute significantly towards the EC goal of 50% reduction of fatalities by 2010. In order to reach these objectives, three sub-goals have been defined:

1. Development of a model for prediction of behavioural effects of driver assistance and information systems. This model will be the basis for the design of the adaptive integrated driver-vehicle interface.
2. Development of a generic, industrially applicable, methodology for the evaluation of road vehicle human-machine interfaces with respect to safety. This methodology will be used for verifying the quantified goals stated above.
3. Design, development and evaluation of three prototype vehicles, one city car, one luxury car and one heavy truck, with the adaptive integrated driver-vehicle interface implemented.

The S&T approach adopted in the AIDE IP is firmly based on a set of basic tenets, which are in line with the general approach set out in the IST e-Safety Report [11]:

- Systems perspective: As stated in the IST e-Safety Report [11] integrated approach to road safety requires that the "involvement of and the interaction between the driver, the vehicle and the road environment are addressed together" (p. 11). This holistic, "systems"-, perspective will be adopted throughout the AIDE project, where the central object of study is the driver-vehicle-environment system.
- Multidisciplinary approach: The objectives stated above cannot be achieved by technological development or behavioural research performed

in isolation. Rather, these must be addressed together by a strongly multidisciplinary team.

- User-centred design and development: Development of HMI technologies should not be driven by technology per se, but need to be based on user needs and expectations. This requires a user-centred development procedure where design, prototyping and evaluation proceeds in an iterative, incremental way, involving end users and/or experts at each step.
- Product focus: As mentioned in section 5, the AIDE safety impact ultimately depends on the deployment and market penetration of its results. Thus, AIDE will adopt a product-oriented focus, including near-product prototype development as well as identifying and addressing the main obstacles and enabling factors for market exploitation– e.g. requirements on the vehicle electronics architecture, organisational issues in product development and analyses of the cost-benefit of the proposed integrated driver-vehicle interfaces.

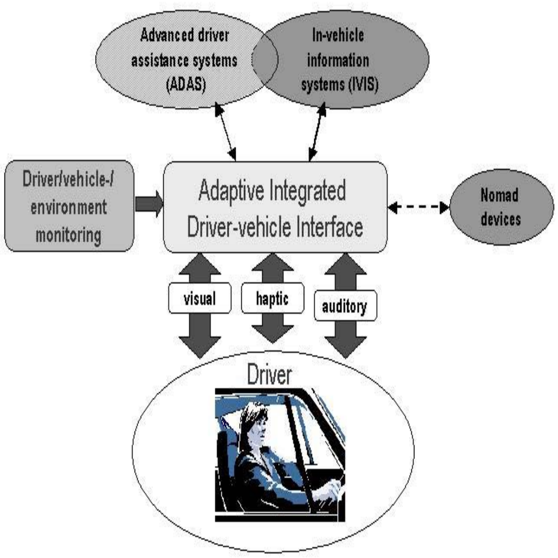

Figure 3 : Illustration of the general Adaptive Integrated Driver-vehicle Interface concept

As illustrated by Figure 3, the AIDE concept entails a unified approach to in-vehicle interaction design that resolves conflicts between systems and exploits synergies. One of the main features the AIDE concept is the utilisation of multimodal interaction technologies for conveying information to the driver in an intuitive and efficient way. Another key feature is the simplification of the vehicle cockpit via multiple use of the same device and availability of functions only when needed. AIDE should be able to integrate in a safe and efficient way a wide range of ADAS, IVIS (including Telematics services) and nomad devices.

Another major feature of the AIDE concept is the awareness of, and adaptivity to-, the context of use, e.g. the external traffic and environmental scenario, the real time dynamics of the vehicle and the driver's level of activity (primary and secondary task). The adaptive interface will also be re-configurable for the different drivers' characteristics, needs and preferences and available for seamless connectivity to nomad devices.

The Project AIDE, which is a European funded project, started in March 2004 and will last for 4 years. The coordinator of the project is Volvo Technology (SE). The core group of the project consists of Bosch (D), ICCS (EL), CRF (I), PSA (F), JRC (I), BMW (D) and TNO (NL), while the whole Consortium consists of 28 partners from both research and industry.

The AIDE is divided into four sub-projects dealing with various interrelated research topics:

- Sub-project 1: Behavioural Effects and Driver-Vehicle-Environment Modeling.
- Sub-project 2: Evaluation and Assessment Methodology
- Sub-project 3: Design and Development of and Adaptive Integrated Driver-vehicle Interface
- Sub-project 4: Horizontal Activities

5 Conclusions

In this paper aspects of designing future automotive environments were presented focusing on the optimization and the adaptation of the Human Machine Interfaces to the driver, the vehicle and the environment. Results presented in the paper come especially from COMUNICAR project, while the vision of AIDE project was analyzed and industrial and research trends were investigated.

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