BEYOND CONTEXT-AWARENESS: DRIVER-VEHICLE-ENVIRONMENT ADAPTIVITY. FROM THE COMUNICAR PROJECT TO THE AIDE CONCEPT

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Abstract: This paper presents the principle of the design of the "intelligent core" of next generation driver vehicle interaction systems towards the objective to obtain a safe and sustainable mobility. Mobility in the future has to be characterised by a reduction both in number and in severity of accidents, has to facilitate the movement of every user and should be promoted towards "intermodality" to reduce traffic congestion and optimise travel planning. This causes an increasing demand for on board information systems. These needs together with the demand for new in-vehicle support and services and the users' expectation to be connected to their own personal information systems is increasing the amount of interaction of the driver with the systems inside the vehicle thus raising the potential risk of driver's distraction and fatigue which are among the main causes of road accidents.

Keywords: Intelligent systems, Adaptivity, Human Machine Interaction, Driver-Environment-Vehicle supervision, Real time systems.

1. INCREASING TRAFFIC AND GROWTH OF THE ON-BOARD TELEMATICS MARKET

More than 40,000 people die and 1.7 million are injured on Europe's roads every year. The direct cost is €45 billion and the indirect cost is three to four times higher. The increments in traffic density, the increasing number of on-board sources of data, and the new in-vehicle infotainment and comfort systems are making the driving task more demanding than it was in the past. That's particularly relevant considering that it is estimated that 90 per cent of road accidents are caused by human errors. Introducing new opportunities to be informed "everywhere about everything" it means to face the problem of potential distraction during safety critical actions. To guarantee that driver's activity is maintained below acceptable levels, the development process of on-board systems must pay a great attention to Human Machine Interaction (HMI) aspects by including user-centred design and evaluation activities. Moreover when more than one system is used simultaneously there is the need to design and develop an on-vehicle multimedia HMI, able to harmonize the huge volume of messages oncoming from the new and traditional functions for the driving support. Such functions can be both Advanced Driver Assistance Systems (ADAS) (e.g. Adaptive Cruise Control, Lateral and Longitudinal Control, Collision Warning, etc.) and telematic systems or services (e.g. navigation, traffic and weather information, remote diagnosis, messaging, Internet, etc.). 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. The final goal is to let the in-vehicle communication to adapt to the characteristics of the driver, the vehicle and the surrounding environment in a way that guarantees drivers and vehicles safety.

2. COMUNICAR: MANAGING THE ON-BOARD COMMUNICATION

COMUNICAR is a European funded project (within the 5th Framework Programme "Information Society Technologies") started in January 2000 and completed in May 2003 involving a consortium of 11 partners belonging to 6 European countries. The objective was to design and test an innovative multimedia HMI able to manage and harmonise the messages coming from Advanced Driving Assistance Systems (ADAS), telematic systems and services and entertainment functions. As main project's output a context-aware system, the Information Manager (IM), able to choose the best way to provide information to the driver on the basis of the environmental conditions, the traffic density and the driver's activity in the driving task has been designed and tested.

Fig 1 Cars of the future are crowded of information

3. A RULE-BASED CONTEXT-AWARE SYSTEM TO INCREASE DRIVING SAFETY

The Information Manager developed within the COMUNICAR project is a rule-based system able to control the selection and the management of the information to be given to the driver. Its aim is to select in real time the best time and modality to present each information to the driver avoiding conflicts between different messages both conflicts between different messages and overlapping of information to particularly demanding driving situations. This aim has been reached through the development of dedicated algorithms for messages prioritisation. A method based on the state-of-the-art researches in Human Factors has been applied in order to specify the final formats for the driver's input and the system output. The management of all the interactions between the driver and the on-board information system has been studied and a real time selection of how, when, where and in which format to send each message to the driver taking care of any possible overlapping has been implemented. This selection is done on the basis of the external scenario and the primary task evaluation. Both the evaluations are included in the calculation of the so-called Total Level of Risk.

In particular, the evaluation of the external scenario is performed using the data coming from different sensors (e.g. the radar to detect the presence of dangerous obstacles close to the vehicle, the status of the lights, the activation of the wipers and their speed, etc.). The driving task evaluation is performed by the Driver Status Recognition Unit (DSRU, an electronic control unit firstly developed in the European project CEMVOCAS).

According to the Total Level of Risk (TLR) value, only the relevant information is provided to the driver and the simultaneous messages are managed and prioritised on the basis of their priority level and of the current TLR. The priority level of each message has been defined according to the time frame within which the message has to be interpreted by the driver in order to maintain its validity.

Finally, the selected and prioritised messages are sent through the selected channel.

The Information Manager acquires the DSRU states, the Total Level of Risk, the whole priority tables and the possible output modalities and runs a set of independent rules. It works like an expert system where the data flow is scheduled by a programme based on rules that are written by human experts, validated during different test campaigns and improved on the basis of the human factor tests results.

In details, the whole management process is organised around three dependent classes of rules (i.e. TLR related rules, Priorities rules, Output modality rules). According to the value of the TLR (first set of rules) and on the basis of the priority of the information that in each time have to be sent to the driver, the corresponding output modality rule is activated and runs.

The Information Manager is the first attempt to develop a context-aware system able to modify the provision of information according to the external scenario and to the activity of the driver. The results of the COMUNICAR project, came to the point that the intelligent management of on board information is a powerful mean to guarantee a higher compatibility between the primary task and the driver's need for information. The driving scenario (that includes "where" the driver is, "how" the driver is driving, "what else" the driver is doing and which are the weather conditions) has to be identified by the "intelligent core" of the information management that needs the availability in real time of as many information as possible about the driver, the vehicle, the traffic and the environment.

4. THE EVOLUTION: THE NEW AIDE CONCEPT

The step beyond the rule-based prioritisation of the information to be provided to the driver made by COMUNICAR is the design and development of a continuous interaction flow between the driver and the vehicle. With the harmonisation of the communication channels the information exchange can be perceived by the driver as a single flux of information: now it's the car which dialogues with the driver and no more its individual subsystems.

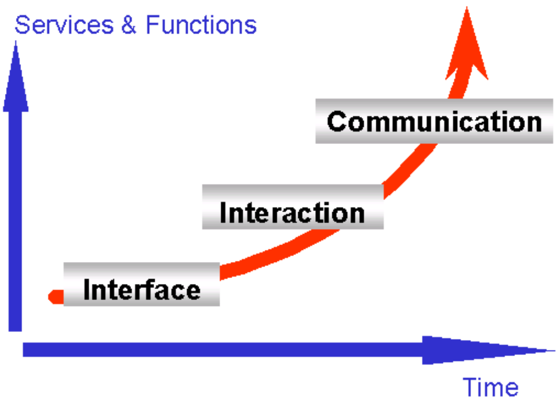

Fig 2 "From the design of different interfaces to the design of a dialogue communication "

In these years the design of the driver-vehicle interaction is going through different phases:

1. INTERFACE PHASE: the addition of HMI systems integrated into the vehicle cockpit to provide additional driving services;
2. INTERACTION PHASE: the development of on vehicle systems introducing new interaction channels (vocal, haptic, etc.);
3. COMMUNICATIVE PHASE: the introduction of continuity in the on vehicle interaction which is transformed into a true dialogue with the vehicle.

To enable phase 3 the design of the driver-vehicle interface as a dialogue needs an administrator of the information complexity, designed with a user centred design approach, which make use of all the information available. That information can come from the environment (visibility, bad weather), the road scenario (dangerous situations, road signs, road surface, traffic density, road typology), the current interactions (driver's actions, incoming / outcoming messages in course) and the driver itself (his/her workload due to the activity on the primary and secondary task).

The step forward that will be made by AIDE (a European funded Integrated Project started in March 2004 within the 6th Framework Programme "Information Society Technologies") is to keep into account more deeply the driver behaviour, his/her profile, status and availability (physical conditions, distraction, mental workload, performance). Increasing drivers' situation awareness will also be a key task, thus optimising driver's workload, promoting a change in driving behaviour, reducing distraction while extending the use of information services to all users.

The basic concept of "driving with safety and comfort" will be transformed into driving with all the information needed to navigate and to prevent situations of potential danger and into driving with all the information channels useful to communicate with the external world. One may argue that to fulfil the primary driving task the "communication to the external world" is not needed and moreover it is a source of distraction, but an easy answer is that, for example, nobody would ever accept to have his/her own mobile phone blinded when driving.

In this future context it is easy to predict that vehicles will be more and more crowded of information. The COMUNICAR system allowed to test the effectiveness of the concept of calculating in real time the level of risk and of prioritising the information exchange on the basis of this level. The AIDE system is extending this concept from the use of rule based algorithms to the development of a dynamic predictive model conceived to take into account in a more extensive way driver's behaviour and profile, vehicle dynamics and driving context.

This will be performed not only on a real time base, that means estimating a level of risk due to the instantaneous conditions, but keeping into account also the past and the near future in addition to the driver profile. The AIDE system will be thus able to consider what has been the activity of the driver during the previous part of the travel, if he is doing something usual or not according to his/her habits, and, in a predictive way, what could be his/her workload in the near future due to the characteristics of the environment.

It means that from a real-time system that considers only a picture of the current instant to estimate the risk associated to the scenario, the new concept takes into account the history and the future of the scenario. So the driver's activity is not only considered as "how the driver is driving now" but also as "how many hours has he/she been driving" and "how he/she is going to drive within the next minutes taking into account his/her profile and the road characteristics". Following this approach the AIDE system will adapt the onboard communication according to the profile of the driver, the vehicle and the environment. The behavior of the driver will be compared in each moment to his/her profile and to the stored data about his/her previous behaviours. This will enable the AIDE system to be more accurate in the identification of potential risks and to be more precise in understanding what can be dangerous for the specific driver, driving that particular car in that context.

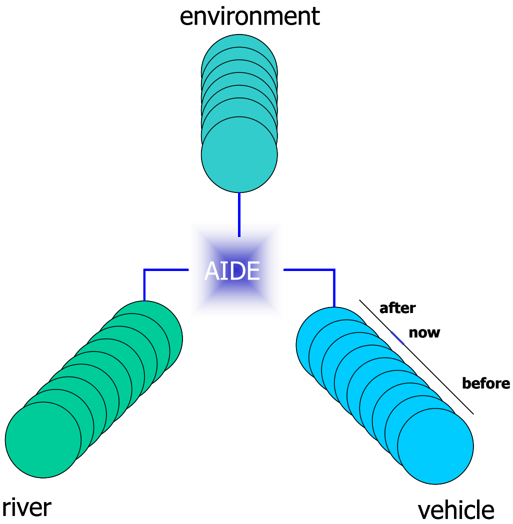

Fig 3 The AIDE adaptive system and the driver-vehicle-environment models

A simplified example is the definition of the level of risk based on driver's profile: "10 AM, the driver is driving within speed limits and he/she's interacting with radio system using the steering wheel buttons".
On the basis of these data, a simple rule-based system would estimate a low level of risk and in case of an incoming low priority information, such as a telephone call, it would provide it to the driver.
A dynamic adaptive system knows in addition what the driver has done before and thus what probably he/she will be doing next. For instance, in the proposed scenario, the system knows that the driver began to drive at 7AM and that this is unusual for him/her, it knows that the driver is driving on an unknown road (because the road is not included in his/her profile, updated everytime he/she drives) and that he/she's interacting with a function of the radio system that he/she uses very rarely (e.g. to set the rear speakers balance) and that is for this reason more demanding than others. Therefore the dynamic adaptive system could stop every incoming low priority information to maintain the driver's workload at an acceptable level.

The AIDE design starts from the state of the art and looks at the interaction between the driver, the vehicle and the context.

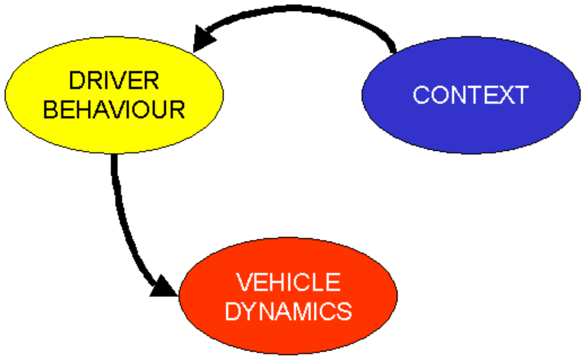

Fig. 4 Scheme of the basic interactions

At a first sight seems that simply the driver can influence the vehicle dynamics and be influenced by the context. Looking more deeply to this scenario a number of considerations arise. The first one is that while the driver influences mainly vehicle dynamics, the context influences the driver's behaviour, but has as well an impact on vehicle dynamics. The second consideration is that from the information point of view the context is also a source of useful information (i.e. crosses, ice, fog, daylight, etc.) to both the vehicle and the driver while the vehicle with its dynamic gives useful information to the driver. The third one is that also the driver with his/her behavior can give information to the vehicle to optimize both its dynamic and, as a counter-reaction, the behavior of the driver him/herself. On the basis of these considerations the AIDE system will be able to determine the risk level not only depending from the vehicle and the environmental conditions but as well from the current driver's availability as it results both from the driver's profile and from his/her current status.

The AIDE concept is thus to create a sort of "real time virtual awareness layer" gathering all relevant information about the context, the vehicle dynamic and the driver's behaviour and status to close the loop and to put the driver into the loop itself. In this way the subsequent communication channel selection and information prioritisation will become a powerful way to increase driving comfort and safety.

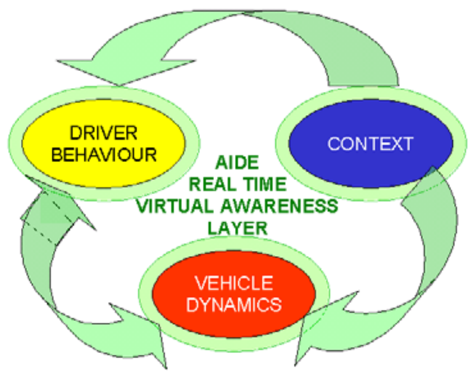

Fig. 5 Scheme of the interactions considered by AIDE

The design of the driver-vehicle dialogue will be the core of the “Interaction and Communication Assistant” (ICA) that will define the communication and data exchange protocol.
The ICA will be the central intelligence of the AIDE system, it will be responsible for managing all the interaction and communication between the driver, the vehicle and the driver’s personal nomadic devices. Starting from the assessment of the Driver-Vehicle-Environment (DVE) status/situation provided by the DVE monitoring modules it will select the presentation modality, the message prioritisation and scheduling and the global adaptivity of the driver-vehicle interface (e.g. display configuration and function allocation).

As already mentioned the ICA has also the aim to perform a safe integration of nomadic devices. At this purpose AIDE will develop concepts and guidelines for the integration and use of these devices on board, defining which functions should be available while driving and/or be controlled by the ICA.
The car will therefore enable the use of all existing and new preventive safety functions, of all new telematic services and of nomadic devices (brought on board by the user and connected in a wireless way), thus allowing the citizens to improve safety on the roads while properly using the vehicle and all the information and services that will become available in the future and at the same time avoiding driver’s distraction and overloading.

In AIDE, all relevant parameters related to the driver, to the vehicle, to the incoming/outcoming information available or requested (both from safety related systems and from information systems), to the traffic and to the external environment will be interpreted so to provide a real time situation awareness in a centralised intelligence.

The design and implementation of a “safe and efficient communication” between the driver and the vehicle or the external environment involves the definition of a number of HMI factors including:

- Definition of Input and Output channels (e.g. acoustic, visual, tactile, haptic, etc.)
- Selection of individual or multiple HMI modalities (sound, speech, icons, text, images, etc.);
- Design of warning format for safety application or vehicle signals;
- Message and information prioritization;
- Graphical layout;
- Speech dialogues (which can be adapted to different situation);
- Development of concepts and guidelines for the on board integration and use of nomadic devices.

Within this framework a number of innovative issues are identified as follows:

- 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 (to improve driver’s behaviour and to enable the use of the needed info);
- The integration of the HMI both for ADAS, for telematic systems and services and for a safe use of nomadic devices (to come towards the concept of HMI for integrated safety on board systems);
- The design and development of a seamless connectivity to driver’s personal information (to satisfy user needs);
- The use of new devices for novel design towards a greater easiness and intuitiveness of use and towards an efficient use of functions (only when needed);
- The enhancement of drivers’ perception of the external world to improve safety and 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;
- The reduction of the time to learn the use of a new system or service again avoiding misuse.

CONCLUSIONS

Within the COMUNICAR project the first rule-based “information management system” has been designed and tested, within the AIDE integrated project the development of an advanced administrator of Driver-Vehicle-Environment (DVE) information complexity, namely the “Interaction Communication Assistant” (ICA) allows the use of a dynamic DVE model to estimate the risk. The Interaction and Communication Assistant will be more efficient because of its adaptivity to the context and to the driver behaviour and profile and it’s additionally conceived to include the management of the information coming from nomadic devices: a step towards a future of “seamless connectivity” where everyone will have the availability of every information in every context at every time and everywhere.

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