

TOWARDS THE NEXT GENERATION INTELLIGENT DRIVER INFORMATION SYSTEM (IDIS): THE VOLVO CAR INTERACTION MANAGER CONCEPT

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ABSTRACT

In 2003, Volvo Cars introduced the IDIS (Intelligent Driver Information System) on the market. IDIS represents the first-generation of a driver-vehicle interaction management system that continuously monitors the demands of the driving situation and schedules certain types of messages, such as incoming phone calls and text messages, in order to reduce the potential for driver information overload. The present paper describes work towards a more advanced, second generation, IDIS system, with the responsibility to manage the interaction between the driver and all types of in-vehicle functions.

INTRODUCTION

Driver-vehicle interaction management is a currently hot topic in the automotive industry. From a general perspective, interaction management (IM) could be viewed as a structured way to deal with human-machine interaction (HMI) issues arising from the rapid functional growth in today's vehicles. The proliferation of in-vehicle functions leads to strong requirements for integration and harmonization and interaction management can be viewed as the "HMI-part" of a general trend towards more integrated vehicle systems.

The in-vehicle functional growth poses both technical and human factors challenges. The technical problems concern how to utilize different HW and SW components in the most efficient way. In the HMI domain, this concerns, for example, how to allow multiple applications to share access to a display¹. The general human-factors-related challenge is to integrate a large number of functions into a common HMI, without compromising safety, usability and comfort.

¹ The analogous problem exists on the sensor side, where sensor fusion is a currently very hot topic.

A key issue concerns the potential risks of excessive levels of workload and distraction caused by multiple, uncoordinated, in-vehicle functions.

One of the first comprehensive efforts in this area was the EU-funded-project GIDS [9] , conducted between 1989 and 1992 as part of the EU DRIVE programme. GIDS has since been followed by a number of EU-funded projects aiming towards the development of interaction- (or workload-) management systems, e.g. CEMVOCAS [2] COMUNICAR [10] and the ongoing AIDE project [4] Similar developments exist in the US, most notably in the ongoing SAVE-IT [13] project. There are also several examples of company specific developments, such as the Toyota workload manager [14] the Motorola Driver Advocate [12] TNO's Co-Drive [15] and a system developed by BMW and Bosch in collaboration with University of Regensburg [11] . See [6] for an overview of existing initiatives.

Despite the extensive research activities, there are still very few interaction management systems on the market. One exception is the Intelligent Driver Information System (IDIS) that was introduced by Volvo Cars in the new S40 and V50 models in 2003. IDIS represents a first-generation interaction manager, comparable to the first generation of Motorola's Driver Advocate, demonstrated in a prototype vehicle with DaimlerChrysler [3] The IDIS system continuously monitors the demands of the driving situation and schedules certain types of messages such as incoming phone calls and text messages accordingly. For example, if the driver enters an intersection, incoming phone calls are delayed until the intersection has been passed. Due to its relative simplicity, it was possible to implement IDIS on the existing vehicle architecture, exploiting sensor information already existing on the vehicle's data bus. While the IDIS solution is sufficient for realising the use cases it was designed for (relating mainly to message scheduling), it cannot resolve conflicts *between* different in-vehicle functions. This requires a centralised interaction management architecture, which puts stronger requirements on the underlying electronics architecture. The present paper describes the Volvo Cars Interaction Management concept which represents a more advanced, second generation, IDIS system, with the responsibility to manage the interaction between the driver and all types of in-vehicle functions.

THE INTERACTION MANAGER CONCEPT

The general purpose of the Interaction Manager is to resolve HMI conflicts between different systems, or between systems and the current driving situation. Specifically, the key Interaction Manager functions envisioned are:

- Management of the allocation of I/O resources to applications
- Resolution of conflicts between applications with respect to their interaction with the driver
- Resolution of conflicts between system initiated events and secondary tasks performed by the driver
- Resolution of conflicts between applications and the driving situation
- Application adaptation, e.g. optimizing warnings with respect to the driver state

The Interaction Manager concept is illustrated in Figure 1.

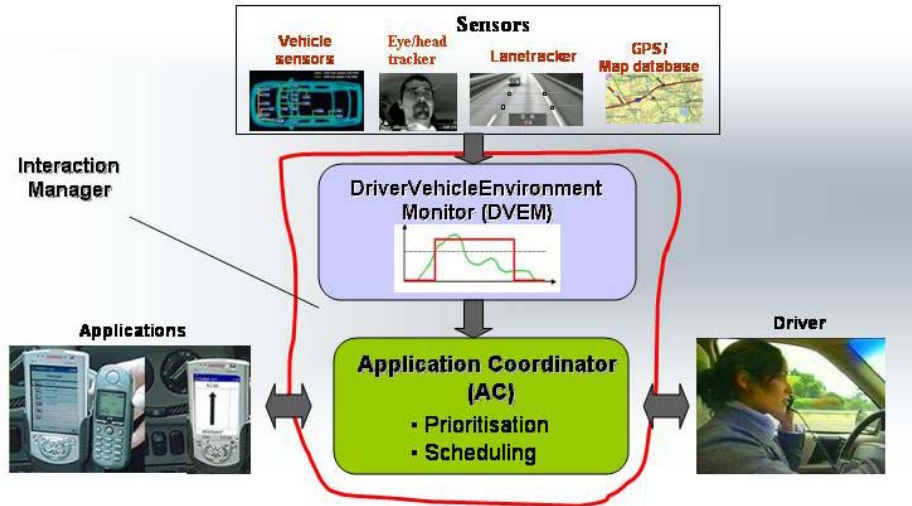


Figure 1. The Interaction Management concept (see the text for explanation)

As illustrated in Figure 1, the IM consists of two main components: (1) the *Application Coordinator (AC)* and (2) the *Driver-Vehicle-Environment Monitor (DVEM)*. The AC is responsible for the centralised management of interactions between the driver and different applications. The AC thus contains the logic for I/O HMI resource management, action prioritization and DVE-dependent scheduling.

The DVEM represents a generalization of the current IDIS Workload Estimator (WE). While the IDIS WE focused on estimating the demand of the driving situation based on information available on the vehicle data bus, the DVEM monitors multiple relevant aspects of the driver, vehicle and environment state, using data from a wide range of sensors such as radar, eye-/head tracking and other data sources such as GPS combined with digital maps.

THE IM ARCHITECTURE

The functional architecture is a high-level description that specifies the relations between the different components in the IM system and the data flow between them. This description is largely independent of the underlying communication buses and the ECU configuration (although the functional architecture obviously has important implications for the electrical and electronics architecture).

The functional architecture of the present IM solution is illustrated in Figure 2. This architecture solution is based on a centralized approach with the AC as the central manager of all application actions and resource allocations. The general approach is similar to the one adopted in the AIDE project [8]

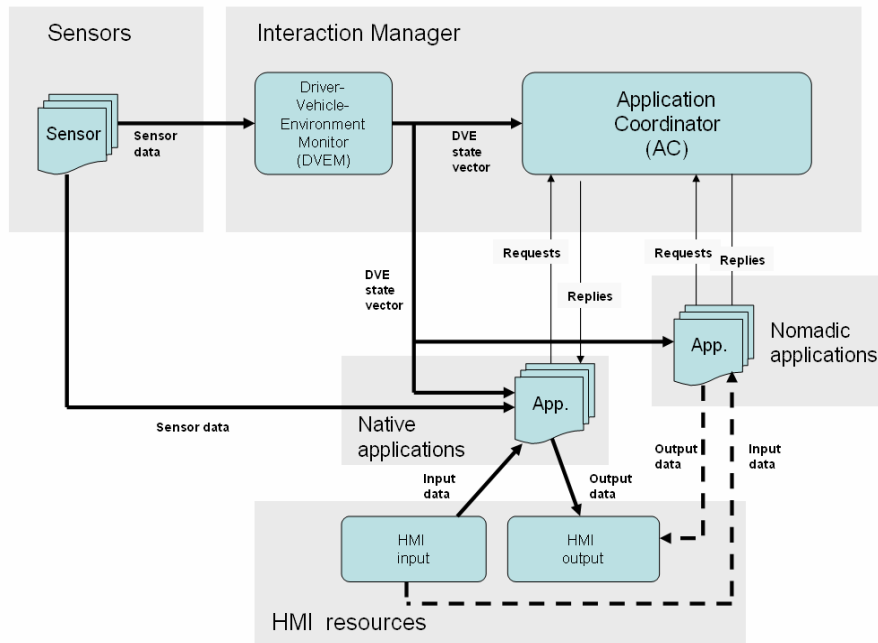


Figure 2. The general logical architecture of the Interaction Manager

The key properties of the logical architecture illustrated in Figure 2 are:

- HMI input output resources as well as sensors are shared between applications
- The AC manages all application actions and allocation of resources
- Applications running on nomadic devices are managed in the same way as embedded applications
- The applications are directly connected to the HMI I/O devices
- Applications listen directly to the DVE state

THE APPLICATION COORDINATOR (AC)

The general principles of the AC and its relation to other components were indicated in the description of the logical IM architecture in the previous chapter. A further illustration of the role and operation of the AC is given in Figure 3. As illustrated in the figure, when an application wants to perform an action, it sends a request to the AC in a specified format. The request contains information on the importance, duration, type etc. of the action, and also a specification of the HMI resources requested. Based on the request, the status of other actions, and the current DVE state vector (obtained from the Driver-vehicle-environment monitor), the AC replies to the application, either “Yes, go ahead!” or “No, wait!”. The decision function implemented by the AC can thus be represented by the general expression

$$AC \text{ reply} = F(\text{Application request}, \text{Status of other actions}, \text{DVE state})$$

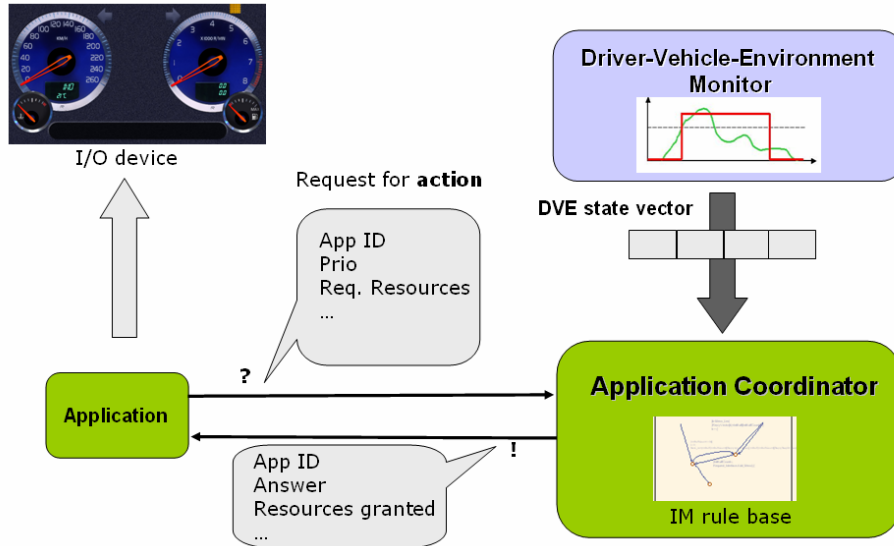


Figure 3 General working principles of the Application Coordinator

The application coordinator has been developed with generality and flexibility in mind. Most of the management rules can be adjusted only by means of changing parameters.

THE DRIVER-VEHICLE-ENVIRONMENT MONITOR (DVEM)

The DVEM developed in the present project can be considered as a generalization of the IDIS Workload Estimator (WE). The IDIS WE computes an estimation of the current demand of the driving situation based on sensor data already existing on the vehicle data bus. The DVEM extends the IDIS WE in two main ways. First, the IDIS workload estimation is enhanced by exploiting new sensor signals (radar, head tracking and GPS+digital map). Second, a number of other DVE parameters, supporting new types of IM functions, have been added. Thus, rather than outputting a single binary value like the IDIS WE, the DVEM outputs a *vector* of output parameters used by the AC and the applications. This contrasts to most existing solutions, e.g. COMUNICAR [1] where the different DVE-related parameters are weighted together to a single risk value. The parameters of the DVEM vector were derived based on a set of formalised use cases, representing the key situations where the IM system is intended to be used, and include representations of the current driving demand, driver impairment state and drivers' secondary task activity.

PROTOTYPE IMPLEMENTATION

The IM solution outlined above was developed and tested in an iterative, incremental, fashion, starting with implementation of the real-time system in a driving simulator environment. After some design iterations, the system was moved to a real test vehicle for verification and testing in the real world.

The simulator prototype setup featured an LCD instrument cluster, a touch screen, seat vibration and a HUD (head-up display) simulator where the image is projected onto a large glass screen (replacing the windshield). A number of HMI I/O devices and infotainment/active safety applications were simulated in order to create a realistic in-vehicle information environment to

be managed by the IM. All simulated applications and I/O devices were fully functional and worked in real time. In accordance with the general architecture illustrated in Figure 2, the applications and HMI I/O devices were logically separated (so that an application could – in principle – be configured to any HMI I/O device). Moreover, an IM Visualiser application was developed with the purpose of illustrating in real time what was going on “behind the scene” in the IM algorithm.

The vehicle IM prototype was implemented in a Volvo S60 test vehicle. The main objective of the vehicle prototype implementation was the development and testing of the Driver-vehicle-environment monitor (DVEM). However, a subset of the simulated applications from the demonstrator, a full-scale Application Coordinator and the IM Visualiser were implemented in the vehicle as well. Besides the standard vehicle sensors, the vehicle was equipped with front radar, a Seeing Machines Facelab eye/head/eyelid tracker, a lane tracker, and a GPS receiver. Moreover, computation hardware for the different IM components was integrated.

The simulator and vehicle demonstrators constitute proofs-of-concept of the feasibility of the Interaction Management approach adopted. This holds not only of the IM functionality but also of the suitability of the functional architecture for satisfying the key requirements of flexibility and modularity of the HMI.

DISCUSSION AND CONCLUSIONS

The present paper described a general concept for the next generation Intelligent Driver Information System (IDIS) under development by Volvo Cars, known as Interaction Management. The general principles and functional architecture behind the IM approach were outlined, and some early demonstrator implementations described.

From a general perspective, there are two key driving forces behind the development of Interaction Management systems (and related concepts such as workload managers and adaptive, integrated interfaces): (1) The need to handle the rapid in-vehicle functional growth and (2) the expected benefits in terms of road safety.

With respect to (1), it is clear that the efficient integration of in-vehicle functions, not only with respect to sensors and computing hardware, but also on the HMI side, is an area that *has* to be addressed if the full benefits of new in-vehicle functions are to be utilized. An Interaction Management system of the type described in the present paper is clearly a key enabler for efficient HMI integration. From a broader perspective, Interaction Management should be viewed as a more integrated approach to automotive HMI design, accounting for interdependencies between functions, both with respect to the look-and feel (e.g. graphics design), and the more general HMI strategies (e.g. methods for message prioritisation, HMI consistency etc.), both of which are important brand differentiators. At the same time, the industrial deployment of in-vehicle HMI functions requires a high level of modularity and scalability, in order to enable different configurations between applications and HMI input/output devices. The present IM solution has been explicitly designed to account for these aspects.

Regarding the expected safety benefits of an IM solution, we know that the majority of road accidents are at least partly caused by driver inattention [7] Thus, the intelligent scheduling of system-initiated information supporting the driver to avoid inattention at inopportune moments clearly has a potential to reduce accidents [6] However, it is currently very difficult to estimate the actual expected benefits of IM-type systems, mainly because of the lack of sufficiently detailed information on how inattention causes accidents in existing crash data bases. One potential way forward is to look more closely on naturalistic driving data, such as the 100-car study [7] investigating which accidents that could have been prevented by means of an IM system. A further possibility is to perform large-scale field-operational testing with vehicles equipped with mature IM systems.

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