INSAFES HCI Principles for Integrated ADAS Applications

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Abstract. In order to integrate several time critical warning systems, e.g. Collision Warning and Lane Departure Warning, in the same vehicle one has to deal with the problem of warning management to not overload the driver in critical situations and to make sure that driver's focus is directed to the right place. This paper presents INSAFES integration schemes to ensure these issues, and gives general as well as specific use cases based on warning systems integrated in one of INSAFES demonstrator vehicles. From these use cases are then requirements on warning management derived regarding prioritization schemes. The requirements concludes in a proposed extension of the warning management concepts derived in the AIDE project.

Keywords: Warning Management, Integrated Safety, ADAS, HMI, Automotive.

1 Introduction

The vehicles of today are being equipped with an increasing number of Advanced Driver Assistance Systems (ADAS) designed to warn/inform the driver of a potentially dangerous situation or even intervene to mitigate an impending accident. Alongside these critical active safety applications are In-Vehicle Information Systems (IVIS), e.g. telematics and communication services, infotainment (CD, Radio) and vehicle diagnostic messages, all requesting the attention of the driver. Studies have shown that allowing all these systems acting independently of each other would severely degrade the effectiveness of each individual application and increase the workload of the driver in safety critical situations [1], [2].

INSAFES is a subproject within IP PReVENT (www.ip-prevent.org) partly funded by the European Commission. The goal of INSAFES is to improve the functionality and reliability of applications developed within IP PReVENT, and to advance from stand-alone safety applications targeting one specific function to an integrated system covering a vast range of applications. To exploit synergies between different ADAS systems integrated in a vehicle INSAFES propose, in [3], integration schemes on different architectural layers, i.e. Perception, Decision and Action as defined in the ProFusion general architecture [4]. The perception layer is responsible for perceiving the surrounding traffic situation. In the decision layer, applications detect hazardous

C. Stephanidis (Ed.): Universal Access in HCI, Part II, HCII 2007, LNCS 4555, pp. 339–348, 2007.

situations and form the decisions on whether to warn, inform or intervene. The action layer is responsible for choosing the appropriate channel to convey the decision of the application to the driver or vehicle. A schematic figure of how these layers are used in INSAFES is shown in fig 1.

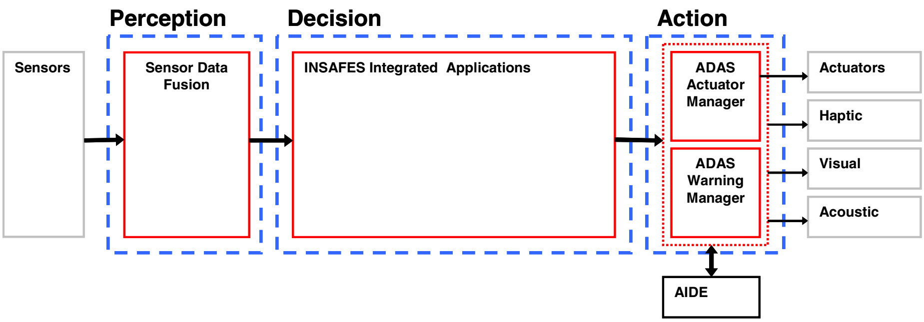


Fig. 1. INSAFES functional architecture

In order for an integrated system to be truly successful one has to deal with the problem of warning management to not overload the driver in critical situations and to make sure that driver's focus is directed to the right place.

2 Problem Formulation

The problem at hand is to find schemes to arbitrate and manage several different safety and time critical warnings integrated in the same vehicle. The applications should be integrated in such way that multiple ADAS functions and systems are allowed to interact with multiple warning devices. The aim is to minimize the reaction time and workload for the driver in a complex multi warning and information situation. The integration shall allow for a unified HMI towards the driver and to limit the number of different HMI channels needed.

INSAFES propose to form ADAS Human-Machine-Interface (HMI) strategies, in order to overcome the problems mentioned above. These strategies are incorporated in an ADAS Warning Manager (ADAS-WM), which is responsible for managing the information and warnings going to the driver from all integrated safety and time critical ADAS applications.

Other current projects such as the AIDE (Adaptive Integrated Driver-vehicle InterfacE) project are also investigating HMI integration. The focus of the AIDE project is to develop general principles and strategies for management and integration of IVIS applications. In some aspects, also ADAS applications are considered, though we argue that the AIDE ICA base architecture [5] is proposed to be extended to be able to handle time and safety critical warnings within an automotive electrical architecture. Within INSAFES, development is exclusively directed towards HMI management strategies for time and safety critical warnings with high priority and which are also crucial for the primary driving task. The management and integration of IVIS and non time critical ADAS is handled through the base AIDE ICA architecture.

3 Applications, HMI and Integration

Within INSAFES three different demonstrators are developed, a Volvo truck, FIAT car and a Volvo car, each demonstrating different applications and HMI solutions. Prioritizations of applications and use cases in terms of safety impact for the INSAFES project are defined in [6]. In this paper we use the demonstrators, developed at Volvo Cars (VCC), to show a possible solution to the problem of an integrated HMI and to give examples of use cases for an ADAS Warning Manager.

3.1 HMI Integration

In the vehicle there exists several different HMI modalities, visual, audible and haptic available to convey information and warnings from ADAS applications. Fig 2 shows placement of all visual HMI modules and a description of each is followed below. Additionally is a 4 way directional sound system integrated in the vehicle.

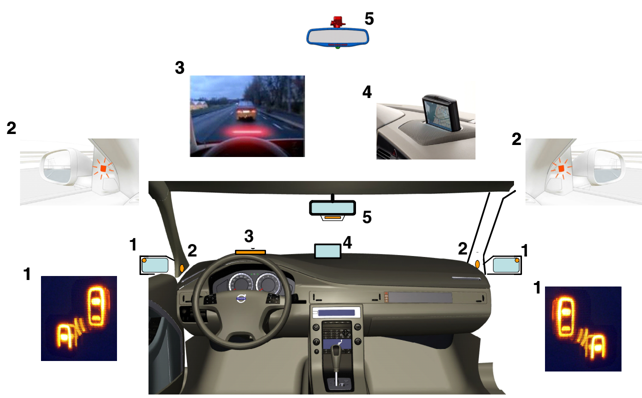


Fig. 2. Visual HMI channels distribution in the vehicle as seen from the driver. 1. Side Mirror Visual Module (SMVM), 2. A-pillar Console Visual Module (ACVM), 3. Head Up Display (HUD), 4. General Warning and Information Display (GWID), 5. Rear-end Monitoring Visual Module (RMVM).

The distributed visual HMI channels, shown in fig 2, follows a user centered approach by directing the driver's attention to the target area. Each of the HMI devices are explained in more detail below:

1. Side Mirror Visual Module (SMVM), shows a amber lit ISO 17a symbol beneath the mirror glass in the upper outer part of the side mirror. Used to inform the driver of events in the lateral area. As the side mirrors constitute the boundaries of the driver's perception area, these warning devices are only used for low priority warnings.

2. A-pillar Console Visual Module (ACVM), shows a amber light in the a-pillar console and is used to warn the driver of events in the lateral area.
3. Head Up Display (HUD), projects a row of horizontal red light onto the windscreen in front of the driver. This is suggestive to the brake lights of a preceding vehicle and directs the attention of the driver to events in front of the car.
4. General Warning and Information Display (GWID), is a general warning and information device. The GWID will in default mode be used for infotainment issues, e.g. radio and navigation, but as a warning is issued, a pop-up window will show the warning.
5. Rear-end Monitoring Visual Module (RMVM) has the same strategy as the HUD but focuses on events behind the car.

The effectiveness of the HUD (for forward collision warning applications (is investigated in [7]. The SMVM, ACVM and RMVM are developed within the LATERAL SAFE project and evaluation results are presented in [8].

3.2 Applications

The integrated ADAS applications utilizing these HMI channels defined in Section 3.1 are the following:

- **Collision Warning with Brake Support**
  Collision warning with brake support warns the driver of an impending front collision as well as gives the driver brake support if the collision is unavoidable, to limit the speed at impact. The warning is presented either as a flashing HUD or to show a bird's eye view of the ego-vehicle including a flashing red segment in the GWID. Both visual channels are combined with an audio signal.
- **Adaptive Cruise Control (ACC)**
  Adaptive cruise control is a comfort function assisting the driver in keeping an appropriate distance and speed to leading vehicles. ACC lets the driver specify a desired cruising speed and a time gap to leading vehicle. As long as there is no leading vehicle in front the vehicle is set to cruise at the desired cruising speed. The ACC application automatically reduces the speed to keep the desired time distance to slower vehicles in front. However, if the system determines that the needed brake power to slow down to the desired speed is too large a Brake Capacity Warning (BCW) is issued by flashing the HUD and an audible warning to encourage the driver to take over.
- **Lane Departure Warning (LDW)**
  Lane Departure Warning detects and warns the driver with an audio signal, if the driver unintentionally drifts over to adjacent lanes.
- **Lateral Collision Warning (LCW)**
  Warn the driver if there is an imminent danger of collision from the side. The driver will be alerted by an audio signal and a flashing light in the ACVM. Alternatively, the GWID will show the warning in similar manner as for CWBS.

- **Curve Over Speed Warning (CSW)**
  Curve over speed warning helps the driver to keep an appropriate speed while entering a curve. If the system decides that the current speed of the vehicle is too high for a safe and comfortable curve taking maneuver a warning is issued. This is made by an audio signal and a popup warning in GWID.
- **Lane Change Assist (LCA)**
  LCA system informs the driver of vehicles approaching in the left and right adjacent lanes to assist the driver while making a lane change maneuver. The information is given via the SMVM or alternatively a popup in the GWID.
- **Blind Spot Detection (BSD)**
  Detects and informs the driver of vehicles in the left and right blind spot. BSD uses the same HMI channels as the LCA application.
- **Lateral and Rear-end Monitoring (LRM)**
  Lateral and Rear end Monitoring supplies the driver with a holistic perspective of the traffic scenario in the left and right adjacent lanes as well as behind the own vehicle. LRM helps the driver to be aware of where other vehicles are in the lateral and rear end area. Information about the surrounding traffic is either given in the GWID or using the SMVM in combination with RMVM.

4 INSAFES Warning Manager Strategies

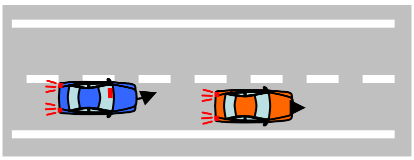
In this section we derive and motivate the concepts and requirements of the INSAFES ADAS Warning Manager. One key requirement is to be able to prioritize between warnings of both different and same level of criticality. In aide in this discussion we define different warning criticality levels as, Informatory (Low Priority), Alert or Cautionary Alert (Medium Priority) and Imminent Warning (Highest Priority). Other aspect are the interaction with IVIS applications and synchronization issues between different warning devices. All this aspects are motivated by means of identified use cases highlighting the need for warning management in integrated vehicles.

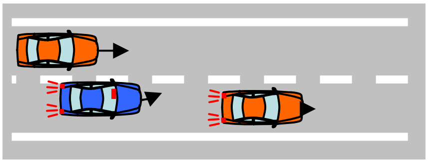
Here we also propose an extension to the basic AIDE/ICA architecture to handle the identified requirements.

4.1 Use Cases and Requirements

To derive the requirements of the ADAS Warning Manager this section gives some illustrative use cases. These use cases are identified situations that drivers may experience while driving such cars as the one described in Section 3. Linked to each use case is a set of requirements. The notation system will here refer to the INSAFES integrated functions.

Table 1. ADAS Warning Manager use cases and requirements

Nr.	Use Case	Requirements
1	The ego-vehicle starts to drift out of its lane, an event that triggers an Alert Warning from the system. Simultaneously, the system also detects a high risk of collision with a braking vehicle in front, which results in an Imminent Warning. The ADAS-WM therefore suppresses the Alert warning an gives the Imminent warning. 	Req 1) When two functions want to use the same modality at the same time the highest priority warning shall be prioritized Req 2) Warnings shall not be stored or delayed.
2	The ego-vehicle is using Adaptive Cruise Control (ACC) on a highway. As the vehicle in front makes an emergency braking, the system first issues an Imminent warning due to the increased risk of collision. Immediately afterwards, the ACC function requests the driver to take over in order to obtain maximum break power. This results in an Alert Warning. Both warnings are in default mode using the same warning devices. However, in this use case, the driver has disabled the audible warning for collision warning. Consequently, the ADAS-WM is enabling a visual warning, followed by an audible warning. The ADAS-WM will suppress consecutive warnings for the same modality within a defined time period.	Req 3) Warnings of several modalities shall be prioritized per modality. Req 4) If a warning has been issued, all lower or same priority warnings shall be suppressed for that device during a defined time period (seconds).
3	The driver is negotiating a lane change operation but fails to recognize the issued Alert Warning, stating a car in the adjacent lane. When the system detects that the ego-vehicle is drifting out of its lane, the ADAS-WM will trigger an Imminent Warning due to the increased risk of a lateral collision collision.	Req 5) It shall be possible to combine two low priority warnings to provide a higher or same priority warning.

		
4	The system issues an Imminent Warning due to a braking car in front while the driver is listening to music and is looking away. If the music is not muted the driver could fail to react on the warning.	Req 6) A warning device that is possible to trigger from both the ADAS-WM and other units (such as IVIS applications), shall incorporate an internal prioritization on output, allowing direct activation of warnings. Req 7) Other sound sources shall be muted while an audible warning is issued.
5	The system detects an fast overtaking car in an adjacent lane, resulting in an Informative Warning. As the car enters the blind spot area of the ego-vehicle, another Informative Warning is issued. The ADAS-WM enables the same warning device for both warnings.	Req 8) The ADAS-WM shall have a consistent approach to warning presentation.
6	The driver gets a navigation message just after a warning is provided and thereby starts to make an avoidance maneuver.	Req 9) The vehicle general HMI manager shall be informed about the warning provided to the driver and stop and delay IVIS messages during a specified time (few seconds). After the delay IVIS messages shall be repeated with updated information.
7	The system issues a Imminent Warning due to a hard braking car in front, while the driver is inattentive. The driver brakes hard and manages to stop the ego-vehicle with only a few meters remaining to the vehicle in front.	Req 10) The latency from activation of a warning state to activation of the HMI device shall be less than 100 ms. Req 11) Warnings of different modality triggered by the same warning state shall be started within a 100 ms period with 85% confidence.

4.2 ADAS WM Architecture Concepts

Current concept for management of in vehicle HMI devices proposed in the basic AIDE concept relies on the Interaction and Communication Assistance (ICA) module discussed in [5]. The general objective of the ICA is to manage all interaction with the driver with the in-vehicle systems by an accept/inhibit scheme. The ADIE principle is that all in-vehicle system (applications) asks the ICA for the use of a certain HMI channel. The ICA determines whether to accept the request or inhibit the system from using the HMI channel (based on certain criterions) and communicates this decision back to the application. If the application receives an affirmative response the application proceeds to take control of the HMI channel. This scheme is shown in Fig 3.

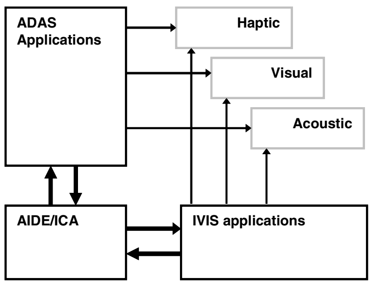


Fig. 3. Schematic view of AIDE HMI management concept

This is a very suitable scheme for IVIS and non time critical ADAS application but introduces an longer latency in the system for time and safety critical ADAS applications as it has to wait for a reply from the ICA in order to give its warning to the driver. Instead INSAFES propose to use the following scheme shown in Fig. 4. Here time and safety critical ADAS applications are managed separately by the ADAS Warning Manager (ADAS-WM). The link is still present to AIDE and the ICA module which, in this scheme, is responsible for coordination of IVIS and non time critical ADAS applications in much the same way as before. The main differences in the INSAFES proposal are shown in that the ADAS-WM only informs the ICA that it will use a certain HMI channel and will not wait for a reply. Further on the INSAFES proposal adds the possibility to add a local prioritization module in each HMI channel indicated with a red box in the HMI modules in Fig 4.

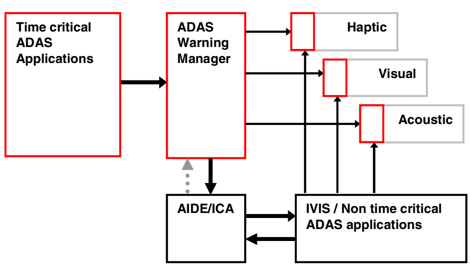


Fig. 4. Schematic view of INSAFES ADAS Warning Manager scheme

Fig. 5 shows a comparison between the described schemes in terms of latency in a likely automotive implementation where different applications can be situated at different networks and the communication has to go through a gateway. Here we clearly see drawbacks with the basic AIDE architecture compared to the extensions proposed by INSAFES.

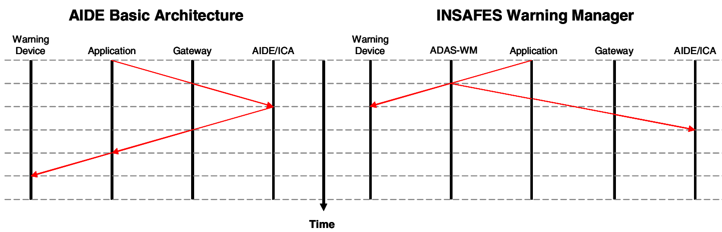


Fig. 5. Latency comparison between the basic AIDE architecture and the INSAFES proposal

5 Conclusions

The HMI integration scheme proposed in this papers allows for incorporation of general ADAS HMI arbitration and prioritization strategies for time and safety critical warnings. By tight integration in between ADAS applications and Warning Manager and direct access to warning devices latency can be reduced to an acceptable level. Using the possibility of local prioritization in the HMI devices in combination with the AIDE ICA module ensures an effective, unified HMI towards the driver with limited distractions.

Acknowledgements

We wish to acknowledge to the INSAFES Subproject Consortium of the PReVENT IP project, for their valuable contributions to this work. The PReVENT IP project is partially funded by the EC.

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