HMI Principles for Lateral Safe Applications

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Abstract. LATERAL SAFE is a subproject of the PREVENT Integrated Project, co-funded by the European Commission under the 6th Framework Programme. LATERAL SAFE introduces a cluster of safety applications of the future vehicles, in order to prevent lateral/rear related accidents and assist the driver in adverse or low visibility conditions and blind spot areas. LATERAL SAFE applications include a lateral and rear monitoring system (LRM), a lane change assistant (LCA) and a lateral collision warning (LCW). An effective Human Machine Interface (HMI) is being developed, addressing each application, on the basis of the results emerged from mock-up tests realised in three sites (one in Greece and two in Sweden), aiming to determine which is the best HMI solution to be provided in each case. In the current paper, the final HMI principles, adopted and demonstrated for each application, are presented.

Keywords: HMI, lateral safety, rear monitoring, evaluation.

1 Introduction

The target applications of LATERAL SAFE project are namely the following:

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- The **Lateral Collision Warning (LCW)** application, which reduces the risk of accidents between the ego-vehicle and other obstacles in the lateral side of the vehicle. In this case, the driver is informed about dangerous relative displacement of obstacles in left and right side area of the ego-vehicle.

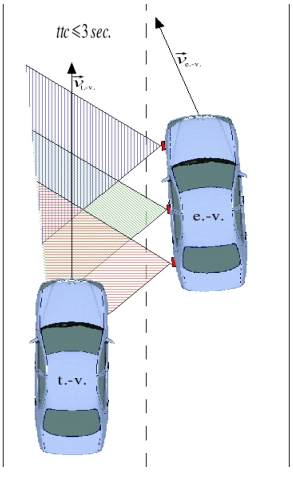

Fig. 1. "Lateral Collision Warning" application indicative scenario

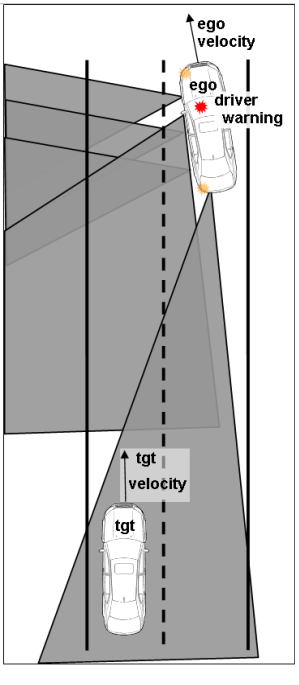

Fig. 2. "Lane Change Assistance" application indicative scenario

- The **Lane Change Assistance (LCA)** application, which provides information about vehicles approaching in adjacent lanes and vehicles present in the blind spot to assist the driver with lane change manoeuvres.
- The **Lateral and Rear Area Monitoring (LRM)** application, which reduces the risk of accidents between the ego-vehicle and other obstacles both in the lateral and rear neighborhoods. The traffic information from the sensors is used to enhance the driver's perception of the traffic situation (see figure 6).

The Lateral Collision Warning (LCW) and the Lane Change Assistance (LCA) applications were initially intended for passenger cars, whereas the Lateral and Rear Area Monitoring (LRM) system was designed as a truck application at the beginning. However, adjusted versions of the LCA and the LCW for the trucks and LRM for cars came up during the project progress. Thus, a common HMI approach has been implemented for all applications finally developed in LATERAL SAFE.

2 Background Research

In order for LATERAL SAFE project to determine HMI solutions for the support of the driver in the different tasks addressed by each LATERAL SAFE application, a series of preliminary tests were realized, in order to perform a cross-comparison of a series of HMI mock-ups intended for all different systems.

HMI mock-up tests were carried out in VTEC (desktop tests with 5 subjects), with VCC research car (10 subjects) and with CERTH/HIT car simulator (18 subjects). The main evaluation objectives of the HMI tests were the following:

- Which is the appropriate level of explicitness for the displayed visual cautionary warnings to the side mirror;
- Which is the appropriate HMI per application, based on subjective and objective evaluation measures;
- How driver behaviour is affected in case of an imminent or a cautionary warning.

The evaluation was performed upon a common evaluation plan and supplementary experimental plans for each test site, defining the type, the number and the sequence of the scenarios used, the experimental conditions and the size and profile of the sample. The scenarios selected in each test site for the assessment of the respective mock-ups were tried by the subjects with and without the system. A series of pre-test and post-test questionnaires were distributed, to evaluate user acceptance and user interface assessment, before and after the evaluation, as well as drivers' workload while testing the different HMI mock-ups. In addition, a series of objective measurements were collected during the HMI evaluation, namely the number of received warnings and the level of users' compliance to them, the system and users' failure percentage in recorded errors, the number of accidents or successful manoeuvrings, the minimum time-to-collision (TTC) and headway values when performing a manoeuvre (i.e. lane change, etc.) and the required driver time to take an evasive action in case another vehicle is drifting against the ego vehicle, which is one of the main Use Cases of LATERAL SAFE, together with the ego vehicle lane change.

The evaluation results, coming from all three types of trials, led to the determination of appropriate HMI solution for each application, presented in the

following section of the current paper. These solutions however, need to be further developed and refined when going from a research system to a production system, where possibly other factors need to be considered then the ones taken into account here. The solutions presented herein give an input to this work.

3 HMI Solutions for Lateral (and Rear Monitoring) Applications

3.1 Lane Change Assistant (LCA) and Lateral and Rear Monitoring (LRM) Applications for Cars

The LCA application has two operative modes, which are adopted also by the HMI approach implemented for this application, and are the following:

- In case no actual lane change wish is detected, the presence of vehicles in the blind spot or vehicles approaching fast from behind on the neighbouring lanes is visualised by a yellow symbol (led) in the respective side mirror. This operation mode is called "**information mode**" and is beneficial for drivers who plan to make a lane change decision. The driver can acquire the information whether the LCA system judges the situation to be potentially dangerous for lane changes, by looking in the side mirror. By providing the information in the side mirrors, the risk of abuse for this function, by "blindly" relying on it, is minimised. The information provided in the side mirror covers also the lateral monitoring functionality of the "Lateral and Rear Area Monitoring" application, as this is adjusted for passenger vehicles.
- In case the driver's lane change wish coincides with potentially dangerous vehicles on the neighbouring lanes, the driver is warned by a flashing red symbol in the side mirror and with a warning sound in case the adjacent lane is occupied. This mode of operation is called "**warning mode**". The warning sound is produced by a directional sound system in the car, so that the drivers' attention is drawn to the source of danger. For detecting the driver's lane change wish, the condition of each direction indicator (on/off) is used.

The main descriptive info of the leds implemented in the side mirrors are the following:

- Symbol designed according to the working document ISO 2575.
- ISO symbol K17A.
- Symbol size > 10 x 15 mm.
- Orange/Red colour (~620/660 nm) – 2 warning levels.
- Directed towards the driver.
- Light intensity > 2000 mcd (controllable intensity: Night/Day).
- Minimum contrast: 2:1.

The side mirror led described above is implemented in the CRF demonstrator (Fiat Stilo), as shown in the following figure.

In addition, a dedicated rear view mirror is designed and realized, to integrate the selected HMI solution for the monitoring of the rear area of the vehicle (for the adjusted version of the Lateral and Rear Area Monitoring application for passenger vehicles). In the rear view mirror, there are leds that report two information levels

Fig. 3. HMI solution (side-mirror led) for the lateral area of the vehicle addressing LCA and the lateral functionality of the LRM for cars applications

(yellow or red), related to the presence of vehicles to the rear following at a close time gap (see following figure). The main characteristics of the rear view mirror leds are provided below:

- Two warning levels:
  - Level 1: One amber diode.
  - Level 2: Three red diode.
- Amber (~620 nm) and red (~660 nm) colours.
- Directed towards the driver.
- Light intensity >= 1000 mcd (controllable, Night/Day).
- Symbol size Ø >= 5 mm.
- Minimum contrast 2:1.

Fig. 4. HMI solution addressing the LRM application for car (rear view mirror leds)

3.2 Lateral Collision Warning (LCW) for Cars

The HMI for the Lateral Collision Warning application has been realised in the a-pillar. The used symbol has been designed following the guidelines provided by the working document ISO 2575 and using the ISO symbol K17B. A lighted warning triangle is associated to another symbol (see following figure), with the following main characteristics:

- Visual symbol size > 10 x 10 mm.
- Red colour (~660 nm).
- Light intensity >= 1000 mcd (controllable, Night/Day).
- Light directed towards driver.
- Minimum contrast: 2:1.
- Flashing.

In addition to the visual symbol, an acoustic warning is generated. The acoustic warning is generated by the application with directional features, in order warn the driver about the direction of the risk (mainly left or right and rear or front).

The HMI components integrated for the LCW functionality are shown in the following figure.

Fig. 5. HMI solution addressing the LCW application for car (a-pillar, red)

3.3 Lateral and Rear Area Monitoring (LRM), Lane Change Assistance (LCA) and Lateral Collision Warning (LCW) for Trucks

A display-based solution of LRM application is mounted on the truck dashboard, showing the objects in the surrounding area from a bird´s eye view and is implemented only in trucks (see following figures).

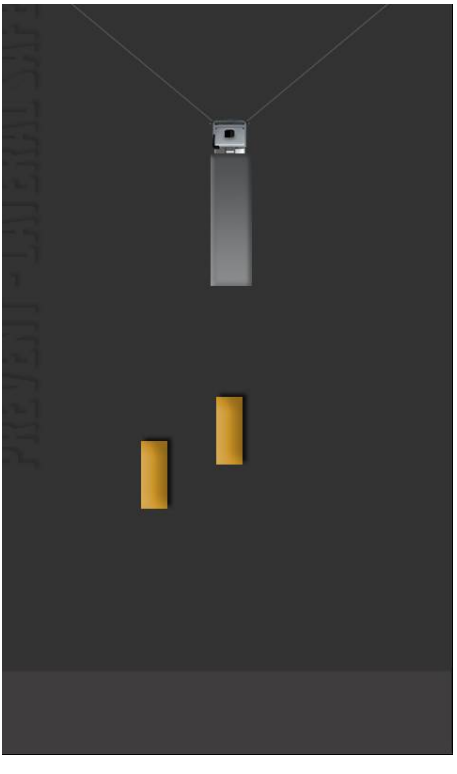

Fig. 6. LRM information presented to the driver in a truck

The HMI solution for the LRM application for trucks is summarised below:

- The objects behind the ego-truck, moving in the same lane, are coloured yellow under normal conditions and red if the object is very close behind the truck (headway value < 0.3s).

The objects in the adjacent lanes are normally coloured yellow. However, the colouring changes to red if the system detects that the object is closing the truck rapidly (lateral TTC < 1.5s) and combined with an acoustical LCW warning. Additionally the following strategies are followed for the colour coding change:

- Objects two or more lanes away are represented in the display, if they are closing the truck rapidly (TTC< 3s). It is coloured yellow if lateral TTC is between 1.5 and 3s and red if TTC is < 1.5s.
- If the driver intends to change lane (use of turn indicator) with an object, that is or within 1.5 s will be to the side of the truck, an acoustic LCA warning is issued and the object turns red.
- If an object is extremely close laterally (< 0.25 m) to the subject vehicle, then it is coloured red in the display.

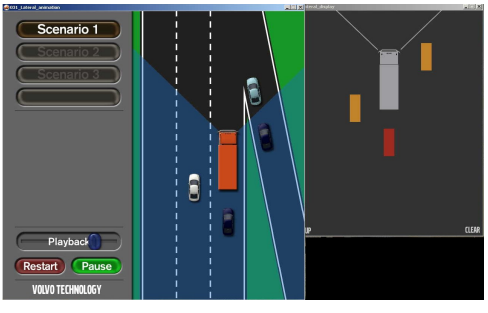

Fig. 7. LRM scenario description and information presented to the driver in a truck

Fig. 8. LRM display mounted in the truck dashboard

An algorithm for the hysteresis of warnings and highlighted objects is also implemented (minimum time is 4sec between acoustic warnings of the same type and minimum time for highlighting of objects is 2sec). Objects are not presented at all if they are moving away with relative speed > 1 s (object driving slower than truck). All objects moving are shown in the screen, using the correct speed vector information.

4 Further Steps

The HMI warning strategies and elements addressing all LATERAL SAFE project applications have been re-evaluated in the final evaluation of the project. The HMI's have been evaluated by 21 users in the VTEC demonstrator and 12 users in the CRF passenger vehicle, on specifically designed scenarios. The users have performed a series of trials with and without the system and quantitative and qualitative measurements have been collected, through subjective forms (pre- and post-questionnaires) and log files data, providing input for the final ratification and improvement of the HMI's: among others, from the warning strategies point of view, but also regarding integration and "look and feel" aspects.

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