INTEGRATED DRIVERS' LATERAL SUPPORT SYSTEM: THE LATERAL SAFE PROJECT

Angelos Amditis[1], Uwe Kaiser-Dieckhoff[2], Aris Polychronopoulos[1], Maurizio Miglietta[3], Evangelos Bekiaris[4]

[1]Institute of Communications and Computer Systems (ICCS)
Iroon Polytecnhiou 9, 15773 Athens, Greece
Phone: +30 210 772-2398, Fax: -2291,
{a.amditis, arisp}@iccs.gr
[2]Robert Bosch GmbH
3Centro Ricerche Fiat (CRF)
[4]Hellenic Institute of Transport (HIT)

SUMMARY

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 will be built in a common multi-sensor platform and include a lateral and rear monitoring system, a lane change assistant and a lateral collision warning, extending the operative scenarios of existing systems to all weather conditions and congested urban areas. Moreover LATERAL SAFE offers also a common multi-sensor platform suitable for integrating the results of other functions in a later stage. Its results will be evaluated and demonstrated in a city car equipped with all LATERAL SAFE applications, a luxury car equipped with a lane change assistant and a truck tested in a driving simulator. LATERAL SAFE is within the PREVENT Integrated Project co-funded by the European Commission under the 6th Framework Programme.

INTRODUCTION AND ACCIDENT ANALYSIS

The project is pertinent to the objective of reducing the number of accidents (mainly fatal ones) in situations that are considered as more frequent (i.e. Accidentology approach). Human miss-perception accounts for a significant percentage of fatal accidents, which is crucial for representative situations like overtaking, crossings, vehicle merging situations, rear-end collisions, car-two wheeler or car-to pedestrian collisions; this underlines once again that the continued development of more powerful technical sensor and perception systems is of utmost priority. Lateral area related fatal accidents represent a large percentage of the overall accidents; while the rear related accidents represent a smaller amount of fatal accidents, but at the same time they represent a large amount of accidents with injuries and with large damages. The main goal of this project is to develop a system that deals with perception in a holistic approach covering the lateral and rear scene and warning the driver in the imminent case of collision, and assisting him/her in scenarios of overtaking or blind spots and adverse weather conditions. Thus, there is a focus on blind areas, by giving the driver information/warnings on objects present in such areas and when the driver intends to perform a change of the vehicles trajectory (manoeuvre).

Within LATERAL SAFE, accident analysis has been performed through questionnaires, focus groups, experts' opinions and several other sources (e.g. NHTSA, ISTAT, Public authorities etc.) and estimated that rear and lateral related accidents represent a significant amount of all

accidents (**35.38%** of all the accidents recorded, according to the classification performed by the experts in this Accident Analysis). Among this percentage, it is needed to discern and isolate the ones that concern the LATERAL SAFE field of interest. The differentiation lies only in the "Road Accidents Classification per Major Road Accident Type and Pre-Crash Scenarios" field, since the rest parameters are independent of the target vehicle areas and are in any case applicable. In Figure 1, the coverage of LATERAL SAFE system is depicted accompanied with frequency percentages corresponding to each of the LATERAL SAFE identified areas, indicating in this way which and how many accidents could be prevented by each sensor covered area.

Figure 1: Percentages of accidents for each vehicle area

Thus, the major target of the sensorial system should focus on the maximum possible coverage of areas in front, since the accidents percentages that could be prevented are the most significant (10.33% - 10.22%) in comparison to the rest recorded.

Referring to the above mentioned types of accidents, LATERAL SAFE develops integrated lateral support functions, namely:

- A Lateral and rear area monitoring application enhancing the driver's perception and decreasing the risk of collision in the lateral and rear area of the vehicle; in particular when the driving task is critical because of limited visibility or critical workload of driver's attention.
- A Lateral collision warning application that detects and tracks obstacles in the lateral and rear field and warns the driver about an imminent risk of accident (collision, road departure, merging etc.). This application can be stand-alone or improved by the surrounding model developed in the monitoring application.
- A stand-alone lane change assistance system with integrated blind spot detection assisting the driver in lane change maneuvers while driving on roads with more than one lane per direction.

TECHNOLOGY AND SENSORS

Existing sensing systems can identify the presence of obstacles and are able to support the driver, generally, in front of the vehicle or only on “single slices” of the scenarios around the vehicle. Consequently, different sensor technologies need to be integrated today in the vehicle in order to cover all the area around it and to provide a complete support in all traffic and environmental scenarios and in particular in urban congested situations. The system intends to allow the extension of the operative scenarios of the Advanced Driver Assistance Systems beyond their current limits and will allow enabling a considerable step forward the actual development and implementation of data fusion techniques. The proposed lane change assistance and collision warning system will base on short- and long range radar sensors and is aiming a rear view with sufficient driver warning time for approaching vehicles with high relative velocity (more than 100 km/h) and a direct measurement of absolute speed of approaching vehicles greater than 200 km/h. With this performance most overtaking situations on highways should be covered. Warning should alert the driver when is changing lane: before the lane crossing of the vehicle. Moreover a Blind Spot Detection down to 0 km/h will be integrated thus being useful also for urban areas

Thus LATERAL SAFE is intended to be a key component in future systems for multiple Advanced Driver Assistance Systems. Its use will be performed in a progressive way towards the improvement of road safety functions, extending them from the collision warning, the pre-crash and collision mitigation up to, in the future prospect, collision avoidance. This approach could allow the reduction of the overall system cost and a wide and fast introduction of the ADAS in the market for the increase of the road safety by significantly reducing the number and the severity of the accidents.

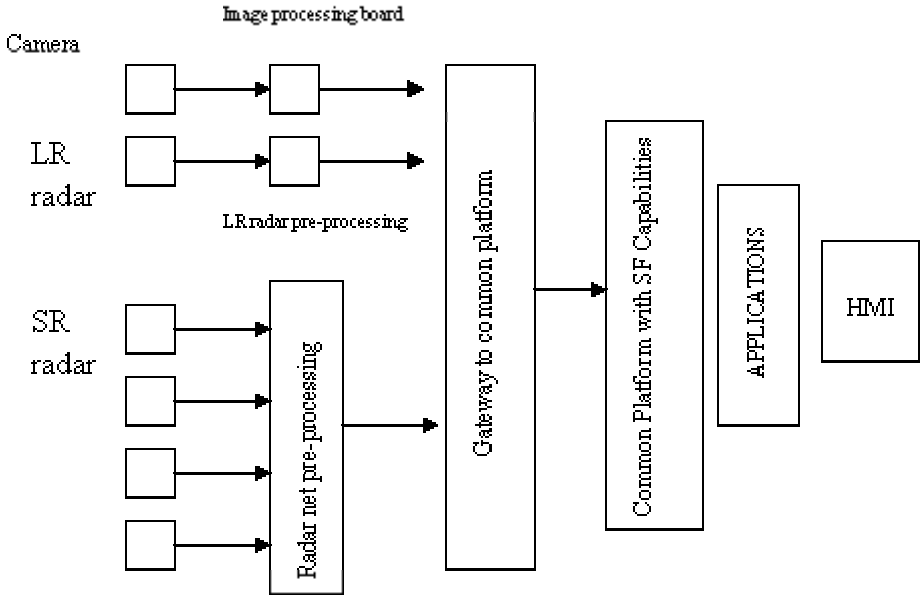

Figure 2: Architecture of LATERAL SAFE

The technological means, with which the objectives will be achieved include:

- A Multi-sensor platform based on short range radar sensors, long range radar sensor and/or vision sensor including H/W and S/W interfacing for the integration of all sensor

and system technologies needed for lateral and rear monitoring and warning in an open and reconfigurable architecture switching between different applications.

- Data/sensor fusion and synthesis techniques for obstacle detection and tracking from various but synergistic sources.
- Selection of a reliable and flexible sensor array (short and long range radars, vision sensors, etc.) and development of a sensor network interfaced to the above mentioned automotive platform.
- Heavy truck simulator where the application for lateral and rear monitoring will be evaluated by human factor tests.
- A Visualization tool for lateral and rear monitoring to be used for evaluation, namely for the visualization of the lateral and rear scene in a virtual environment adding also sensor data.
- An HMI, where lateral monitoring application will be combined with warning strategies implementation for all LATERAL SAFE applications.

The developed applications will be implemented, demonstrated and evaluated through human factor tests at a passenger vehicle of Centro Ricerche Fiat, whereas the lane change assistant will be demonstrated in a luxury car from Robert Bosch. Additionally, lateral and rear area monitoring application will be evaluated in an advanced driver simulator from Volvo Technology. Different configurations will be examined and an evaluation will be performed in terms of technical performance but also in terms of development and implementation costs. The different approaches include the utilization of a network of short range radars for the lateral scene, long range radars and monocular/stereo vision sensor systems in different configurations. The appropriate sensors will be selected with respect to the requirements versus performance and cost.

LATERAL SAFE APPLICATIONS

As it is also mentioned above LATERAL SAFE subproject develops three applications/functions Lane Change Aid (LCA), Lateral Collision Warning (LCW), Lateral and Rear area Monitoring (LRM). A brief description of the objectives of each of these functionalities follows. The output of these modules is input to the HMI following some specific warning strategies. In Figure 3 above the warning strategies of the application module are depicted.

Lane Change Aid (LCA)

“LCA” is an application that uses surround- and ego-vehicle information from the perception layer in order to analyse the current driving situation. In case a lane change maneuver is going to be performed and a conflict with an oncoming or neighbouring vehicle is predicted, an LCA-warning will be passed to the HMI/Action layer. The LCA application has two aspects that can be summarized as: (1) inform the driver about presence of vehicles in the blind spot e.g. if the direction indicator is set, (2) collision warning in case of critical lane change maneuvers of the ego-vehicle. An indicative figure for the functionality of LCA is given below.

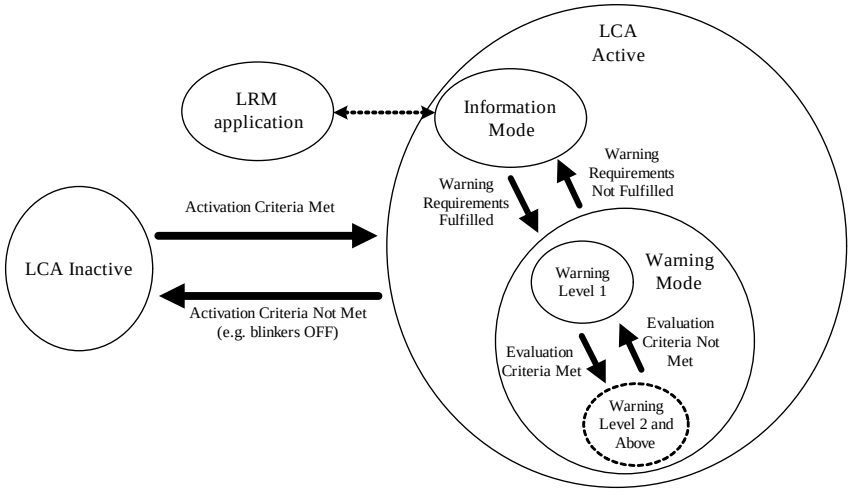

Figure 3: Diagram of the warning strategies in LCA application (example)

Lateral Collision Warning (LCW)

The overall objective of the Lateral Collision Warning (LCW) function is to reduce serious injury accidents, fatalities, and collision severity through warning the driver about potential collisions/imminent risk of an accident in the lateral field.

The LCW function aims to address scenarios that constitute the majority of the lateral-area accidents. The function uses the lateral environmental information provided by a network of short-range radar sensors. The function tracks all relevant obstacles in the immediate lateral field, and in case of a foreseen conflict, triggers a suitable HMI to warn the driver. The potential of accident percentages that could be prevented by such a warning function are the most significant.

Lateral and Rear area Monitoring (LRM)

The overall objective of the Lateral Monitoring is to *inform* the driver of adjacent vehicles, which will assist the driver in the task of detecting and tracking surrounding vehicles. Lateral Monitoring, thus, extends and improves the visibility in direct (window openings) and indirect (mirrors) in the following ways:

Using multiple sensors will cover all of the vehicle surroundings, effectively eliminating the blind spots normally found in mirror systems. The arbitrary placement of a sensor-display based system does not require an optical line-of-sight. This is especially valuable for trucks where ego vehicle/trailer typically blocks rear line of sight.

The integration of sensors presented in a single consistent HMI will eliminate the fragmented viewing; the whole vehicle can be surveyed from a single point.

The nature of the Lateral Monitoring is, thus, *passive*, the function will always present information, and it is up to the driver to choose when to make use of the system and receive the information presented.

LATERAL SAFE ARCHITECTURE

LATERAL SAFE system is consisted of four levels or layers of processing levels that interact in a sequential manner. First is the measurement acquisition level with the data from the system's sensor to pass to the perception layer level which is an intermediate level between sensors and applications. The application level is the core of the LATERAL SAFE system and its separate applications and their interaction was described in the previous paragraph. The output of LATERAL SAFE applications pass to the HMI.

Sensor Platform

In the context of Prevent/Lateral Safe, a platform will be designed that will be used aboard demonstrators vehicles to illustrate safety functions based on a set of sensors, processing data flowing out of these sensors (referred to as Perception), feeding the output of Perception to Applications, which in turn decides how to handle the situation by controlling HMI.

Therefore, the global description of the project can be outlined as follows, the sensors being precisely:

- one Long Range Radar (LRR),
- a set of Short Range Radars (SRR1-n),
- a set of stereovision cameras.

It should be noted that other sensor solution may be tested as long as they maintain the same input/output interface.

Looking one step further into the detailed description of the system, we can split the perception part into separate processing blocks devoted to LRR, SRR and Stereovision, plus an additional Fusion block in charge of merging whatever information comes from the above processing blocks into a sound description of the environment. This description is used in turn by three different applications which decide which controls should be sent to HMI in order to warn/inform/alert the driver of the current situation when found pertinent. It should be mentioned that SRR sensors aim basically at the left and right lateral fields, while LRR direction will be towards the rear area, and finally the cameras will cover partly both some parts of the lateral and the rear fields. The architecture is depicted in Figure 4.

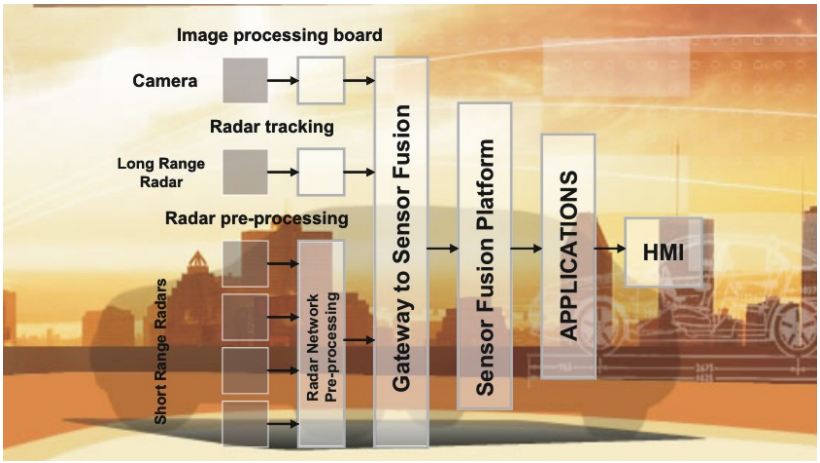

Figure 4: LATERAL SAFE basic architecture

Perception Layer

Perception is identified as the layer in the LATERAL SAFE architecture which intermediates between the sensor system and the three discrete applications. Perception is the tool that gives a realistic representation of the environment to the applications. The basic requirement of the Perception layer is that it should enhance the performance of single sensor systems and provide more robust output to the application. The role of the perception layer is to:

- Carry out “perception enhancement" tasks independent of the application (generic)
- Describe in a formal way the environment and the traffic scenario (semantics)
- Support LATERAL SAFE functions under request (specific)
- Act as a gateway between sensor systems and applications with defined interfaces and I/O protocols.

When the demonstrator vehicle operates in Lateral Safe mode, the Perception Layer will be always “ON” and it will always monitor and model the environment. The Lateral Safe perception layer, will output fused sensor data in the form of a list containing all detected targets and associated data for each target. The minimum information per target will be:

- Object position vector
- Object velocity vector
- Sensor ID
- Object features (width/length/height)

Indicatively, in Figure 6, two targets detection distributions in a common part of the lateral and rear field of ego-vehicle is depicted.

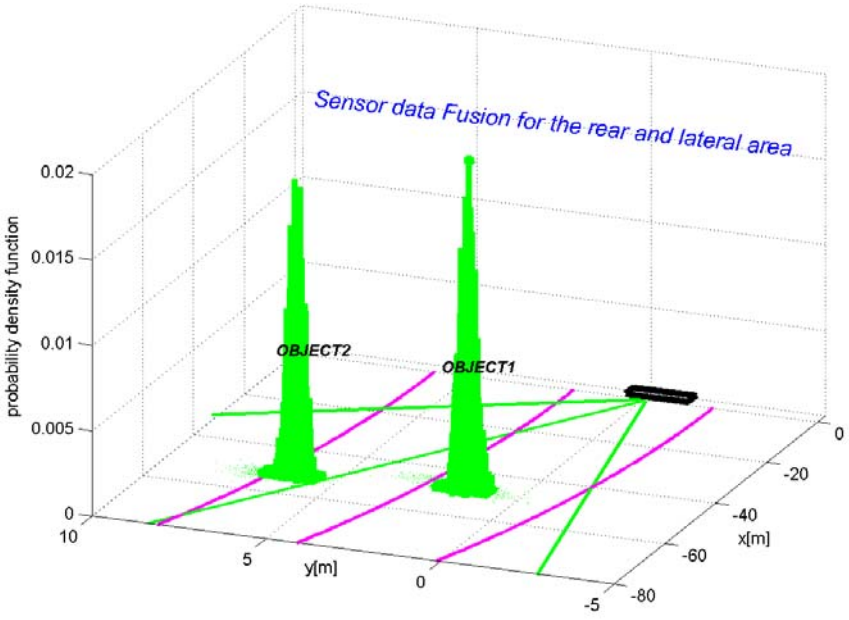

Figure 5: Sensor data fusion for object detection in the lateral and rear area

LATERAL SAFE WORK PLAN

LATERAL SAFE is a three year project, started in February of 2004. The work plan consists of nine (9) interrelated sub-workpackages.

- WP 32.100 Subproject technical coordination (M1-M36)
- WP 32.200 Dissemination and Exploitation (M1-M36)
- WP 32.300 Requirements and specifications (M1-M12)
- WP 32.400 System Architecture and multi sensor platform design (M7-M18)
- WP 32.500 Sensor network development and data pre processing (M7-M24)
- WP 32.600 Sensor data Fusion and Synthesis (M7-M30)
- WP 32.700 Applications and system development (M16-M33)
- WP 32.800 HMI and warning strategies (M1-M36)
- WP 32.900 In-Vehicle Integration, evaluation and demonstration (M1-M36)

The results of LATERAL SAFE are reported according to the following table. The structure of the deliverables is compliant to the structure of the Integrated Project PREVENT.

D32.0	Input to ProFusion	M3
D32.1	Dissemination material	M4, M10
D32.2	Project Presentation	M13
D32.3	Requirements and specifications	M13
D32.4	Validation Plan	M15
D32.5	System Architecture	M18
D32.6	Data synthesis algorithms	M18
D32.7	S/W and H/W components	M24
D32.8	LATERAL SAFE Applications	M30
D32.9	Evaluation and Assessment	M36
D32.10	Technology implementation plan	M36
D32.11	Final Report	M36

Table 1: LATERAL SAFE deliverables

LATERAL SAFE CONSORTIUM

The project is coordinated jointly by Robert Bosch GmbH (Leader) and the Institute of Communications and Computer Systems – ICCS (co-leader).

Leader
U. Kaiser Dieckhoff
Robert Bosch GmbH VBB1
PO Box 10 60 50, D-70049 Stuttgart
Phone: +49(711)8 11-69 33, Fax: -26 31 26 and
Rue Belliard 60-62 B-1040 Brussels
Phone: +32(2)525-57 41, Fax: +32(2)528-94 70
mailto:U.K.Dieckhoff@de.bosch.com
Co-Leader
Angelos Amditis
Institute of Communications and Computer Systems
I-SENSE Group
Phone: +30(210)772 2398, Fax: -2291
9, Iroon Polytechniou St, 15773, Athens
mailto: a.amditis@iccs.gr

Consortium:
Robert Bosch GmbH (D), Institute of Communications and Computer Systems (EL), Centro Ricerche Fiat (I), DaimlerChrysler (D), Volvo Cars Co. (SE), Volvo Technology AB (SE), SAGEM (F), Hellenic Institute of Transport (EL), TNO (NL).

Information for the project and relevant results can be found in PREVENT web-site http://www.prevent-ip.org and LATERAL SAFE web-site http://www.prevent-lateralsafe.org.

CONCLUSIONS

This paper presents the LATERAL SAFE subproject, which intends to prevent rear and lateral area related accidents by developing integrated lateral support functions (lane change assist, lateral collision warning, monitoring functions) in a multi sensor platform. LATERAL SAFE started in February 2004 and with SAFELANE project belongs to the lateral support and driver diagnostics function field of PREVENT IP. LATERAL SAFE is jointly coordinated by Bosch and the Institute of Communications and Computer Systems, Greece. The consortium consists of 4 OEMs (Volvo Technology, Volvo Cars, Fiat Research Centre and DaimlerChrysler), 2 suppliers (Bosch, SAGEM) and 3 Institutes (TNO, ICCS and HIT). The project will finish in January 2007. This paper started with the introduction of the project and the accident analysis that explains the background reason for beginning such a research initiative. Then follows the technology used description, the scheme of the internal interrelated applications that are integrated in the LATERAL SAFE system and the overall sensor and module architecture. The paper ends with the presentation of the planned work and deliverables, the subproject's consortium and contact details.