SAFESPOT INTEGRATED PROJECT - IST-4-026963-IP

DELIVERABLE

SAFESPOT
COOPERATIVE SYSTEMS FOR ROAD SAFETY

SP4 – SCOVA

Actual safety application V2V based

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Abbreviation List

ADAS	Advanced Driver Assistance System
ABS	Antilock Brake System
ACC	Adaptive Cruise Control
ASR	Anti Slip Regulator
APIA	Active Passive Integration Approach
BA+	Brake Assist Plus
CMOS	Complementary Metal Oxide Semi-conductor
C2CC	Car to Car Communication Consortium
CCD	Charge-coupled device
CICAS	Cooperative Intersection Collision Avoidance System
ESP	Electronic Stability Program
FCC	Federal Communication Commission
GPS	Global Positioning System
IVBSS	Integrated Vehicle Based Safety System
LCA	Lane Change Assist
LDW	Lane Departure Warning
RSD	Reduced Stopping Distance
V2V	Vehicle To Vehicle
V2I	Vehicle To Infrastructure
VII	Vehicle Infrastructure Integration
VRU	Vulnerable Road User
WLAN	Wireless Local Area Network

Table of contents

Executive Summary

This deliverable D4.2.1 called “Actual Safety Application V2V based is intended to present an overview of the state of the art for the V2V applications, giving guidelines and references for several activities in SAFESPOT. It analyses a number of existing products and applications with relevance for SAFESPOT addressed in last years from a system point of view. The analysis has been focused on the safety benefits of these systems and how these benefits can be extended by using a cooperative approach, mainly considering Vehicle-to-Vehicle (V2V) communication.

Brief descriptions of each relevant application is made, including the technology that has been used as well as possible advantages that can be achieved by using a cooperative approach. These findings are intended to give input to the Safety Margin Concept, scenario descriptions and input to the SAFESPOT sensor related subprojects (SAFEPROBE, INFRASENS and SINTECH).

The results indicate that there are different kinds of advantages that can be achieved by a cooperative approach.

The data communicated between vehicles (and the infrastructure) can range from high level information such as direct HMI-related signals to low level information that can be used in a sensor fusion process to assessment of the current situation for vehicles on the road such as the quality of the lane markings on a specific section of a lane.

More detailed descriptions can be found in each related section in the report. Proposed examples, applications and projects are given as a starting reference for the further analysis that will be performed in SAFESPOT.

1. Introduction

SAFESPOT project aims to understand how smart vehicle and smart road can cooperate to produce a breakthrough for road safety. The extension of the driver assistance systems with their effective real time "vehicle surrounding situation awareness" will be improved by cooperative actions among vehicles and infrastructure. The overall concept will be represented by the implementation of the Safety Margin Assistance for the equipped vehicles. The current driver assistance systems provide functionalities in the operative ranges of their sensors, while the cooperation of vehicles and infrastructure through communication technologies could increase the coverage of many other dangerous situations. The focus of SCOVA project is the specification and development of safety cooperative systems application mainly based on the vehicle to vehicle communication system, even if the cooperation with the infrastructure is possible as well.

1.1. Contribution to the SAFESPOT objectives

At the start point of the SCOVA sub-project, it is useful to establish a state of art of existing solutions based on the same concept (V2V and V2I) which have been developed previously or always on-going in some other EU or national initiatives. The results of the cooperative approach will be presented. It is also interesting to highlight some active safety features which are not covered by this cooperative approach and then limited to the on-board range sensors.

The deliverable describes the most relevant active safety applications and how those performances could be improved thanks to the cooperative system such as V2V and V2I communication.

For all the examples the applications in the projects and technologies used will be pointed out. Possible cooperative approach benefits are described.

The content of this deliverable gives input to D4.2.2 Safety Margin concept and D4.2.3 Use Cases.

1.2. Methodology

Information on projects and applications has been collected by all partners in SCOVA and possible advantages of a cooperative approach for each project / application has been highlighted.

The gathered information has been classified in application types and a summarising analysis on each application type has been performed.

1.3. Deliverable structure

The deliverable content is structured by the types of applications and adding chapters with summaries and conclusions.

Chapter 1 is the introduction.

Chapter 2 through 5 describes applications.
The start of each chapter contains an explanation on the main features of the application type. Each project is then described in detail including a sections on the technologies used.

Since many applications are overlapping, a summary of potential benefits are collected in a separate section after the projects descriptions in each chapter.

Chapter 6 describes projects in the American ITS program coordinated by the US Department of Transportation.

Chapter 7 contains a table summarizing the applications and projects as well as a short description on potential benefits.

Chapter 8 contains the deliverable conclusions.

Chapter 9 contains some useful references.

2. Road Departure applications

2.1. Functional description – Road Condition

This application introduces the possibility for a vehicle to exploit the information of slippery road status and general road condition status. This can be due to for example weather condition, ice, fog, rain and gravel on the road. This information is used to inform or warn the driver about a dangerous area.

2.1.1. APOLLO PROJECT

PROJECT DESCRIPTION

The goal of APOLLO project was to create an intelligent tyre for improving road traffic safety.

The objectives were

1. Provide vehicle and tyre manufactures with new products to increase traffic safety
2. Enable improvements for chassis control systems and ADAS
3. Enable the implementation of new services concerning tyre and road conditions for users both inside and outside the vehicle.

TECHNOLOGIES USED

The project developed sub-systems for communication from tyre to vehicle systems, power generation for communication and the actual sensor for tyre-road contact monitoring. The realisation and integration of all these sub-systems into a mechatronic tyre prototype required innovative approaches and a new deep understanding of tyre phenomena and tyre-vehicle system level behaviour.

The target of the project was a prototype of a mechatronic tyre capable of providing information on various parameters of tyre-road contact such as forces exerted on tyre, slip information, friction potential, tread wear, prediction of tyre damage and road surface qualities. Many of the targets of the project were met, except that friction estimate was not achieved.

The system uses 3-axial acceleration, optical positioning and strain sensors. These sensors give voltage analogical data to a converter, which inputs the numeric data to a microprocessor. It communicates then the data via RF to a control unit that processes the data and makes information available on CAN network.

2.1.2. FRICTION PROJECT

PROJECT DESCRIPTION

The project leader is VTT.

FRICTION is part of the Sixth Framework Programme and started in January 2006. The objective of the FRICTION project is to develop μ-estimation using on-board sensors, using both dedicated sensors and data already available on the vehicles sensor systems.
This project planning is in parallel with SAFESPOT. It could be interesting to investigate if some cooperation between these projects is possible as the system is intended to be implemented in the end of 2008. SAFESPOT do not aim to develop new sensors to detect road condition status but could use some technology develop in the framework of Friction.

TECHNOLOGIES USED

Sensors already on-board the vehicle (such as ABS-sensors, ESP sensors, temperature, etc) are combined with sensors developed in the Apollo project (smart tires with friction estimation based on micromechanics sensors).

2.1.3. IP PREVENT- WILLWARN

PROJECT DESCRIPTION

The project leader is DaimlerChrysler AG

PReVENT is part of the Sixth Framework Programme; it started in February 2004 and will end in 2007. In the WILLWARN subproject a system is developed for on-board hazard detection, in-car warning management, and decentralised warning distribution by communication between vehicles on a road network. One of the hazards detected is reduced friction.

It is a direct forerunner to the SAFESPOT project and has been examining some cooperative approaches that SAFESPOT will use.

TECHNOLOGIES USED

On-board vehicle sensors (such as ABS-sensors, ESP sensors, temperature, etc) are combined with special logic to determine whether the road is slippery.

The detection of the reduced friction is an estimation of the friction value. Information about currently used friction value is delivered by analysing the acceleration values. The current maximum friction value can be detected if one of the regulating systems like ESP/ABS/ASR is in action.
Necessary sensor information for the calculation of the friction are:

- Longitudinal acceleration
- Lateral acceleration
- ESP/ABS/ASR systems action

If the friction value is between defined thresholds, the algorithm will use additional sensor information to establish the reasons of the reduced friction and provide additional information to the driver both for reacting in the right way and for monitoring the reliability in an early stage.
Necessary sensor information for the pattern recognition:

- ASR-Action
- Wiper status
- Temperature
- Speed

The project uses V2V communications technologies and in particular the WLAN IEEE 802.11g / 5.9 GHz standard.

2.2. Use of cooperative approach – Potential benefit on Road Condition

The obvious advantage is that friction estimation, obtained by a vehicle that passes through a critical spot, can be transferred among incoming vehicles as a forecast on available friction on the road. A cooperative approach will also add the possibility to transfer friction estimation to the road side control centres that can analyse and check for the integrity and quality of the signal as well as distribute the information back to the other vehicles on the road.

2.3. Functional description – Curve Warning

This application considers the possibility to warn or inform the driver about possible risk associated to a curve regarding its geometry, possible road status condition and vehicle dynamics. The risk of road departure, mainly in terms of speed to be respected, according with the received information on the road geometry, surface status, traffic condition is communicated to the driver.

2.3.1. SAFEMAP PROJECT

PROJECT DESCRIPTION

The project leader is ERTICO

SafeMAP is a DEUFRACO project with the aim to assess the socio-economic effectiveness of a dedicated digital map data base comprising safety related data only. Safety applications as speed limitation, curve and anti-rollover warning, intersection warning or accident spot warning are developed. The main partners are DC, PSA, Volvo, Navteq and Teleatlas.

TECHNOLOGIES USED

The anti-rollover and curve warning applications are based on digital map information (Navteq or TeleAtlas) for the road geometry and dynamic vehicle data (especially current speed). When the vehicle approaches a curve, its current speed is compared to a recommended speed and a warning is provided to the driver if needed. The recommended speed is function of the acceptable lateral acceleration regarding the vehicle type and the curve geometry.

2.4. Use of cooperative approach – Potential benefit

Improvements on curve warnings are especially interesting for trucks (trucks have more problems with roll-over accidents than passenger vehicles). Digital map information and dynamic vehicle data can be combined with road condition information from other vehicles (or sources) to be incorporated in algorithms to calculate recommended speed into a curve at the current road condition.

3. Vulnerable road user detection and accident avoidance

3.1. Functional description

This group of applications describes the possibility to detect a VRU (Vulnerable Road User) around the vehicle in order to warn or inform the driver about a potential danger. A VRU is usually defined as a pedestrian, a cyclist and in some cases powered two-wheelers like mopeds and motorcycles. The detection of VRU is a technically difficult task and a number of methods for VRU detection have been developed in different projects and these methods can be applied to a SAFESPOT system. The safety for the VRU can be enhanced by a number of strategies also described below.

3.2. State of the Art and Potential benefit with Cooperative approach

3.2.1. IP PREVENT - COMPOSE

PROJECT DESCRIPTION

The project leader is BMW Forschung Und Technik GmbH.

COMPOSE develops and evaluates collision mitigation and vulnerable road user protection systems for trucks and cars. COMPOSE focuses on pre-crash measures to be taken during the last second before a collision. Various application measures are used: mitigation through autonomous braking / brake assist, and also utilization of protective structural actuators. Various innovative sensor data fusion methods will be pursued to achieve the highest degree of sensor reliability, which is mandatory for such applications.

TECHNOLOGIES USED

COMPOSE uses the following sensors: Far infrared camera, ACC-RADAR (Long range radar), Short range radars, Stereo-vision system and LIDAR. Various prototype vehicles use different sensor configurations. The data from the sensors are combined using different sensor fusion strategies to provide enhanced environment estimation.

USE OF COOPERATIVE APPROACH – POTENTIAL BENEFIT

Some VRU detection methods can be used in SAFESPOT; see comments on APALACI for information about the applications.

3.2.2. IP PREVENT - APALACI

PROJECT DESCRIPTION

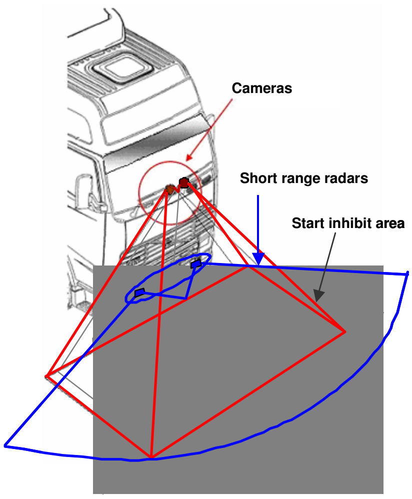
The project leader is Centro Ricerche FIAT

APALACI is an application within the “Vulnerable road users and Collision Mitigation” functional area of PReVENT. The sub project develops a system for advanced pre-crash and collision mitigation. APALACI prevents low speed accidents involving pedestrians, by monitoring the frontal area close to the vehicle and, more generally, mitigates the severity of unavoidable collisions, by significantly reducing the kinetic impact energy and improving the control of restraint systems to enhance the protection of car passengers. Compared to the COMPOSE subproject in PReVENT, APALACI deals with a different set of sensors and a specific data processing approach.

APALACI evaluates two preventive safety functionalities aiming at the protection of vulnerable road users. The first one detects pedestrians in the front area, and provides a warning to the driver; the second application is a start inhibit function for truck drivers, able to inhibit a start from a stationary condition, when a vulnerable road user, not visible to the driver, is present in the monitored area.

TECHNOLOGIES USED

The APALACI truck demonstrator is used for development and demonstration of the start-inhibit function. This function detects if an object or a pedestrian is present within the truck’s forward blind spot, and if it is the case, the driver is informed and acceleration from stand still is inhibited. A low speed proximity warning function, active at vehicle speed below 15 km/h, will also be demonstrated in this vehicle. The sensor coverage area is visualized in Figure 1. Data fusion is done from stereo vision system (Parma) and short range data sensors.



USE OF COOPERATIVE APPROACH – POTENTIAL BENEFIT

The interesting approach in SAFESPOT is the capability to send the information to other vehicles in order to improve the VRU detection. Information on the detected VRU:s can be shared between vehicles and all vehicles in an area can report the detected VRU:s position to indicate a presence of VRU:s.

A relevant scenario is 2-way road in urban areas. It is also possible to avoid collision with bicycle or motorcycle on the side of the host vehicle when it decides to turn or reverse (frequent accident especially with trucks that have large blind spots around the vehicle).

3.2.3. ARCOS PROJECT

PROJECT DESCRIPTION

ARCOS is a French research Project Action for Safe Driving.

This project aims to prevent the vehicles upstream of the presence of obstacles on the road (e.g. stationary vehicle on the road)

TECHNOLOGIES USED

The detection system is based on the data fusion between stereovision and LASER scanner.

The system detects the obstacles and takes consecutive actions depending on the calculated time-to-collision;

1. Auditory warning to the driver.
2. Warning to the surrounding traffic of immanent braking by hazard lights activation.
3. Emergency braking to mitigate the collision.

Pedestrians are one of the objects types that have been evaluated.

3.2.4. PROTECTOR PROJECT

PROJECT DESCRIPTION

Preventive Safety for the unprotected road user.
Duration: January 2000 – March 2003

Demonstrators are

- a MAN truck with Siemens VDO 24 GHz RADAR intended to detect bicyclists
- a FIAT passenger car equipped with IBEO LASER scanner to detect pedestrians
- a DC passenger car with DC stereo vision that detects pedestrians

TECHNOLOGIES USED

- Three sensor technologies; LASER scanner, 24 GHz RADAR and stereo vision.
- Coverage area: 10-25m in front, 2.7-4m lateral
- Environment: moderate to good visibility, daytime
- Vehicle speed: up to 30km/h

3.2.5. SAVE-U PROJECT

PROJECT DESCRIPTION

Sensors and system Architecture for Vulnerable road user protection
Duration: March 2002 – February 2005

TECHNOLOGIES USED

Demonstrators are a VW passenger car and a DC passenger car (includes DC stereo vision system for comparison).
Vulnerable road user detection (pedestrian) is performed using sensor fusion from mono colour video and a Far Infrared camera combined with a 24 GHz RADAR.

The system outputs driver warning and/or vehicle braking to protect VRU.

The intended performance of the system is:

- Front coverage area of 5-25m
- Lateral coverage area of 1.4-4m
- Environment: moderate to good visibility
- Vehicle speed: up to 40km/h

3.2.6. WATCH OVER PROJECT

PROJECT DESCRIPTION

Watch Over is part of the Sixth Framework Programme and started in January 2006. The project is carrying out research and development activities for the design and development of a cooperative system for the prevention of accidents involving vulnerable road users (i.e. pedestrians, cyclists and motorcyclists) in urban and extra-urban areas. The project focuses on a joint interaction among in-vehicle sensor and communication technologies, as an extension of the vehicles autonomous systems. Collaboration could be set up between SAFESPOT and WATCH OVER witch are dealing both with ad-hoc network. WATCH OVER use this cooperative concept for the vulnerable road user detection as SAFESPOT use it to disseminate the information to other vehicles and applications development associated.

TECHNOLOGIES USED

The sensing technologies to support the detection of vulnerable users can be summarised in the following categories:

- Far Infrared camera
- Vision based systems (2D and 3D)
- Microwave RADAR
- LIDAR

3.3. Use of cooperative approach – Potential benefit

Detection and positioning of VRU is a great challenge attempted in many other projects. Sharing intelligence among vehicles is an advantage of cooperative system. VRU objects detected by one vehicle can be shared with others; this makes it possible to track objects that are not possible to detect by conventional sensors that are limited to line-of-sight.

A second aspect is that all vehicles are not equipped with the same sensor configuration; some may completely lack VRU sensors but may still be able to receive the information of an object detected by others. This will make the system as a whole more effective in preventing accidents compared to the use of standalone sensors.

4. Lateral Manoeuvring

4.1. Functional description – Safe Overtaking

This application aims to perform an overtaking manoeuvre in safe conditions, by verifying the absence of third vehicles incoming behind. This is more applied in a generic 2 way road, but can also be applied in a generic 1-way road.

This application is intended to enhance the safety during different kinds of lateral manoeuvres involving lane changes. Overtaking manoeuvres can be made safer by monitoring the traffic around the host vehicle to ensure that all approaching traffic is taken into account. Lane change manoeuvres are made safer by monitoring possible collisions due to vehicles close in path.

No relevant project with this focus has been found but the function is relevant for SAFESPOT. Some projects with similar approaches like lane change are described in the next chapter.

4.2. Functional description – Lane Keeping and Lane Change support

This application considers the possibility to warn or inform the driver about possible obstacle approaching from the side or detected on the side of the vehicle in different kinds of driving situations.

4.2.1. IP PREVENT - SAFELANE

PROJECT DESCRIPTION

The project leader is Volvo Technology.

SAFELANE develops a lane keeping support system that operates safely and reliably in a wide range of adverse road and driving situations. If an unintentional lane departure is detected, an adaptive decision system triggers a driver warning or active steering system. SAFELANE will be demonstrated in commercial and passenger vehicles on test tracks, motorways and rural roads.

TECHNOLOGIES USED

SAFELANE will utilize camera, digital map databases and optionally forward looking active sensors (e.g. RADAR/LIDAR/LASER).

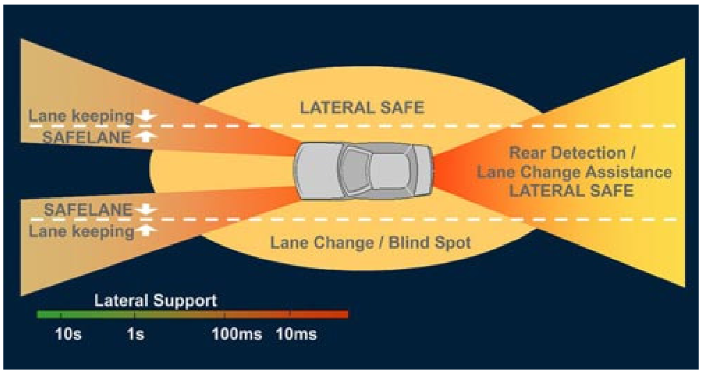
USE OF COOPERATIVE APPROACH – POTENTIAL BENEFIT

Other vehicles can be informed about an accidental lane change, or informed about a lane change even if the driver does not use a turn signal.

4.2.2. IP PREVENT - LATERAL SAFE

The project leader is Robert Bosch GmbH.

FUNCTIONAL DESCRIPTION



Different applications are demonstrated in the SAFELANE approach:
- A lateral monitoring application that enhances the driver's perception and decreases the risk of collision in the lateral area of the vehicle. This support is of particular relevance 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 field and warns the driver about an imminent risk of accident (collision, road departure, merging etc.);
- A stand-alone lane change assistance system with integrated blind spot detection, assisting the driver in lane change manoeuvres while driving on roads with more than one lane per direction.

TECHNOLOGIES USED

- Short and long range RADAR sensors
- Vision system to monitor the rear of vehicle

The usual limitations of these kinds of system does apply, the sensors cannot cover all of the surroundings around the vehicle.

4.2.3. LANE DEPARTURE WARNING SYSTEM BY NISSAN

APPLICATION DESCRIPTION

For LDW an assessment is made whether the vehicle is moving out of the lane (depending on the distance and lateral velocity to the lane). The LDW system is temporarily disabled by driver activation of the vehicle's turn signals, which informs the system's control unit of intended lane changes.

TECHNOLOGIES USED

The Lane Departure Warning System recognizes lane markings through the use of a small camera mounted behind the rear view mirror. The camera's signal and the vehicle's speed are sent to the system's micro-processing unit, which combines the information to

calculate both the distance between the vehicle and the lane marking and the lateral velocity.
The system also features a manual cancel switch that allows the driver to turn the system off when desired.

4.2.4. LANE DEPARTURE WARNING (LDW) BY CONTINENTAL

APPLICATION DESCRIPTION
The environmental sensing and data processing concept for LDW by Continental is the same as Nissans Lane Departure Warning System. The HMI is scalable from an optical or acoustical warning to a vibration or a torque in counter direction superposed to the steering torque.

TECHNOLOGIES USED
See comments in Lane Keeping system by Continental.

USE OF COOPERATIVE APPROACH – POTENTIAL BENEFIT
See comments in Lane Keeping system by Continental.

4.2.5. LANE CHANGE ASSIST (LCA) BY CONTINENTAL

APPLICATION DESCRIPTION
The Lane Change Assist is strongly related to the Lane Departure Warning. On each side of the equipped vehicle a camera is integrated into the rear-view mirror. With these cameras, the lane marks and approaching vehicles are detected.

The data from the image processing generates the lateral distance and relative speed to the lane marks. At the same time the speed and the position of the upcoming car is extracted from the images.

If the driver tries to do a lane change while he is passed by and this will lead to a critical situation the driver will get an optical warning. Additionally there will also be an acoustical warning if the driver uses the turn signal.

Shortly before the own car crosses the lane mark there will be a haptic warning by applying a torque to the steering wheel. This torque indicates the driver to counter steer and is slightly higher than the torque used for the LDW.

TECHNOLOGIES USED
The description for lane detection is described in the following chapter. Regarding the object recognition, see the APIA application in the frontal collision chapter.

USE OF COOPERATIVE APPROACH – POTENTIAL BENEFIT
The benefit for the Lane Change Assist is also linked to the above mentioned chapters.

4.2.6. Lane Keeping system by Continental

Application description

The Lane Keeping system uses the same sensors as the Continental Lane departure warning and applies an active steering. The information received from the image processing is used to keep the car between the lane marks without any intervention by the driver. If the driver tries to do a lane change, he will get the same recommendation as he would get with a LDW-system. The extended HMI are exactly the same as they are for LDW. The driver has the possibility to change the lateral position of the car without any intervention if the vehicle is kept inside the lane markings.

Technologies used

A camera system is used to detect the lane marks. In general the limitations are the ones related to the cameras perception of the lane marks. The sensors perception is mainly influenced by bad weather condition, incorrect or even missing lane marks. In opposite to the weather conditions and missing lane marks, wrong lane marks could not be detected by the camera system.

Use of cooperative approach – Potential benefit

Known temporary wrong or missing lane marks can be communicated to the system by Car2Car-Communication and the driver can be informed that the system has degraded performance well in advance of the critical spot. Information about complex road topologies could also be send by roadside infrastructure.

4.3. Use of cooperative approach – Potential benefit

The cooperative approach overcomes the blind spots of existing sensors that are due to the limited field of view of present sensor technology.

The information about changes in lateral position can be distributed to other vehicles in more ways than the normal turn signals to enable more HMI-efficient alternatives. There are also possibilities to inform traffic around the vehicle if lane change intentions by the driver are detected.

4.4. Road intersection safety

A large number of accidents on urban roads happen at intersections. This is determined by the high workload of the driver which results of the very complex situations. These could be:

- Many vehicles
- Many different road users (car, truck, pedestrian,..)
- Buildings and walls are not possible to “see-through”,
- With a vehicle crossing the intersection the visibility of other vehicles is limited
- Many road signs

The road intersection safety application highlights or anticipates a conflict in an intersection. It is assumed that an accident or a critical situation is always based on a violation of traffic regulations. This could be red light or stop-sign violation. But as described, intersection are complex and there is also the possibility to cause an accident by observing the traffic rules, like braking immediately if a signal turns to red.

Additionally intersection safety has a special position in SAFESPOT. On one side it connects SP4-SCOVA internal functions like “VRU – detection”, “Frontal collision warning” or “Lateral collision” and on the other side it is strongly connected to SP5-CoSSIB when it comes to a red-light warning.

4.4.1. IP PREVENT - INTERSAFE

FUNCTIONAL DESCRIPTION

The project leader is IBEO Automobile Sensor GmbH.

The INTERSAFE project started in February 2004 and will end in January 2007. The main objective of the project is to improve safety and to reduce (in the long term also to avoid) fatal collisions at intersections. Driver shall be prevented from missing red lights at intersections or to ignore stop signs. Furthermore, drivers will be informed in case of potential collisions with turning vehicles by use of infrastructure to vehicle communication and path prediction of other road users. Furthermore the infrastructure can get information about the latest friction coefficient from crossing vehicles, so the infrastructure can warn for low friction coefficients, if the street is wet, ice, oily etc.

TECHNOLOGIES USED

INTERSAFE will contribute to intersection safety using precise localisation with on board cameras. Also detection classification and path prediction of all other objects at the intersection is done. Bidirectional communication with road side systems such as traffic lights will be setup. The communication techniques developed in the WILLWARN project will be used. All the information on the intersection will be linked to high level map information

The project is also using driving simulator evaluations of intersection to create algorithms and sensor requirements for the next generation integrated safety applications.

USE OF COOPERATIVE APPROACH – POTENTIAL BENEFIT

Information exchange between the intersection infrastructure systems and the vehicles will make the drivers aware in advance about the surrounding scenario, giving hints to perform appropriate manoeuvres, anticipating driver actions and helping to ensure that road signals are noticed and followed.

4.4.2. INVENT – VAS

FUNCTIONAL DESCRIPTION

Four applications have been shown in INVENT-VAS. Right of way violation, red light violation, failures by left or right turns and lateral danger by other vehicles.
The aim of this research project was to minimize accidents in intersections, considering only Vehicle-Vehicle crashes. Vulnerable road users were not included.

TECHNOLOGIES USED

Several sensor technologies were used to detect the dangerous situations. Those were GPS and Differential-GPS, maps, cameras and RADAR to detect the traffic situation.

To detect a right of way violation, a map and a camera were used to detect the traffic-signs. Red lights were only detected by camera.
In left-turn situations (driving on the right side of the road) a RADAR Sensor was used to detect oncoming vehicles. Due to their high lateral speed crossing vehicles were detected by the camera system.

4.5. Use of cooperative approach in intersections – Potential benefit

For intersection safety application the benefit of a cooperative approach is evident, traffic lights, stop-signs and other actors are able to send the actual right-of-way situation to the cars. This type of scenarios is addressed in SP5-CoSSIB.

For SP4-SCOVA the major benefit is the communication between vehicles which are unable to detect each other, due to walls, houses or other obstructions. Basing on this advanced situation model and the possibility to transfer this model between the vehicles, obstacles and other road users can be detected and tracked more robustly.

5. Longitudinal Collision

5.1. Frontal collision warning – Functional description

The presence of static obstacles in front of the vehicle (for instance after a curve) caused by an accident or due to a congestion with slow moving traffic, may be detected and broadcasted to the incoming vehicles. Related information can be used to warn the drivers in advance about the dangerous situation.

5.2. Relevant projects and Applications

5.2.1. ACTIVE PASSIVE INTEGRATION APPROACH (APIA) BY CONTINENTAL

APPLICATION DESCRIPTION

The goal of APIA is to reduce the severity of accidents or even avoid the accident by integrating active and passive safety systems into cars. For the situation analysis objects are detected by several sensor systems mounted in the front of the vehicle. Those could be RADAR, LIDAR or camera systems and also combinations like a fusion of RADAR and camera. In order to reduce the stopping distance of a vehicle it is reasonable to support the driver through the deceleration phase. Therefore the driver's behaviour, the environmental and vehicle information are measured and analysed.

The danger calculation software evaluates the risk of an impending crash or traffic hazard based on the derived object list of a long range environment sensor and the criticality of the longitudinal and lateral vehicle dynamics. Based on these evaluations and the driver's behaviour three different assistance levels are separated, which differ within the intensity of assistance: Prefill, Prebrake and Extended Brake Assist (BA+) situations. This application is called RSD (Reduced Stopping Distance).

In addition to RSD, Continental developed the Run-Up-Mitigation. This application differs only in the used sensor-systems. For the object detection only short-range sensors are used. Due to this, Run-up mitigation is limited to low absolute speeds and low relative speeds. Above these speeds the support is smoothly deactivated by fading out. The advantage is the reduction or mitigation of non-avoidable rear-end collisions. Resulting of the modularity all activation thresholds could be set individually. It is very probably that the C2CC will have a great impact on those thresholds.

For an optimal brake performance and a very short response time, a small hydraulic pressure is built up autonomously to overcome the system immanent free travel. This function is called Prefill and will not cause any deceleration. Additionally the hydraulic pressure is increased to decelerate the car. With this Prebrake function the kinetic energy is reduced during the drivers switching phase from accelerator to brake pedal. With a fusion of camera and RADAR;

Continental extended the RSD application to a fully autonomous brake intervention in case of an emergency situation.

During driver braking, the Brake Assist Plus (BA+) gives additional brake support to reduce the kinetic energy. Therefore the thresholds for the activation of the described Brake Assist (BA) will be adjusted to provide the full brake force due to driver's braking with a higher reliability and sensitivity.

Unlike the intervention assistance the Hazard Warning function warns the driver in a critical driving situation. The warning will be activated within a major dangerous traffic situation. Therefore different HMIs are available to be used separately or in combination:

- Acoustic
- Visual
- Haptic
- By a brake pulse
- By reversible seatbelt tensioning

If the collision is not avoidable anymore, also passive safety systems are activated to protect the driver. Examples of intervention possibilities for the passive safety systems are:

- Belt slack reduction
- Occupant Positioning and Fastening
- Closing windows and sunroofs
- Preconditioning of Air-Bags

TECHNOLOGIES USED

The sensor systems used for the object detection are camera, RADAR and LIDAR. Each sensor is enabled to detect the object next to the own vehicle in the application relevant area. Objects behind obstacles or out of the relevant area could not be detected. This has no cause to the application itself, but there is no information about the surrounding situation, so the intervention depends only on the parameters of the next vehicle.

Additionally, all sensors have a maximum range, so not every object could be detected. The range is determined by the sensor performance and obstacles like curves or hills. Due to this, in very complex roadwork situations the application reliability is restrained.
The speed and acceleration of a detected object is measured by the incremental change of the objects position, relative to the own car. There is no possibility to measure the speed and acceleration directly, so the information of the acceleration and speed of the relevant object is calculated and therefore has a delay.

5.3. Use of cooperative approach for Frontal Collision – Potential benefit

By using a cooperative approach, information about all vehicles surrounding the ego vehicle could be used to cover critical scenarios and possibly to provide an earlier warning. Due to such an earlier warning, the intervention could be reduced or even omitted. In critical situations the increased reliability and measurement confidence could be used to for an immediate emergency intervention, which was, because of the delay in object and situation classification, not possible until now.

The cooperative approach has also big influence to the object classification. If both vehicles have V2V Communication, the classification resulting from the sensor systems is redundant because of the direct exchange of such information. Together with this information, also the speed and the acceleration of relevant objects could be received directly from the objects themselves.

If all cars have suitable communication units (such as SAFESPOT) it is possible to realize the functions like APIA, RSD and Run-Up-Mitigation using only the information of the Car2Car Communication and RADAR, camera or LIDAR systems may not be needed anymore if the precise positioning demands of the these systems can be met.

5.4. Functional description – speed limitation and safety distance

Vehicles are informed about legal speed and distance. The safety margin is calculated by the state of the vehicle in front (can be increased for dangerous goods for instance).

5.5. Related research projects and products

5.5.1. SAFETUNNEL PROJECT

PROJECT DESCRIPTION

The project leader was Centro Ricerche FIAT.

The Safe Tunnel concept is to use wireless public network to exchange information between infrastructure and vehicle in order to reduce numbers of accidents or fire inside road tunnels.

One application in this project is the speed and distance control inside the tunnel. The procedure is as follow:
Before entering the tunnel, the vehicles receive speed and inter-distance to be respected from the control centre. The driver uses the Adaptive Cruise Control system which will be automatically adapted to the control centre instructions (legal speed and distance to be respected). It will not allow the driver to exceed legal speed and will manage the correct distance with the vehicle in front.

Other applications are vehicle diagnosis for access control to an infrastructure, and dissemination of emergency information to the driver.

TECHNOLOGIES USED

Communication technologies:
• GPRS is used for vehicle to infrastructure communication with propitiatory protocol implemented
• Bluetooth is used as an alternative solution for short range vehicle detection to initiate or close GPRS connection

On board sensors technologies:
• RADAR is used for Adaptive Distance keeping
The inter-distance length is limited by the performance of the RADAR (around 150 meters)

USE OF COOPERATIVE APPROACH – POTENTIAL BENEFIT
Vehicle and infrastructure cooperation is the core concept of the SAFETUNNEL project.
The benefits can be summarize as follows

- Any relevant information regarding the infrastructure or vehicle status is sent to the receiver immediately. This can be a very high benefit in case of emergency situation like an accident or stopped traffic.
- Dynamic speed and distance instructions can be transferred from the infrastructure to adapt to the real traffic situations. No database is embedded on the vehicle, some static rules is incorporated in the infrastructure.

5.5.2. LAVIA PROJECT

FUNCTIONAL DESCRIPTION
LAVIA is a demonstration, test and evaluation of speed limitation in the Yvelines Department (France).

About 100 test runs by different drivers were preformed. The system is based on digital map embedded with speed limitation information included as attributes. The driver attitudes to this speed limit constraint are being currently analysed.

TECHNOLOGIES USED
The system relies on relative dead reckoning + GPS based estimation of the vehicle position together with embedded speed limits on a digital map database.

These limits are then fed back to the user by various means as a function of the vehicle current speed. The project strength is the extensive user trials.

5.5.3. IP PREVENT - MAPS&ADAS

PROJECT DESCRIPTION

The project leader is ERTICO.

A subproject of PReVENT - Safety-enhanced digital maps & standard interface to Advanced Driving Assistance Systems (ADAS). The project aim to use an a priori map as a predictive sensor called ADAS horizon, providing look-ahead capability. The main goal of the project is the development and validation of a standard interface including data model between map data sources and ADAS / Navigation applications.

Current Results:

- An ADAS Interface is ready for implementation by PReVENT applications.
- Methods for safety attribute acquisition enabling the provision of accurate and up-to-date digital maps compliant to ADAS application requirements.
- Provision of ADAS maps for PReVENT applications' test sites (Lower Saxony, Torino, Valladolid and Gothenburg)

TECHNOLOGIES USED

Maps&ADAS uses information stored on a navigation database enriched by topology & geometry attributes. The project uses navigation-positioning/map matching / map access to extract an ADAS horizon and broadcast the information to all applications onboard the vehicle.
There is a framework for interface specifications and a data dictionary.

MAPS&ADAS will implement two applications

- ACC (Active Cruise Control) to validate the ADAS interface
- Driver Warning System (HotSpot and Speed Alert) to assess the safety impact of ADAS maps

5.5.4. IP PREVENT - SASPENCE

PROJECT DESCRIPTION

The project leader is Centro Ricerche FIAT.

The SASPENCE project aims at developing a system able to suggest to the driver the most appropriate speed depending on the external situations and the right distances to keep towards the leading vehicle. These suggestions are based on the reconstruction of the current scenarios with special attention to specific situations, such as approaching a curve or an icy road too fast, to keep a too small headway and so on.
All in all, the SASPENCE system covers several items, including the road departure, the frontal collision warning, the speed limitations

and safety distance applications, using in many cases the V2V communication as well.
Under this view, many synergies and data exchange can be envisaged with SAFESPOT-SCOVA project.

TECHNOLOGIES USED

Technology used in SASPENCE
On board sensors technologies Long-Range RADAR (LRR), Communication Part (common with WILLWARN), (D)GPS + Digital Maps, CCD Camera + Enhanced Image Processing. The communication technologies based on WILLWARN protocol (WLAN IEEE 802.11g / 5.9 GHz standard).

5.5.5. CARTALK 2000 PROJECT

PROJECT DESCRIPTION

CarTALK2000 is a European research project lead by DaimlerChrysler focused on new driver assistance systems based on vehicle to vehicle communication finished in 2004. The main achievement is the development of a mobile ad-hoc radio network as a communication platform in view of developing future cooperative systems based on vehicle to vehicle and vehicle to infrastructure communication.

TECHNOLOGIES USED

A key technology for CarTALK 2000 was the specification and the development of a mobile multi-hop ad-hoc radio communication system meeting the requirements set by the applications. The target system was based on a UMTS radio access technology, using a spatial-aware position-based multi-hop routing protocol. For demonstration purposes, a prototypal communication platform using Wi-Fi as radio technology was used.

CarTALK 2000 defined three application clusters.

- Information and Warning Functions: vehicles transmit a warning message in case of breakdown, high traffic density and a congestion, critical driving situations (two vehicles approaching a crossroad simultaneously), etc.
- Communication-based Longitudinal Control Systems: adaptive Cruise Control systems that integrate communication to anticipate an early braking manoeuvre when an invisible vehicle beyond the direct predecessor in front is braking.
- Co-operative Assistance Systems: by exchanging information up to simple trajectory plans, critical situations can be foreseen and solved by the vehicles themselves.

5.5.6. NOW PROJECT

PROJECT DESCRIPTION

The NOW project is joining the efforts of German industry and academia to solve technical key questions on the communication protocols and data security for car-to-car communications and to submit the results to the standardization activities of the Car2Car Communication Consortium, which is an initiative of major European car manufacturers and suppliers. Furthermore, a test bed for functional tests and demonstrations is implemented which will be developed further on toward a reference system for the Car2Car Communication Consortium specifications.

Network on wheels will support active safety applications as well as infotainment applications and will thus provide an open communication platform for a broad spectrum of applications. This is of particular importance regarding the market introduction of car-to-car communication systems.

Cooperation between NOW and SAFESPOT could be benefit in the framework of communication standardization.

TECHNOLOGY USED:
Radio systems based on IEEE 802.11 technology

5.6. Use of cooperative approach – Potential benefit

These projects inform the driver of recommended speeds and in some cases also recommend safe following distances. The benefit of the cooperative approach is about the coverage of the most critical scenarios and concerning the recommendations that can be quickly and dynamically adjusted to the current traffic situation. Traffic can be safely slowed down before congestions if the driver is informed about slower traffic ahead, in this way reducing panic braking. Information about temporary obstacles on the road, both vehicles and other objects can be distributed quickly.

6. USA activities

In 2005, was distributed the final report of the IVI (Intelligent Vehicle Initiative) program. Lessons learned from IVI led to development of three major Federal ITS initiatives: Vehicle Infrastructure Integration, Cooperative Intersection Collision Avoidance Systems and Integrated Vehicle Based Safety Systems. This chapter introduces these three projects.

6.1. Integrated Vehicle-Based Safety Systems (IVBSS) project

The intent of this initiative is to work cooperatively with private sector partners in industry and academia to accelerate the introduction and commercialization of integrated vehicle-based safety systems for light vehicles, heavy trucks, and buses. These systems will assist drivers and reduce the number and severity of injuries resulting from rear-end, run-off-road, and lane change crashes. Integration will increase the system effectiveness by improving system performance, and improving the driver system interface.

The three noted crash types are:

- Rear-End Collision Avoidance
- Road Departure Collision Avoidance
- Lane Change and Merge Collision Avoidance

6.2. Vehicle Infrastructure Integration (VII) project

The project aim is a nationwide deployment of a communications infrastructure on the roadways and in all production vehicles to improve transportation. The objectives are crash prevention and congestion relief through vehicle-to-vehicle and vehicle-to-roadside communication. Such advanced, wireless communication is supported by Dedicated Short Range Communications (DSRC), a tool approved for licensing by the FCC (Federal Communications Commission) in 2003.

The purpose is to enable a number of new services that provide significant safety, mobility, and commercial benefits. The safety applications are the following (some can be also oriented mobility):

- Intersection Collision Avoidance
- Violation Warning
- Turn Conflict Warning
- Curve Warning
- Weather/Road Surface Data
- Construction Zones
- Highway Rail Intersection
- Emergency Vehicle Signal Pre-emption

A VII consortium has been established to determine the feasibility of widespread deployment and to establish an implementation strategy. The consortium consists of the vehicle manufacturers already involved in the IVI, AASHTO, ten State Departments of Transportation, and the US Department of Transportation.

6.3. Cooperative Intersection Collision Avoidance Systems (CICAS) project

The CICAS program is an intersection collision project combining sensors and communication on vehicles as well as infrastructure.

The system uses both vehicle-based and infrastructure-based technologies to help drivers approaching an intersection understand the state of activities within an intersection. CICAS aim to warn drivers about likely violations of traffic control devices and to help them manoeuvre through cross traffic. Eventually, the CICAS system may also inform other drivers (i.e., potential victims) about impending violations as well as identify pedestrians and cyclists within an intersection.

CICAS consists of:

- Vehicle-based technologies and systems—sensors, processors, and driver interfaces within each vehicle
- Infrastructure-based technologies and systems—roadside sensors and processors to detect vehicles and identify hazards and signal systems, messaging signs, and/or other interfaces to communicate various warnings to drivers
- Communications systems—dedicated short-range communications (DSRC) to communicate warnings and data between the infrastructure and equipped vehicles

The CICAS initiative builds on research and operational tests previously conducted under the US DOTS Intelligent Vehicle Initiative. It is being closely coordinated with the Vehicle Infrastructure Integration and the Intelligent Vehicle-Based Safety Systems initiatives. The CICAS initiative working group is being formed from partnerships with automotive manufacturers, State and local departments of transportation and university research centers throughout America.

Through additional research, system integration activities, and demonstrations, the CICAS initiative will produce a system prototype that addresses both control violations and gap acceptance crash problems. The initiative will culminate in a series of coordinated field operational tests to help achieve an understanding of safety benefits and user acceptance.

7. Summary Table

The table is a brief summary of the systems and advantages described in the report.

Application	Projects	Technologies	Co-operative approach	Potential Benefit
Road Condition	• IP PReVENT – WILLWARN • FRICTION • APOLLO	Micromechanics devices and the use of vehicle dynamic signals to estimate friction.	Yes	Information on friction can be validated and distributed
Road Properties – Curve Warning, Anti-rollover	• SAFE MAP • IP PReVENT – SASPENCE	On-board Map Data	No	Dynamic road conditions can be considered.
VRU protection	• IP PReVENT - COMPOSE and APALACI • EDEL • ARCOS • PROTECTOR SAVE-U • WATCH OVER	RADAR LIDAR Mono- and stereo vision systems. Infrared Cameras	No	Information about detected VRU can be shared among a number of vehicles.
Lateral Collision	• IP PReVENT - SAFELANE and LATERAL SAFE • Nissan system • A number of Continental systems	Camera lane tracking Map data	No	Vehicle can communicate the relative positions. Low level data can be shared to enhance position estimates. Enhanced HMIs possible.
Intersection Safety	• IP PReVENT - INTERSAFE		Yes	The sensors are not limited by line-of-sight, can see through corners. Traffic signals can be distributed to vehicles.
Frontal Collision	• APIA • RSD • Run-up Mitigation • IP PReVENT – SASPENCE	RADAR LIDAR Vision	No	Information can provide earlier warnings, better object classifications and in situations with all vehicles equipped distance measuring devices such as radars become redundant.
Safe Distance / Predictive speed reduction	• SAFETUNNEL • LAVIA • IP PReVENT – MAPS&ADAS • IP PReVENT - SASPENCE	RADAR Map Data Vision system	Yes	Distance and Speed can be dynamically adjusted to a recommended value dependent on the actual traffic situation. Undetectable scenarios can be covered (even partially)

8. Conclusion

An overview of the state of the art for relevant V2V applications and projects has been proposed. Guidelines and references for the start up of many SAFESPOT activities have been also given, pointing out the specific advantages that can be foreseen by means of a co-operative approach.

These advantages are of different kinds, ranging from sharing low-level data to the usage of integrated information for implementing the Safety Margin Assistance concept into the equipped vehicles.

Low level sensor-type data can be shared and used as inputs to various sensor fusion algorithms executed on-board of vehicles or in an infrastructure unit. Examples of this type are the quality of a lane marking at a position along a line or a given friction-estimate at a certain position. At an intermediate level, information can be shared as objects or properties. This can be for example the actual position of a VRU or the position of a vehicle.

At a higher application level the advantages of using a cooperative approach are also significant; the complete situation around the vehicle can be described as a local dynamic map shared by all vehicles in the surrounding. Two vehicles can share their position in respect to each other and negotiate for lane changes; dynamic hot spots information can be shared among the vehicles. This level of information would be especially useful for the lesser equipped vehicles that do not carry full ADAS equipment but only have available a basic SAFESPOT unit. Finally unequipped vehicles may also benefit as some information can be transferred from data collected by traffic control centres and data can be distributed by more traditional medias such as information on the public radio or road signs with dynamic text.

To sum up the situation, V2V and V2I are useful and helpful in order to:

- Overcome sensorial system limitations due to technical and physical constraints (in specific scenarios)
- Cover most critical situations (in undetectable conditions)
- Complete information to the drivers at HMI level
- Enhance the confidentiality of measurements and (more generally) of information
- Improve the safety-level of other less equipped vehicles acting on the roads

Specific descriptions and references for the different applications and projects have been given, pointing out the adopted technologies and the advantages achievable by exploiting the SAFESPOT co-operative approach.

9. References

9.1. List of websites

All PReVENT – IP projects can be found on the website
http://www.prevent-ip.org/

FRICTION
http://friction.vtt.fi/

EDEL
http://www.crfproject-eu.org/sites/edelfolder/homepage.htm

SAVE-U
http://www.save-u.org/

WATCH OVER
http://www.watchover-eu.org/

SAFETUNNEL
http://www.crfproject-eu.org/

NOW
http://www.network-on-wheels.de/

American activities
http://www.its.dot.gov/ivbss/index.htm
http://www.its.dot.gov/cicas/index.htm
http://www.its.dot.gov/vii/index.htm