SAFESPOT APPLICATIONS FOR INFRASTRUCTURE-BASED CO-OPERATIVE ROAD-SAFETY

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ABSTRACT

SAFESPOT is an Integrated Project co-funded by the European Commission, under the strategic objective “eSafety Cooperative Systems for Road Transport”. The Goal of SAFESPOT is to understand how intelligent vehicles and intelligent roads can cooperate to produce a breakthrough in road safety. This paper presents the SAFESPOT applications where decisions are taken by the road infrastructure in cooperation with vehicles. They are designed on the basis of road accident data analysis for the urban, rural and motorway roads. The applications detect in advance potentially dangerous situations and extend the driver’s awareness of the surrounding environment by generating warnings.

INTRODUCTION

By combining data from vehicle-side and road-side sensors the SAFESPOT project will allow to extend the time in which an accident is forecasted, from the range of “milliseconds” up to “seconds”. The transmission of warnings and advices to approaching vehicles, by means of vehicle-to-vehicle and vehicle-to-infrastructure communications, will extend in space and time the driver’s awareness of the surrounding environment (7).

The SAFESPOT project is also a part of a more complete approach around road safety and efficiency implying other European projects as shown in figure 1. All these projects, except the APROSYS project, imply cooperation between vehicles and the infrastructure by means of wireless communications.

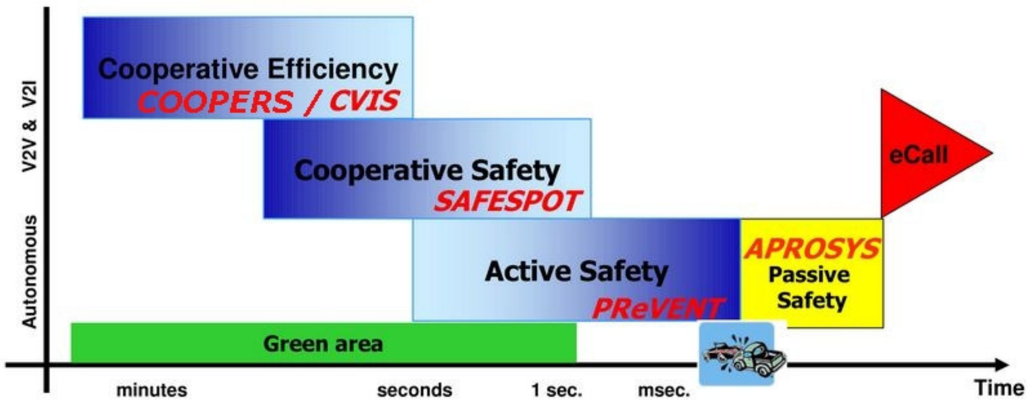

Figure 1 - Time-to-crash of the SAFESPOT approach

The CVIS and COOPERS projects mainly focus on increasing efficiency in the road network. They provide reliable information about road status, traffic jams, road works or accidents, local services like the presence of parking lots, and may suggest alternate roads to the drivers. They use long range communication to significantly improve traffic control via effective and reliable transmission of information adapted to the current location of the vehicle.

SAFESPOT focuses on detecting potentially dangerous situations and providing warnings to drivers with real-time communications. Complementary to COOPERS and CVIS, it is the last chance to keep the driver inside a safe area, where he still has the time to react to a potential danger.

The PREVENT project focuses on the objective to increase the active safety by controlling the vehicle and activating for instance immediate braking of vehicles or avoiding dangerous manoeuvres of vehicles. Then, APROSYS and eCall systems are designed to mitigate the consequences of an accident.

BACKGROUND

The SAFESPOT integrated project is divided into eights subprojects, with two subprojects responsible for the definitions of the cooperatives applications of the system: the SCOVA subproject, for Cooperative Systems Applications Vehicle Based, that deals with applications processed inside the vehicle, and the COSSIB subproject, for Cooperative Safety System Infrastructure Based, where the applications are processed on the road side. This paper presents applications triggered by the infrastructure.

THE DESIGN METHODOLOGY

In order to design safety applications based on cooperative sensing technologies, a user-centred approach was adopted (6). The user's needs explain what the system is expected to provide, and the constraints under which it must operate. Simultaneously to the definition of the user needs there was an extensive analysis of the accident data. The analysis was separated in three driving environments: the urban area, the motorway area and the rural area; for different European countries in order to find out what were the most relevant safety scenarios. This is necessary in order to customize the applications to the needs and to derive a high benefit at the end. The Figure 2 below shows the used methodology in an overview.

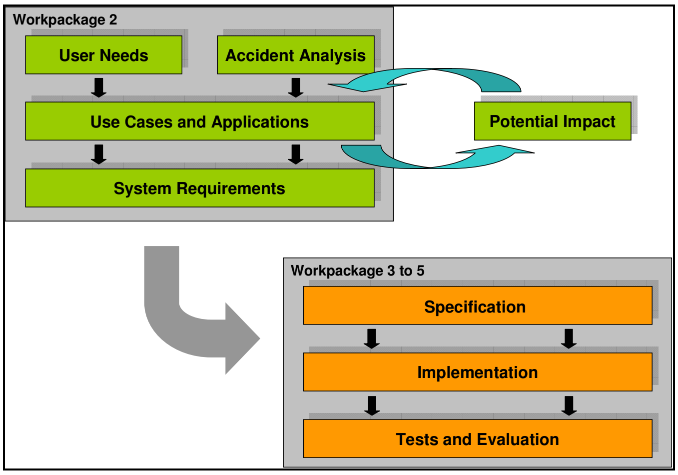

Figure 2 - The SAFESPOT design methodology

The available accident data at a European level form the Eurostat institute, the CARE and EACS databases, or the SAFETYNET, RANKERS or PENDANT projects provide an overview of the European accidentology (1). They highlight main similarities or differences between countries, and confirm that rural, urban or motorway areas have different accidentology characteristics. The available details are mainly based on criteria like the age, the gender or the day of the week, but they do not provide further details as they are not available in all European countries or not captured in the same way.

To have a more precise description of accidents, the SAFESPOT project has performed a detailed road accidents data analysis based on data from different European countries, regions or cities were the expected details were available. Data was gathered from Italy and the city of Turin, from French motorways and rural roads of the Brittany province, from urban areas in Germany, and from the Netherlands. In addition some specific studies about road departure (3) or intersections accidents (2) were taken into account. Those data provide different accidents characteristics like their seriousness, their different sources, their locations, the types of involved vehicles, the traffic or weather status, the vehicles' trajectories and the possible rule violations. They are then exploitable to design safety applications that can operate on the different factors that lead to accidents.

The analysis was based on the modelling of accidents into a cause-effect relation. An accident cause, which is due in 90% to a driver misjudgement or inattention, leads to a dangerous behaviour like a wrong trajectory or an excessive speed, which finally leads to an accident like a collision between vehicles, a run off road, or a collision with a pedestrian. Those situations may also be aggravated by a dense traffic or a low friction of the road surface. By observing and anticipating all these aspect of an accident, the applications combined together, are able to warn the drivers in advance in almost all dangerous situations.

Based on the accident analysis and the user needs, the use cases and scenarios are drawn to generate a first picture of the usage of the applications. During this process twenty-four use cases were described, concerning the above mentioned driving environments and classified on different topics: ‘Obstacles’, ‘Misjudgement’, ‘Rule violation’, ‘Critical environment conditions’ and ‘Collision avoidance’. Then primary requirements of the system were derived from these use cases. Based on a first description of the applications that should cover the use cases, the system engineers have completed the requirements list, and provided the functional characteristics of the system. To validate the applications, the analysis of their potential impact in term of safety has been achieved, and has given interesting results to optimize them.

After this first phase of the SAFESPOT project the specification phase will follow; then there will be the implementation phase and the evaluation of the applications in real situation. The evaluation will be carried out on several test sites located in six European countries.

THE FUNCTIONAL ARCHITECTURE

The SAFESPOT applications rely on a complex functional architecture whose definition was achieved with the collaboration of all the SAFESPOT subprojects, and more particularly the “Core Architecture” subproject. If the sensors and warning devices differ between SAFESPOT vehicles and SAFESPOT infrastructure, the functional architecture is designed to be almost the same for these two main entities of the system. It enables real-time exchange of the status of the vehicles and of all the detected events or environmental conditions of the road. The continuous and real-time exchange of these data between the infrastructure and vehicles and between vehicles is necessary to take advantage of the cooperative approach and permit the design of effective safety applications.

As presented in the figure 3, information measured by sensors are provided to the “Data Fusion” module or transmitted through the network to be provided to the “Data Fusion” module of other entities. This module analyses and synthesizes arriving data to put them on the “Local Dynamic Map” of the system. The “Local Dynamic Map” enables the cooperative applications of the system to retrieve relevant variables and parameters depending on their purpose. The applications are then able to trigger relevant warning to be transmitted to appropriate entities and showed on the onboard Human Machine Interface (HMI) or road side Variable Message Signs (VMS). Other complex mechanisms are inherent to this architecture, but they will not be described in detail as it is not the main focus of this paper.

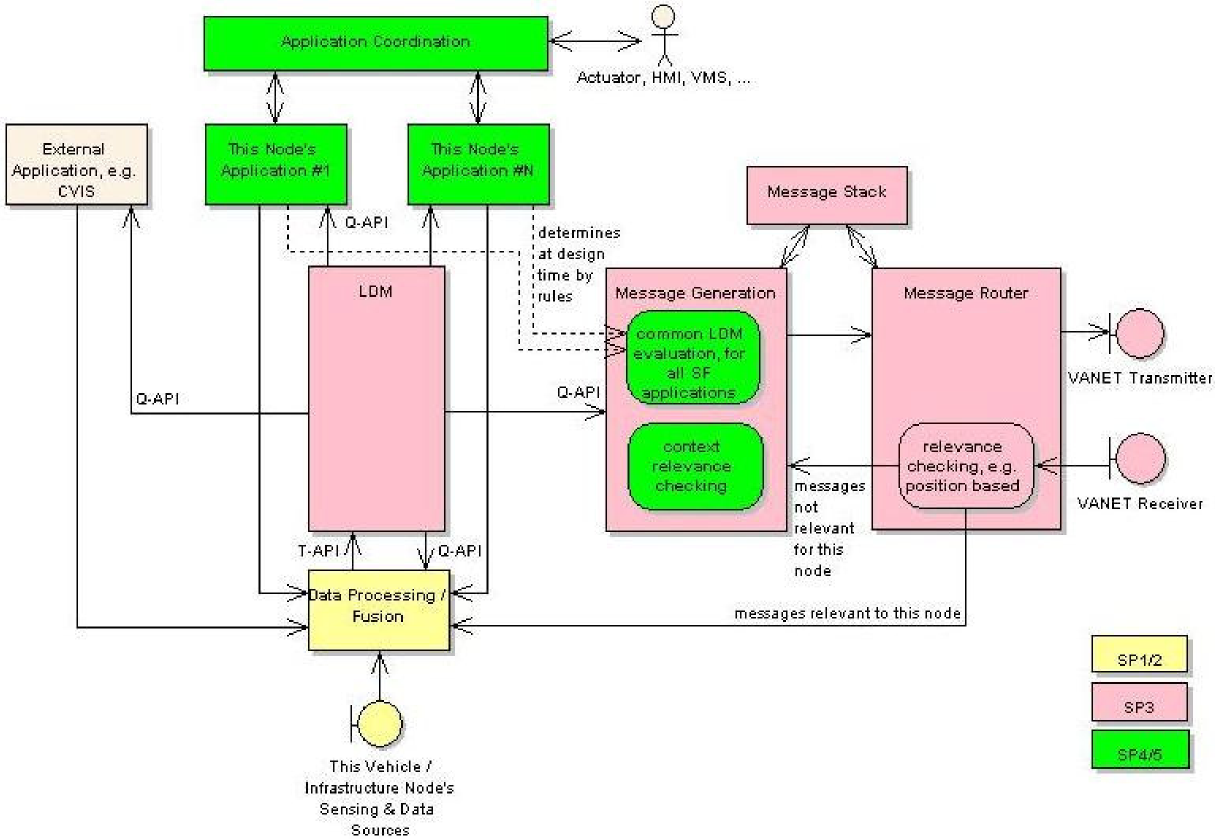

Figure 3 - The SAFESPOT Functional Architecture

THE SAFESPOT INFRASTRUCTURE-BASED APPLICATIONS

Within SAFESPOT five main infrastructure-based applications were defined: “Speed alert”, “Hazard and incident warning”, “Road departure prevention”, “Co-operative intersection collision prevention” and “Safety margin for assistance and emergency vehicles”. These applications are designed to provide the most efficient recommendation to the driver through the onboard HMI and through road side VMS (4).

HAZARD AND INCIDENT WARNING

The aim of this application is to warn the drivers in case of dangerous events on the road. The selected events are the most relevant in terms of safety: accident, presence of unexpected obstacles on the road, traffic jam ahead, presence of pedestrians, presence of animals and presence of a vehicle driving in the wrong direction or making a dangerous overtaking. This application also analyses all environmental conditions that may influence the road friction or decrease the visibility of the drivers.

More generally, this application aims at describing the road status and driving conditions. Based on the cooperation of vehicles and road side sensors, this application provides warnings to the drivers and feeds the SAFESPOT road side systems and vehicles with the description of new driving situations. This application is essential to enable the other applications to have latest relevant road description.

SPEED ALERT

This application provides recommended speed to drivers, with different levels of intensity, on the basis of a real-time evaluation of parameters such as: the legal speed limit, the weather status, road surface conditions, topology of the road, traffic flow speed and any events like road works, traffic jam or deviations. These parameters may be static or provided by the "Hazard and Incident Warning Application".

This application was justified by the analysis of accident data, as excessive speed is an indirect cause in more than 40% of accidents on rural roads and motorways. It is also clear that infrastructure system gives more consistent recommendations than the sole interaction between vehicles, since it has an extended 'vision' of the road status(5).

Three main sub applications are foreseen for speed alert:

1. Legal Speed limit: to warn driver if his speed exceed legal speed limit. Moreover this application deals with the update of legal speed limit on the map. For instance, an infrastructure manager can decide to change speed limit on a specific area, or in case of rain, the speed limit must change, according to legal aspect.
2. Critical Speed limit: this sub application deals with dynamic update of speed limit according to the alerts generated by the "Hazard and Incident Warning" application. For instance, when a vehicle arrives at a road section that is subject to a traffic jam, the system will warn the driver if he does not slow down early enough.
3. Excessive Speed alert: this sub application focuses on the static black spot and on the management of driver speed while approaching this black spot. For instance, when a vehicle is approaching a sharp curve or a tunnel with a speed recommendation below legal speed limit, the application manages the warning to the driver and the speed limit.

The message could be sent to the driver either using a road side unit, like a VMS, or directly inside the vehicle, if it is equipped with SafeSpot compliant devices.

ROAD DEPARTURE PREVENTION

Accident analysis results published by the French road administration for year 2004 show that a large part of road fatalities implies a road departure: approximately 30% (3). "Road Departure Prevention" is an extension of the "Speed Alert" application, and is aimed at computing an accurate safe speed according to road geometry, vehicle dynamics and driver capacity.

For instance, drivers arriving at a bend with inappropriate speed, or leaving their lane due to drowsiness, lack of attention or use of alcohol or drugs, will be warned by the "Road Departure Prevention" application. Briefly, a set of admissible trajectories is defined on the basis of the local road geometry. Each time a vehicle crosses the monitored zone its position and speed are measured in real time. In case of critical trajectory a warning is given to the driver. The warning can also be extended to the surrounding vehicles and people, for instance, to the operators of an adjacent road works site.

In the design of the application itself, the main aspect to be tackled is the definition of the allowed trajectories, which in principle depend on road geometry, road friction, vehicle speed and driver skill; whereas in the overall system development the most crucial issue is the speed in detecting and giving the feedback to the driver.

COOPERATIVE INTERSECTION COLLISION PREVENTION

This application typically concerns a static black-spot for urban roads: the intersections (2). It deeply exploits real-time computation and communication through high-speed local networks. The application will calculate and predict the trajectories of the road users present in a given intersection. An intensive use of road side sensors like cameras or radars associated to the control of local traffic lights are the cornerstones of this application. Also, a full coverage of the intersection with bidirectional communications between vehicles and the infrastructure is mandatory.

Based on the trajectories of vehicles and of vulnerable road users like pedestrians or bicycles, safety-critical situations will be identified and a decision will be drawn, to appropriately warn concerned actors. However, infrastructure support will broadcast information to drivers not only in specific points, but also in wider areas beyond the black-spot to implement an efficient strategy.

SAFETY MARGIN FOR ASSISTANCE AND EMERGENCY VEHICLES

It is important that assistance and emergency vehicles can pass through the road network as safely and fast as possible. This application enables assistance and emergency vehicles to have a driving priority toward other road users. By sending a warning, directly from the emergency vehicles and through road side equipment, this application provides a “green route” to these vehicles by urging other vehicles to give a way and by switching traffic light controllers. Thus, this application needs to cooperate with the other applications like “Cooperative Intersection Collision Prevention”, “Hazard and Incident Warning” and “Speed alert”.

Due to the need to have very high speed communications between vehicles and the infrastructure, the chosen technology introduces a limitation in the communication range. The SAFESPOT system cannot rely on a continuous coverage of the road network except for specific identified black spots. Thus, SAFESPOT assistance and emergency vehicles will have the ability to implement the “Hazard and Incident Warning” and “Speed Alert” applications on non covered areas, during their intervention. They are considered as mobile road side units that can be deployed in case of the occurrence of dangerous situation.

CONCLUSIONS

Following the recommendation of the European Commission, the analysis of accident data has proven its effectiveness, giving an enhanced knowledge on the main safety problems that drivers may face when using European roads. Furthermore, it has improved the design of the SAFESPOT applications based on the cooperation of the infrastructure equipment and vehicles. With this set of five applications processed on the road side, the SAFESPOT system will enhance the road users' security in major dangerous situations.

Constrained by real-time requirements, the SAFESPOT system has chosen relevant equipments that cannot be deployed on the entire road network. This limitation is widely mitigated by the identification of road black spots, the design of adapted functionalities like in the "safety margin for assistance and emergency vehicles" application and the use of vehicles based applications. Also, the integration and compatibility of SAFESPOT with the other European projects like COOPERS or CVIS almost suppress this limitation.

The growing interest and involvement of all road actors on Intelligent Transport Systems motivated by economic, environmental and safety interests enable to consider that great progresses will be achieved on road technologies. By its rigorous consideration of road safety problems, the SAFESPOT project proves that it is a part of this motivating progress.

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