VEHICLE-TO-VEHICLE COMMUNICATION FOR ENHANCED INTEGRATED SAFETY

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Page Number 09-0391

ABSTRACT

Passive safety systems are reaching a limit in improving vehicle safety. Fundamental enhancement of passenger protection can only be obtained by including predictive, active safety systems. This field of development is termed integrated safety. A central step to tap the full potential of integrated safety is the expansion of this topic by vehicle-to-vehicle communication.

The paper discusses the embedding of applications using vehicle-to-vehicle communication into an enhanced integrated safety concept. The main objective is to increase vehicle safety by using a proactive sensor which exceeds the physical limits of existing sensors and augments the context information for the driver.

The development process is designed by including impartial and subjective characteristics and evaluations. The impartial part consists of, e.g., accident research, simulations and trial runs. The subjective part covers experiments with probands who have to evaluate the new safety concept with the upgraded information context for the driver, for example acceptance tests or human machine interface development.

In addition to presenting the methodical development this paper discusses a first implementation of this method using as example the vehicle-to-vehicle communication.

Expected results are rules and standards for the development of new enhanced integrated safety concepts in the future. The paper highlights the basic necessity of new methods for developing safety concepts in the course of technological change of integrated safety.

INTRODUCTION

Since the development of the first car an increase in road traffic can be observed. Also, the number of accidents increased dramatically due to the lack of standards to improve vehicle safety. This topic gained importance already in the 1960s. [1]

During the history of vehicle safety, the influence of electronics expanded continuously in the field of safety systems.

At first vehicles learned “to feel” - to detect a crash and to activate airbag systems.

Today vehicle safety departments are developing cars which can “see”. The sense “seeing” is essential for the development of foresighted active safety systems to detect imminent accidents.

In the future vehicles have to learn “to hear and to speak” using vehicle-to-vehicle communication. This will be a fundamental milestone for the integrated safety approach to prevent accidents and to decrease accident severity.

THE INTEGRATED SAFETY APPROACH

In the future new vehicle safety systems have to be designed to merge active and passive safety components. Passive safety systems are starting to achieve saturation in efficiency to protect occupants. In contrast, active safety systems significantly foster the potential to enhance the efficiency of vehicle safety. A further improvement for occupant-, pedestrian- and bicyclist protection at the advanced efficiency level can be achieved by combining active and passive safety systems. Figure 1 illustrates this issue.

![Figure 1. Efficiency of the Integrated Safety Approach](image)

Due to this approach, the objective of vehicle safety broadens: not only occupants should be protected as good as possible but also the severity of accidents should be decreased by the pre-
conditioning of safety systems (e.g. brake prefill) or even accidents should be prevented.

The integrated safety approach includes not only the combination of active and passive safety but also every system along the timeline of different driving conditions. Figure 2 shows the timeline of the integrated safety approach within several driving conditions.

The integrated safety is segmented into four main parts: driver condition, active safety, passive safety, save and rescue. The driver condition part includes comfort systems acting in a normal driving condition. Comfort systems help drivers by exchanging information. The second part of the timeline is the active safety. These driver assistant systems are working in critical and instable driving conditions by warning and supporting drivers. The passive safety part describes pre-crash and restraint systems in unavoidable crash situations and crashes respectively. In the fourth part -save and rescue- drivers are helped by activating emergency systems in situations after a crash.

Figure 2 shows the timeline of the integrated safety approach within several driving conditions.

During the alteration of vehicle safety a change of the components involved as well as a redefinition of the respective weightings and importance occurs. Beside classical components like airbag and seatbelt which belong to the main component vehicle/system a further important factor comes to the fore – the driver. Figure 3 presents the four main components of integrated safety:

- driver
- vehicle/system
- environment
- task.

Figure 3 shows that the main components driver and vehicle/system are sharing the task of vehicle guidance. So far it has been assumed that the driver has to solve a task for which he uses the vehicle as a tool. Due to the improvement in the area of integrated safety, the vehicle also learns to feel, to see, to hear and to speak. Thus the environment can be perceived by the new “sense organs” of vehicles. Tasks (Table 1) can now be performed by vehicles to support drivers in normal, critical, instable driving conditions, crashes and after crash situations, respectively. The task sharing between vehicle and driver depends on the driving conditions which vehicles must assume.

Approaching a crash situation, the vehicle takes over more responsibility. During a normal driving situation the vehicle supports drivers in navigation tasks (e.g. providing information about routes). The vehicle performs guidance tasks in critical driving situations by using a driver assistant system (e.g. adaptive cruise control system). Additionally driver assistant systems can support drivers by assuming stabilization tasks in an instable driving condition (e.g. electronic stability control system). The vehicle takes full control during a crash situation by protecting occupants (e.g. airbag deployment).

Also the type of task changes along the timeline (Figure 2). First of all, vehicles support drivers in navigation tasks. In critical driving conditions vehicles can undertake tasks of vehicle guidance and vehicle stabilization. Thereby, task sharing must not let the driver off the hook of vehicle guidance [2]. The driver is simply supported during his tasks by a system.

Table 1 shows the tasks of vehicle guidance.

Figure 3. The Four Main Components of the Integrated Safety Approach

![Diagram](image-url)
Table 1. Tasks of vehicle guidance [3][4]

<table>
<thead>
<tr>
<th>primary task</th>
<th>secondary task</th>
<th>tertiary task</th>
</tr>
</thead>
<tbody>
<tr>
<td>navigation task</td>
<td>environmental and traffic-related tasks</td>
<td>tasks to satisfy comfort-, entertainment- and information requirements</td>
</tr>
<tr>
<td>length scale: n x 100 km</td>
<td>e.g. to indicate, to honk, to wipe, light on/off, etc.</td>
<td>e.g. to use radio, air-conditioning system, etc.</td>
</tr>
<tr>
<td>time scale: minutes to hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vehicle guidance task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>length scale: 0.2 to 200 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>time scale: 1 to 10 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vehicle stabilization task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>length scale: 1 to 10 meter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>time scale: 1 to 50 ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A further main point, that has to be discussed is the perception of the environment. The two main components driver and vehicle/system share this task with each other. Future researches have to survey which task plays an important role in environmental perception. What can be perceived better by humans and what by sensors?

Drivers perceive the environment by sense organs (e.g. eye, ear). Vehicles have to use sensors for the perception task. Thereby, it can be distinguished between inertial sensors and foresighted surround sensors. The integrated safety approach attributes great importance to foresighted sensors like autarkic onboard-sensors or cooperative systems which communicate with other traffic participants or infrastructure. The main objective is to increase vehicle safety by using a proactive sensor which exceeds the physical limits of existing sensors. For example, a “view around a corner” can be achieved by using vehicle-to-vehicle communication. This requires further research in the field of vehicle-to-vehicle communication. Can the environment be perceived by vehicle-to-vehicle communication in the accuracy which is required to perform tasks of guidance? Can vehicle-to-vehicle communication exceed physical limits (e.g. coverage, aperture angle, occlusion) of existing sensors?

VEHICLE-TO-VEHICLE COMMUNICATION FOR INTEGRATED SAFETY

The chapter “integrated safety approach” identified the communication channel as an important mandatory sensor for integrated safety to tap the full potential of safety efficiency.

In this chapter a concept is developed to incorporate vehicle-to-vehicle communication into integrated safety. Development methods are demonstrated which are indispensable due to the enhancement of the main component driver. Furthermore, this method is applied for a first draft of vehicle-to-vehicle communication in vehicle safety.

So far, an impartial path for developing safety systems is used exclusively in the classical passive vehicle safety. For example crash tests are conducted; scenarios are simulated on computers; etc.

Thanks to the enhancement of vehicle safety due to systems of active safety, driver assistance systems and driver conditioning systems the driver moves into the focus of development. From now on it is not enough to develop systems using impartial criteria, but subjective components and features of the future customer have to be considered during the development task.

Figure 4. Processes for Developing Vehicle-to-Vehicle Communication Concepts

Figure 4 illustrates the impartial and subjective methods which have to be considered in the development process of new systems of integrated vehicle safety. The impartial methods are currently established.

In the following, subjective methods have to be considered in detail.

The human factor has to be involved early in the development process because it has a relevant effect on future use and sales figures respectively. The first step consists of a proband survey without input. It analyzes contents which users accept and need. This can be studied by questionnaires, individual interview or by focus groups.
In the second step a proband survey with visualized use cases, simple mock-ups or videos as use cases are shown to potential users. Thereupon interviews can be done.

In the third step systems are demonstrated to users by simulated scenarios. Probands are able to contribute on the improvement of the human machine interface. They get haptic, optic and acoustic feedback by the system according to interface design.

The final step contains real test runs with probands. Probands are brought in situations where systems should work. Thus impartial system redundancy can be tested against subjective sensation. Furthermore, the human machine interface can be improved in a real environment.

Thus the future user is involved in the continuous development process of integrated safety systems using these four subjective methods.

Initially some impartial methods are applied for a first draft for embedding vehicle-to-vehicle communication in the enhanced integrated safety approach.

Looking at the accident statistics most accidents happen at intersections (Figure 5).

![Figure 5. Accident Statistic Based on Accident Types [6]](image)

However, some accident types provoke a fatal impact on accident severity but do not happen frequently (e.g. accidents caused by wrong way drivers on highways). Considering this fact accident severity has to be included into accident analysis.

Derived from this analysis, a potpourri of functions and applications is defined which influences the vehicle-to-vehicle communication concept:

1. intersection assistant
2. left turn assistant
3. pedestrian-/bicyclist protection
4. wrong way driver warning
5. warning against disregarding of red lights.

Considering the evaluated expert interviews the contents of the message packet for vehicle-to-vehicle communication can be extracted. These points partly enlarge the existing Car2Car Communication Consortium message set [5]:

- vehicle weight
- vehicle dimensions
- position
- velocity
- acceleration
- vehicle type (car, truck, motorcycle, etc.)
- driver condition/- type
- track condition
- time stamp
- yaw rate
- steering wheel
- braking activation
- number of occupants.

Further analysis will be done focusing on the application intersection assistant. The involvement of driver command is a central fact which has to be considered in the development process (e.g. turning request, stopping request).

A general statement about driver behaviours cannot be given because drivers differ extremely in several operation characteristics. There exists a conservative driver which blinks and brakes at an early stage. However some drivers execute these actions late and drive very dynamically. Also in this case the comprehension of the human factor plays an important role.

REFERENCES


