USAGE OF SURROUND SENSOR INFORMATION FOR PASSIVE SAFETY – CHALLENGES AND CHANCES

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ABSTRACT

In this paper an approach of using surround sensor information for passive safety is being proposed. The combination of active and passive safety is necessary to reach the high aims to reduce the fatalities in road traffic up to 50% since 2000. Especially the surround sensor, like the video sensor, offers lots of information that can beneficially be used for advancing the current passive safety systems and design new functions that are not possible with current state of the art passive safety sensors.
An overview about such possible passive safety functions is given with subject to the necessary sensor requirements. These requirements are derived among others from accident statistics and the required restraint system which should be activated. A major outcome of this evaluation, the different sensor requirements for comfort and safety functions, is presented.
As an example for such kind of passive safety functions, the Video-supported pedestrian protection is presented with focus on reducing the crash severity by activation of a brake system and by supporting the current pedestrian protection system to pop up the hood by recognizing the pedestrians.
As another example, Video-based PreSet and Video-based PreFire are presented with focus on protecting the occupant in the best way possible by an optimal choreography of the reversible and irreversible restraint systems. Therefore, the sensor characteristic must be slightly different and well designed to the special functional variant.
In the end a first indication about the potential of such systems and a forecast of future systems is given.

INTRODUCTION

In the European Union still almost 40.000 people die in traffic annually. The aim is, to halve the fatalities from the year 2000 to the year 2010 of the road fatalities (see fig. 1). Current active and passive safety systems have done the first step in this direction. But the current status illustrates, that the set target will probably not be reached in 2010.

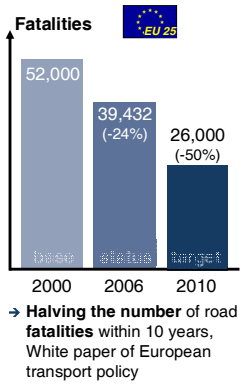

Figure 1. Overview of aim to reduce the fatalities in EU and the current state (see [1])

Nevertheless a positive trend can be seen. Currently the equipment with active and passive safety systems will be supported by legislation and consumer tests (e.g. EuroNCAP).
In the market two movements are perceived for the combination of active and passive safety. On the one hand the functional enhancement of existing hardware, like the use of radar-sensor information for passive safety functions or the use of night vision information for pedestrian recognition is known. The target here is, to use synergies of the systems without influencing the requirements of the specific components. On the other hand the specialization of the surround sensors for optimal use for passive safety is another trend. The chance here is to address new functions which are necessary to handle megatrends like CO_2 reduction for example.

Motivation Of Using Surround Sensor Information For Passive Safety

The expectations in surround sensors are legitimate. With the help of the surround sensors many important information can be produced prematurely. This will be clear as follows.

Physical Motivation – To determine the crash severity the following parameters are relevant:

- Impact velocity
- Crash type (e.g. full frontal crash, offset crash, …)
- Mass / stiffness of crash participant.

Traditionally the typical crash sensors, like acceleration sensors, allow gaining information about

- Mass / stiffness of crash participants
- Crash type (e.g. by using y-part of crash signal).

Basically, the acceleration sensors can provide this information, but typically not within the required time.

The Surround sensors allow getting additional information about

- Impact velocity
- Crash type
- Object type

The advantage compared to the typical crash sensors is that this information is available before the crash. So the information could be used already at the beginning of the crash.

Basically, a lot of surround sensors can deliver one or more of the above mentioned information. But they often differ in the quality of the information. Radar sensors for example deliver a high precision of the closing velocity or distance (see [2], [3]). A mono video-sensor for example offers the potential to deliver a first indication of the crash type (e.g. offset-crash) and the object type.

Many mono video based systems are already in the market. They are used for a wide set of different functions like Night View, Road Sign Recognition and Lane Departure Warning. Additionally the detection of traffic scenario relevant objects is possible. When looking at these functions, there is a trend in delivering the mentioned functions all from the same camera.

It is obvious that the market penetration and the increasing number of such systems give the opportunity to use this information also for passive safety functions, especially the object information without modification of the requirements.

Overview Of Possible Passive Safety Functions

The passive safety covers two topics in general, the pedestrian protection and the occupant safety.

The scope of pedestrian protection is to protect the pedestrian in case of an unavoidable accident. In 2005 for example 18% of all fatalities in European road traffic are pedestrians (see fig. 2). Currently the protection is reached by structural measures (passive solution) and by activation of a pop up hood (active solution). In case of using acceleration sensors in the bumper that detect the collision with a pedestrian and the system activates the pop up hood by a pyrotechnical activation for example. The function Video-supported Pedestrian Protection could be helpful here to classify the collision objects in an alternative way or to reduce the degree of freedom of acceleration-sensor-based classification.

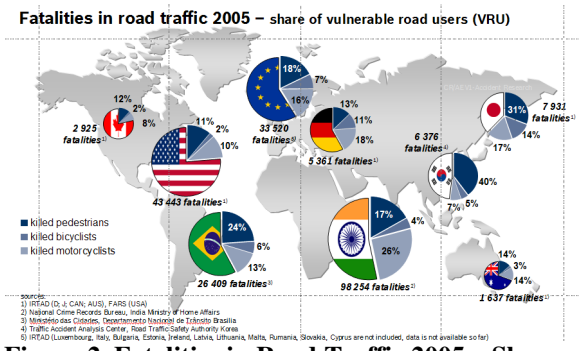

Figure 2. Fatalities in Road Traffic 2005 – Share of VRUs (see. [4])

The scope of occupant safety is to protect the occupant by activation of available restraint systems to reduce the injury risk. Video-based PreSet and Video-based PreFire are two possible functions, who assist to generate an optimized firing choreography and to couple the occupant early on the deceleration of the vehicle. These functions address up to 40% of all accidents (30% of all collisions, see fig. 3). The PreSet functionality is already represented in the market based on radar or lidar information.

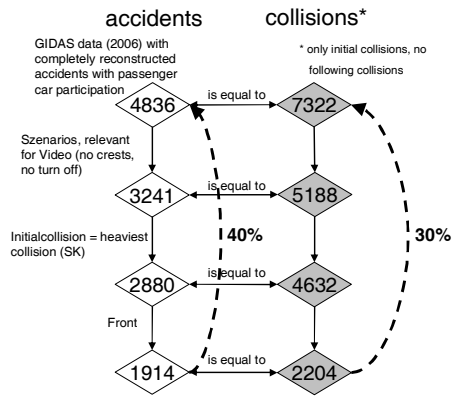

Figure 3. Accident data base analysis of Potential for PreCrash functions

Video-supported Pedestrian Protection

The function Video-supported Pedestrian Protection (VPP) supports the conventional pedestrian protection, which is already in the market.

This support can basically be given in two ways:

- Direct classification, which means that the video sensor information is used to recognize a collision object as a pedestrian
- Indirect classification, which means that video information is used to support the acceleration sensors of state of the art pedestrian protection systems.

The direct classification can be done using strong or weak classification approaches.

By saying strong classification approach, pattern matching and the use of trained classifiers with the

focus on shape and appearance are meant. Strong classification of pedestrians for pedestrian protection, which has to work milliseconds before crash is a very challenging task. In this phase before the crash happens, a pedestrian is partly occluded and can be in a variety of different poses and orientations in front of the vehicle. That is why a weak classification offers more robust support to a pedestrian protection function.

By weak classification, methods using more general features like size and aspect ratio combined with generic features like motion are meant. Especially motion patterns are very powerful for classification, because over 90% of the hit pedestrians are moving before the collision happens (see fig. 4) and 75% cross from left or right (see fig. 5). Measuring motion by using optical flow gives strong support to detect and classify pedestrians. Due to the fact that VPP only needs information at the time of impact, even not moving pedestrians can be detected shortly before collision by the parallax caused through the elevation of the pedestrian.

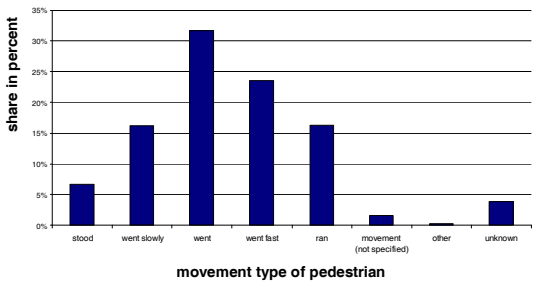

Figure 4. Distribution of the movement types of pedestrians before crash

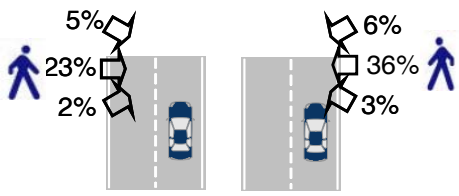

Figure 5. Moving directions of pedestrians before crash

Both methods of classification can be realized with current cameras in principle. But they suffer from limited resources and detection capabilities as well as classification performance.

Indirect classification supports the classification given by the state of the art pedestrian protection systems. The benefit given by video sensors can be found in the better adjustment of fire thresholds according to the information given by the video sensor (e.g. impact position). This can be also fulfilled by using weak classification method as described above.

The aim of both classification methods (directly / indirectly) is to enhance the fire decision characteristics, for example by better separation of the mayfire object from the mustfire objects.

Regarding the necessary field of view, an opening angle of 40° is a possible choice. 100% of the fatal accidents can be addressed by selecting this opening angle and nearly 86% of all badly injured people (see Table 1). By the way, the opening angle of many state of the art video based driver assistance systems is 40°.

Table 1.
Cases of Pedestrian accidents covered according to field of view

	Cases in the range of the field of view		
	slightly injured	badly injured	fatal
± 10°	49,2%	58,7%	84,9%
± 20°	80,0%	85,9%	100,0%
± 30°	90,4%	95,1%	100,0%
± 40°	93,9%	95,8%	100,0%
± 50°	96,4%	97,6%	100,0%
± 60°	97,3%	97,6%	100,0%

A second effort is to support the pedestrian protection in reducing the impact velocity by preparation or activation of the brake system. For this function it is necessary to use a surround sensor who delivers the closing velocity and the time to impact. Mono video is not able to deliver metric information like distance or velocity directly from the sensor. Furthermore pedestrians are strongly varying objects which are very hard to be modeled. Due to these facts the use of a stereo video system is strongly recommended.

Test scenarios, based on GIDAS data base information [5], show that for pedestrian protection the closing velocity will be reduced by around 15%. The underlying assumption is that the system is able to build up the brake pressure to reach a deceleration of 4 m/s² in 400 ms and continues the braking for another 400 ms. To activate the brake system the requirements for the necessary attributes, like closing velocity or time to impact, are higher than for support of classification, because of the avoidance of an inadvertent activation.

The third manner is to warn the driver or the pedestrian in a critical situation that could result in a collision.

The last two points are mostly covered by the BMBF project AKTIV with extensive studies.

Video-based PreSet

The name PreSet stands for **Pre**Crash **Set**ting of algorithmic parameters. The main functionality is to reduce the severity of injury in the case of a crash by optimized deployment of restraint systems. Therefore a high accuracy of the information about

the relevant parameters which define the crash severity is needed.
If Video-based PreSet is realized with a mono video system it is only possible to get information, like offset/overlap and object type of a high quality. According to the accuracy of the desired information there are two ways of data acquisition: One is to get the exact offset and overlap information at the time of impact. Then the distance is known and the relevant data can be calculated from the image dimensions and positions. The second one is to get information before the impact, a model of the collision object has to be assumed. Assuming the collision object is a passenger car, then the width is known and the relevant data can be derived.
Also knowing the type of the collision object by classification helps to prepare the restraint systems accordingly.
Regarding the necessary field of view for PreSet, an opening angle of 40° is also a good choice. Once again, 100% of the fatal accidents can be addressed by selecting this opening angle, and almost 95% of the badly injured people (see Table 2).

Table 2.
Relevant cases of crashes covered according to field of view

Cases in the range of the field of view

	unviolated	slightly injured	badly injured	fatal
± 10°	73,3%	75,0%	86,3%	94,1%
± 20°	81,9%	88,0%	94,8%	100,0%
± 30°	88,4%	92,3%	97,2%	100,0%
± 40°	92,6%	96,3%	98,2%	100,0%
± 50°	95,1%	98,1%	99,1%	100,0%
± 60°	96,3%	98,7%	99,6%	100,0%

If the mono video deliver offset/overlap information in the required quality the algorithmic thresholds can be modified to recognize an offset-crash earlier (see fig. 6).

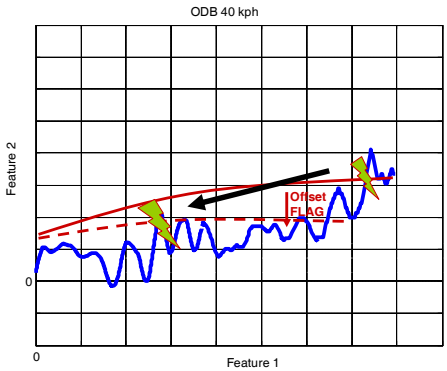

Figure 6. Active principle of a threshold modification in case of offset-information

If the mono video deliver a reliable classification of the object it is possible to make a first estimation of the mass and stiffness of the collision object. With this information it is possible to modify the algorithmic thresholds in the same manner as shown above. In this case the modification is done for all crash types.
If the surround sensor allows getting additionally closing velocity and time to impact in the required quality, then it is possible to prosecute a complete approach in dependency of the expected crash severity.

Video-based PreFire

The name PreFire stands for **Pre**Crash **Fi**ring of **re**versible restraints. The main functionality is preconditioning of the occupant before the crash happens. Because under real driving conditions, the occupants of a vehicle are in many cases not in the optimal position for the best protection offered by today's restraint systems.
For this function it is necessary to get high quality information about the distance and the closing velocity of the objects, preferential to reduce possible faulty activations. If the sensor delivers additional offset and overlap information about the objects the number of inadvertent activations could be reduced significantly.

Challenges And Chances Of Future Systems

On the bases of the already mentioned functions it appears that these functions have different requirements for using surround sensor information. All in all the passive safety systems will adjust their functions on the following information:

- Closing velocity
- Time to impact
- Offset, overlap
- Impact angle
- Contour (point of impact)
- Mass / stiffness of participant

With these attributes on the interface the passive safety is well prepared for the future to enhance the protection of the system. It is evident that the surround sensors could not deliver all information in the best quality. For example, currently there is no existing surround sensor who delivers exact data about the mass and stiffness of an object, but in future C2X-information can complete this. The challenge here is to use the transmitted information in the best possible way.
In the future two trends can be seen in the market: On the one hand, the trend for further networking with existing surround sensors (see also [6], [7]) and on the other hand, developing specialized surround sensors for passive safety. These specialized sensors have to fulfill the high requirements of passive safety more exactly for

further improvement of the passenger protection. Such sensors then allow the use of information for example for new functions like PreAct or PreTrigger. The function PreAct – **Pre**Crash **Act**ivation of structure elements – will modify the stiffness of structure elements of the vehicle before the crash happens. The advantage here is to use an additional control element for further optimizations of the crash choreography or further pedestrian protection. The modification of the front structure provides potential for weight reduction with equal safety for the occupant. This will have positive effects on CO_2 reduction. The function PreTrigger – **Pre**Crash **Trigger**ing of irreversible restraints – will activate new irreversible restraints (e.g. smart airbags [8]) even before the crash contact. This new functions will require high quality of the information from the surround sensors or C2X communication in a high data rate.

CONCLUSIONS

New functions for driver assistance like Adaptive Cruise Control, Lane Departure Warning, Road Sign Recognition etc. use many different surround sensors to process the information about the vehicle's environment. This information can be used to enhance the classical passive safety functions. When looking at the requirements of such functions, it shows up that the sensor field of view is suitable for a wide range of addressable accidents. Considering the required latency times, update rates and accuracy, it comes out that these numbers are often not met by current surround sensors for driver assistance functions.
To reach all theses requirements for passive safety functions, the sensor performance still needs to be improved. This will be a chance to enhance the protection of passengers and pedestrians.

REFERENCES

[1] IRTAD: International Road Traffic and Accident Database

[2] Bunse, M., A. Kuttenberger and M. Theisen. "PreCrash Sensing By Use Of A Radar-based Surround Sensing System." 6th International Symposium and Exhibition on Sophisticated Car Occupant Safety Systems, airbag2002, Karlsruhe, Germany, Dec. 2 - 4.

[3] Scheunert, D. "Potential of Pre-Crash Sensing compared to Conventional Sensing." Car Training Institute Forum "Pre – Crash – Sensorik im Automobil", 2008, Munich, Germany, April 22.

[4] Tiemann, N., W. Branz, D. Schramm "Predictive Pedestrian Protection – Sensor requirements an risk assessment", 21st International Technical Conference on the Enhanced Safety of Vehicle, 2009, Stuttgart, Germany, June 15 - 18

[5] GIDAS: German IN-Depth Accident Study

[6] Gollewski, T. "Integrale Sicherheit – Herausforderungen, aktuelle Funktions- und Auslegungskonzepte aus Sicht eines OEM" IntegratedSafety 2008, Hanau-Steinheim, Germany, July 2 – 3.

[7] Frickenstein, E. "The Next Milestones of Vehicle Safety", 9th International Symposium and Exhibition on Sophisticated Car Occupant Safety Systems, airbag2008, Karlsruhe, Germany, Dec. 1-3.

[8] Wohllebe, T. , M. Gonter and M. Meinecke "Potential of PreCrash Restraints in Frontal Collision " 8th International Symposium and Exhibition on Sophisticated Car Occupant Safety Systems, airbag2006, Karlsruhe, Germany, Dec. 4-6.