INTELLIGENT SAFETY SYSTEMS INTEGRATING ACTIVE AND PASSIVE SAFETY

Ronald de Lange[1], Joachim Tandler[2]
[1]TNO Science & Industry, Business Unit Automotive, P.O.Box 756, 5700 AT Helmond, The Netherlands
[2]Siemens VDO Automotive AG, Peter-Donier-Str. 10, 88131 Lindau, Germany

ABSTRACT

Side crashes occur relatively often and the injury risk in a side crash is higher than in a frontal crash due to the small distance between the occupant and the impacting object. For the same reason, little time is available for optimal deployment of collision mitigation measures using in-crash detection technology. This was identified as an area for further research in the EU funded project APROSYS, which aims to increase the safety of road users. In Sub Project 6 "Intelligent Safety Systems" a novel pre-crash side protection system is being developed and verified integrating both active and passive safety. Environmental pre-crash sensors define the actuators states to mitigate the consequences of the crash. Stereo video and short-range radar were selected for the sensing system. The actuator system, developed to minimize door intrusion and intrusion velocity, uses shape-memory-alloys, is reversible and can be activated almost as fast as pyrotechnical devices. Prototypes for both the sensing and actuator systems have already been built and are currently being evaluated, showing the potential of the combination of these advanced technologies in an integrated side impact protection system.

Keywords: SIDE IMPACTS, INTEGRATED SAFETY, SENSORS, ACTUATORS, APROSYS

THE IMPORTANCE OF improved protection of occupants in road accidents is obvious. Table 1 provides an overview of the relative frequency of occurrence of the different crash types using information on road accidents from the National Highway Traffic Safety Administration (NHTSA, US) accident database and from the European Accident Causation Survey (EACS) database. Because of the low level of detail in the US statistics only general situations are described.

Table 1. General accident statistics

Accident types	US data [%]	EACS data [%]
Frontal / Rear end	28	28
Side	32	41
Pole / Object (some are side impact)	11	8
Rollover	9	4
Others	20	19

As indicated by Table 1 side crashes occur relatively often compared with the other crash modes. Although the EACS database is relatively small (only about 2000 accidents) for drawing general conclusions on European accident situations, it can be seen that both the sum of frontal and rear-end crashes and side crashes are major issues. In addition, it is generally known that the injury risk in side crashes is higher, mainly due to a small distance between the occupants and the impacting vehicle. For this reason, timely deployment of collision mitigation measures, like side airbags, is difficult using existing in-crash sensing technology.

Intelligent pre-crash safety systems consist of environmental sensors, decision algorithms and actuators. The sensors can detect dangerous situations as potential collisions between the host vehicle and other road users or obstacles, before the impact has occurred. If the decision algorithm decides that the crash is unavoidable it will fire the actuators with a reduced injury risk to the car occupants as a result. One of the main advantages is that due to the detection prior to a crash, there is more time to take effective measures for improved occupant protection.

In the European funded Integrated Project on Advanced PROtection SYStems (APROSYS; Wismans & Kellendonk, 2006) Sub Project 6 (SP6) addresses this technology gap and develops a suitable integrated pre-crash side impact protection system using environmental sensors and in-vehicle actuators. Other European funded projects, like PReVENT mainly address sensing technology for the detection of frontal impacts prior to the collision. The main objective of SP6 is to develop a technology showcase of a combination of different advanced technologies for further crashworthiness improvement. SP6 pursues this goal by developing a concrete intelligent safety system. Knowledge of state-of-the-art technologies, advanced methods and design tools has been applied to implement and evaluate the intelligent safety system.

In the next section, a brief overview of the project structure will be given and the main achievements so far are detailed.

APROSYS SP6

In the first phase of the project, the system concept was developed. For the development of the advanced pre-crash side impact protection system, first a detailed accident analysis was performed. In addition, driver reaction during side crashes was investigated in a driver simulator study. The results of these studies were used to develop the system specifications (in terms of sensor field of view, optimal sensor locations, type of actuators). Various concept systems were evaluated and based on the outcome a specific sensing and actuator system has been developed including the system architecture, sensor fusion, collision probability and decision algorithms.

The sensor and actuator systems and the decision logic are currently integrated into several experimental setups. The performance of the sensing system and the actuator system has been evaluated at several stages. In addition, a complete system evaluation is being performed. The evaluation for the pre-crash and crash performance has been largely based on the methodology developed by APROSYS Work Package1.3 (WP1.3; Eggers & de Lange, 2006). Within WP1.3, a generic evaluation methodology has been developed for the evaluation of advanced safety systems. Accident and/or traffic scenarios are used to develop system specific test conditions for the assessment of the pre-crash and crash performance and, if necessary, the driver-in-the-loop behaviour.

SYSTEM DEVELOPMENT

RELEVANT ACCIDENT SCENARIOS: Based on the first general analysis shown in Table 1 a more detailed analysis has been performed using the EACS accident database to derive the most relevant accident scenarios in more detail. All vehicle to vehicle side-impact crashes in the EACS database have been taken into account. Fig. 1 and Table 2 show which impact configurations are most frequently occurring in side-impact. The frequency is related to number of accidents, injuries and fatalities. The separation is in 30 degree steps.

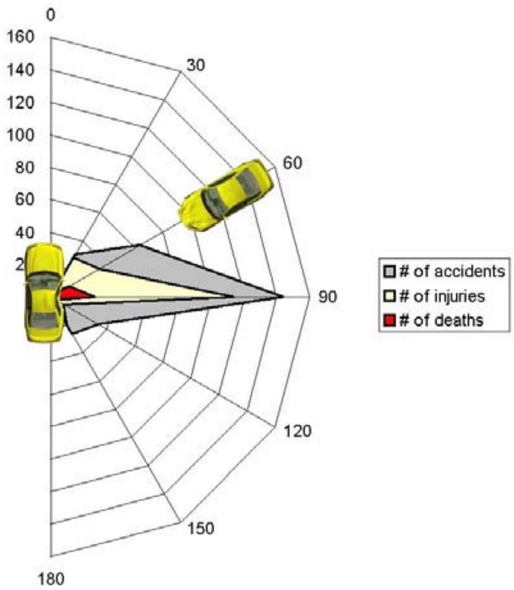


Fig. 1 - Impact angle versus number of injuries and deaths

Table 2. Impact angle and severity

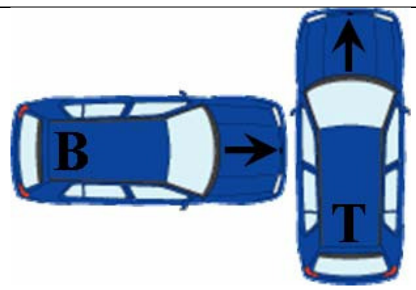
Angle between Vehicles	**Accid.**	**Deaths**	**Injuries**
15-45 degrees (front-side)	10%	6%	14%
45-75 degrees (side-front)	21%	27%	17%
75-105 degrees (side)	48%	55%	55%
105-135 degrees (side-rear)	11%	8%	4%
135-165 degrees (rear-side)	9%	4%	9%

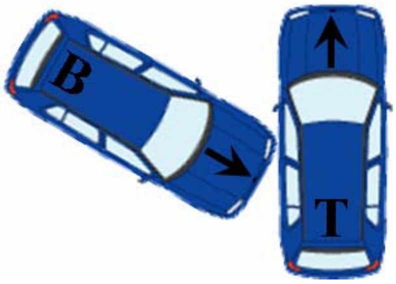
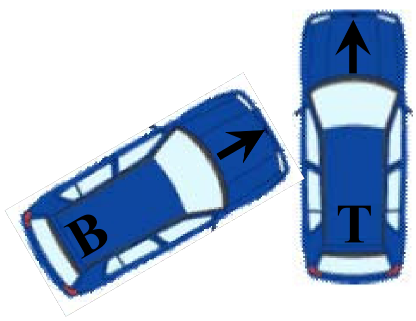
As shown in Fig. 1 and Table 2, the most common impact angle is 90 degrees (perpendicular), covering around half of all side impact vehicle to vehicle crashes. This case also results in severe accidents, as can be seen from the relative numbers of fatalities and injuries. For the other impact angles the amount of cases is significantly lower, with about 30 percent being more forward than the perpendicular case and about 20 percent being more rearward than the perpendicular case. Comparing the fatalities and injuries for the forward crashes (front-side and side-front) with the rearward crashes (side-rear and rear-side), it is observed that in the more frontal crashes the fatality rate and injury rate is significantly higher.

Additional to the impact angles the impact velocities of both the target and the bullet vehicle have been analysed. Mass and geometry have not been derived from the EACS database. Although the effect the mass has on the severity of the accident is expected to be significant, it was decided that both the actuator and the sensing system should be able to cope with vehicles of different size and mass.

According to the WP1.3 methodology, four scenarios were selected from the accident analysis representing the most frequent and dangerous side-impact situations on the road. The selected scenarios can be seen in Table 3.

Table 3. The most relevant accident scenarios

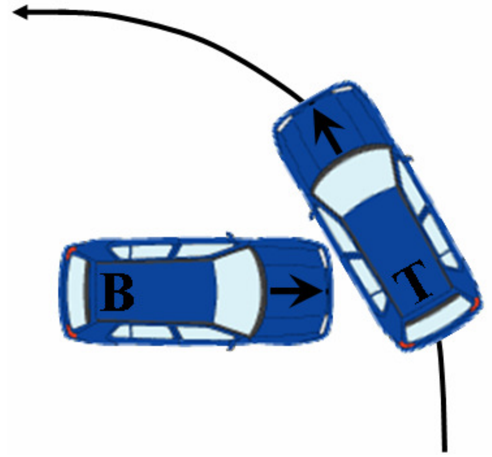
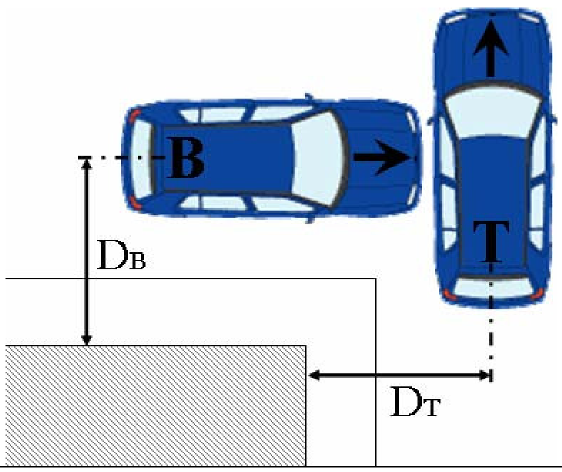
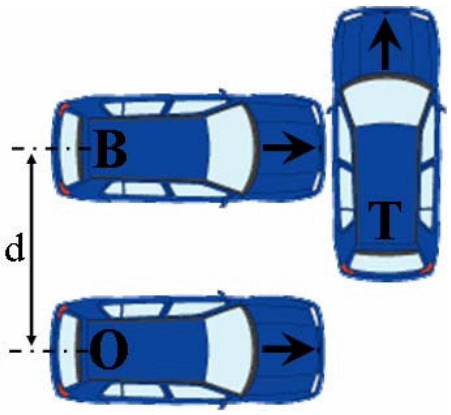
Scenario	**Type**[1)]	**Parameters**		
1		**Impact angle [degrees]** [2)]		90 ± 15
		Velocity [km/h]	**Bullet**	50 ± 20
			Target	30 + 25 / -15
		Relevance [%]	**Fatalities**	55
			Injuries	55

	90 degree impact			
2	 60 degree impact	**Impact angle [degrees]** [2)]		60 ± 15
		Velocity [km/h]	**Bullet**	60 ± 15
			Target	50 ± 10
		Relevance [%]	**Fatalities**	27
			Injuries	17
3	 30 degree impact	**Impact angle [degrees]** [2)]		30
		Velocity [km/h]	**Bullet**	52
			Target	36
		Relevance [%]	**Fatalities**	6
			Injuries	14
4	 120 degree impact	**Impact angle [degrees]** [2)]		120
		Velocity [km/h]	**Bullet**	59
			Target	30
		Relevance [%]	**Fatalities**	8
			Injuries	4

[1)] B = bullet vehicle; T = target vehicle.
[2)] Relative orientation of vehicles at time of first contact.

The four scenarios shown in Table 3 reflect quite precisely what is known from accident statistics. However, it is clear that these scenarios are a simplification from the real traffic environment (as there is no information on the involvement of other objects like vehicles, trees, lamp-posts, walls). Although it is almost impossible to obtain representative information about the "typical" traffic environment of side collisions, the environment is relevant for the performance of the sensing system. Therefore "expert knowledge" has been used to define several more complicated scenarios, which are considered to be typical and expected to be more challenging for the sensing system. The relevance of these additional scenarios cannot be extracted from the accident data, due to a lack of detail in the currently used accident databases. The three additional scenarios are shown in Table 4.

Table 4. The three additional scenarios

Scenario	Type[1]	Description
5		In Scenario 5, the target vehicle makes a left turn, while the bullet vehicle enters from left. This scenario has been selected to evaluate the performance of the safety system during non-straight movements such as cornering. Other parameters are based on Scenario 2. Although the pre-crash paths are different, the impact conditions are similar.
6		Scenario 6 is similar to the 90 degrees impact scenario, but with obstruction of view. This scenario has been selected to evaluate the system performance in case of obstruction of view. Other parameters are based on Scenario 1. Although the pre-crash conditions are different, the impact conditions are similar.
7		Scenario 7 is similar to the 90 degree impact scenario, however two vehicles are coming from right. The first vehicle will hit the target vehicle in the middle, the second vehicle will pass behind the target vehicle. This scenario has been selected to evaluate the multi target capability of the safety system. Other parameters are based on Scenario 1. Although the pre-crash conditions are different, the impact conditions are similar.

[1] B = bullet vehicle; T = target vehicle; O = vehicle causing obstruction of view; DB = lateral distance between bullet vehicle and wall; DT = lateral distance between target vehicle and wall; d = lateral distance between bullet vehicle and vehicle causing obstruction of view.

The scenarios defined in Table 3 and Table 4 are used as the basis for the development and evaluation of the pre-crash side impact protection system.

To identify changes in the position and posture of front seat occupants that occur in a pre-crash environment a driver simulator study was performed (Matusiak *et al.*, 2005).

Appropriate recognition and definition of the driver reactions were thought to be useful for designing the pre-crash sensors to improve safety systems and to reduce the effect of out-of-position situations. Two test series were performed with different traffic scenarios, with in both cases a sudden appearance of the car driving from a perpendicular direction to the test car. The drivers could not avoid the collision in these tests, because they could notice the bullet car only about 6 meters before the crash designed location. Human reactions were recorded with the use of surface electromyography (EMG) by electrodes placed on the upper limbs. The simulated impact velocity, time of crash, time and angle of steering wheel rotation, initiation of braking and overall body motions were recorded.

In total 64 cases of simulated driving were analysed showing that, despite a variation in reaction, an unexpected traffic situation caused additional muscle activity in most cases. This can result from muscle contraction as reaction to stress or contraction caused by upper limb movements. As listed in Matusiak *et al.* (2005) the following reactions were be observed:

- in 23 % of tests (15 of 64) – no reactions;
- in 34 % of tests (22 of 64) – no upper body movements reaction, in 68% of them (15 of 22) the muscles contraction as the typical “fear” reaction was observed;
- in 50 % of tests (32 of 64) – turning steering wheel, in 73% of them (22 of 30) the reaction was commenced before the crash;
- in 25 % of tests (16 of 64) – backward movements of upper body was observed;
- in 3 % of tests (2 of 64) – forward movements of head and upper body was observed;
- in 15 % of tests (9 of 62) – the volunteer started braking before the crash;

The relatively high percentage (57 %) of ‘no reaction / no movement’ cases shows that even with reasonable low speed driving (around 50 km/h) often drivers do not take action in situations leading to side crashes. This indicates the need for an intelligent sensor system that is able to detect side collisions and activate all available safety systems.

SENSOR SPECIFICATION: The defined accident scenarios were used to develop the specifications for the sideward looking sensing system. Parametric studies were performed to identify the optimal sensor set-up, the best sensor location and the required field of view (opening angle, range and orientation). Examples of sensor set-ups that were reviewed are given in Fig. 2. The different setups were evaluated using among others the PreScan software, which is a numerical simulation environment for the design and evaluation of the vehicles equipped with environmental sensors to make road traffic safer. Within PreScan a vehicle can actually sense its surroundings and – based on the decision algorithms implemented – react to it. Typical detection systems that can be used range from radar, lidar and stereo vision, to car-2-car and car-2-infrastructure communication systems. For the numerical evaluation of the sensor set-up, generic sensor models were used, allowing variation of the parameters in a simple and effective way.

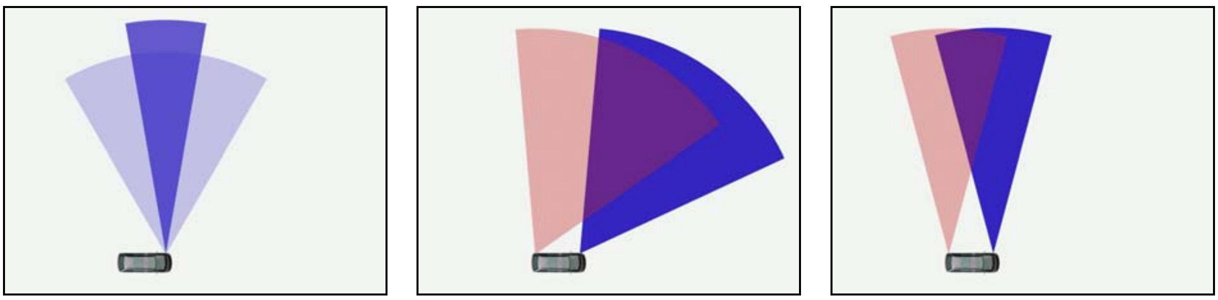


Fig. 2 – Examples of different sensor concepts

For the given parameter ranges of the scenarios, a parametric study yielded the required field of view of the sensors. A detection range of 20 m was found to be sufficient to build up reliable tracks early enough before the crash. Likewise, an angular coverage of 80° was obtained, directed to the front/side of a car.

SENSING SYSTEM: The proposed side pre-crash sensor system that meets the requirements consists of a visible light stereo camera subsystem and two 24 GHz short range radar sensors. The sensing system covers ranges of some 10 cm up to about 20 m. The sensor locations and their field of view of the resulting sensor system can be seen in Fig. 3.

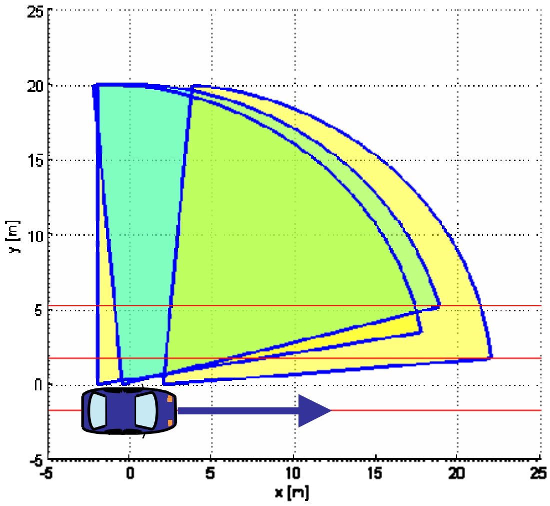
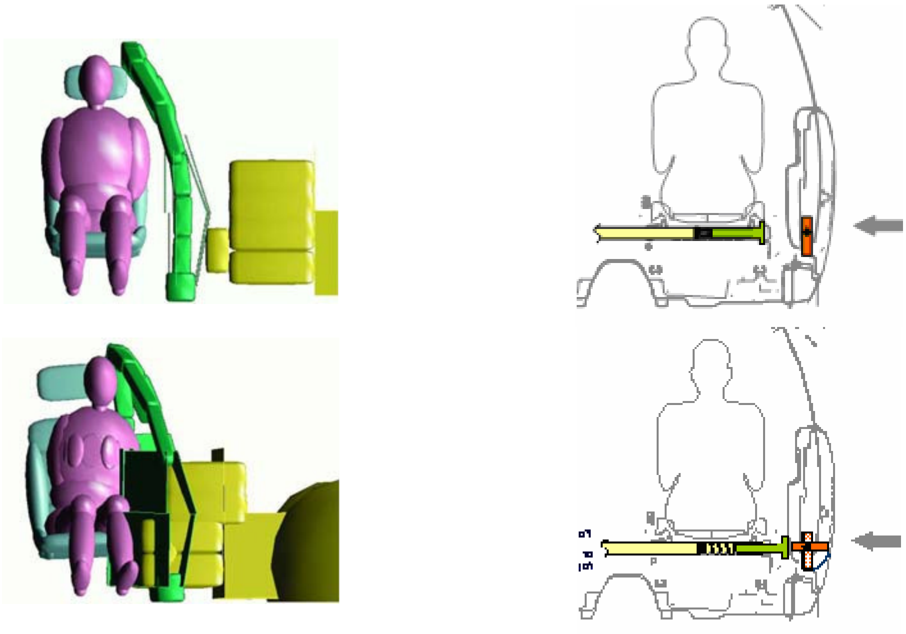


Fig. 3 - The field of view of the two radar sensors (yellow) and the video system (green)

The system senses the side area of the car and tracks approaching objects. Both the video and radar sensors have specific strengths which are complementary to each other. To combine the advantages of both sensors and provide position and speed information of approaching objects the data from both sensor types is fused. In addition, vehicle information as for instance vehicle speed and yaw rate is used via the vehicle CAN-bus to estimate the ego motion of the vehicle.

ACTUATOR SYSTEM: The detailed information from the sensing system enables the decision module to trigger the actuator system depending on crash parameters such as velocity and type of an incoming object. The objective of the actuator system is to reduce intrusion and intrusion velocity into the passenger compartment in order to give other devices, as for instance a curtain airbag, more time and space to react.

Using multibody simulations, several actuator concepts were analysed including e.g. driver seat repositioning and increasing the side door and B-pillar structural stiffness (Ambrósio, 2005) (See Fig. 4a).



(a) (b)

Fig. 4 - Multi-body simulations of the actuator concept (a) and the actuator concept (b)

These concept simulations together with the analysis of full scale crash tests, showing a possible collapse of the A-pillar, revealed that adding structural stiffness directly to the door was the most promising concept. Generic FE simulations were performed to identify optimal load paths. Based on the simulation results the actuator concept was developed as shown in Fig. 4b.

While conventional in-crash sensing techniques can achieve a false alarm rate of virtually zero, pre-crash sensing is inherently more difficult. Hence, the actuator triggered by pre-crash sensors was chosen to be reversible to tolerate a non-zero false alarm rate. However, the actuator must be fast enough to allow a deployment within a limited time (preferably < 200 ms) before the crash. Table 5 lists the candidate technologies that were reviewed and their properties.

Table 5. Three actuator technologies and properties crucial for the application

	Pyro-technical	**Smart materials**	**Electro-magnetic**
Deployment time	~30 ms	~50 ms	> 200 ms
Reversible	No	Yes	Yes

Pyrotechnical devices like airbags are non-reversible. Electromagnetic devices like relays need too much time to be deployed. New promising technologies, which fulfil both requirements, are smart materials like shape-memory-alloys (SMA) or piezo-ceramics. By heating the SMA, the material shows the so-called shape memory effect and changes from a deformed shape to the initial shape (see Fig. 5).

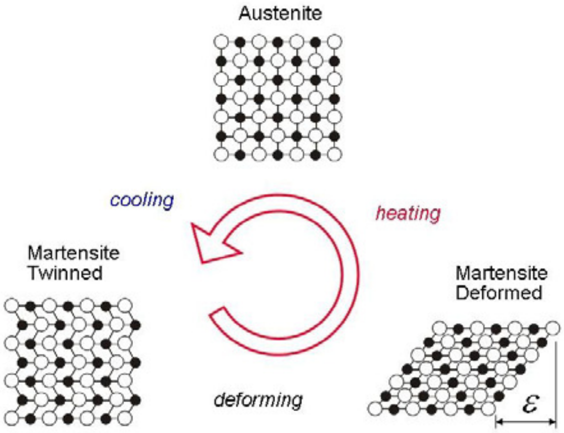


Fig. 5 – Crystal structure at the different conditions of a Shape Memory Alloy

Within APROSYS SP6, an actuator was developed using small release elements of a Nickel-Titanium SMA that can be thermally activated by an electric current. The activation of the SMA's does initiate the moving of a bolt. By this bolt it is possible to selectively connect the door with the seat structure. Thus the crash energy can be directed to normally uninvolved areas of the car structure via additional load paths (see Fig. 4b). The actuator was optimised to cope with automotive requirements, like integration into the compartment and the use of 12V. Finally its timing properties have been verified.

To find optimal dimensions and positions of the actuator, detailed FE crash simulation studies were performed. The selected designs will be realised and tested both physically and virtually, to demonstrate the reduction of intrusion and intrusion velocity.

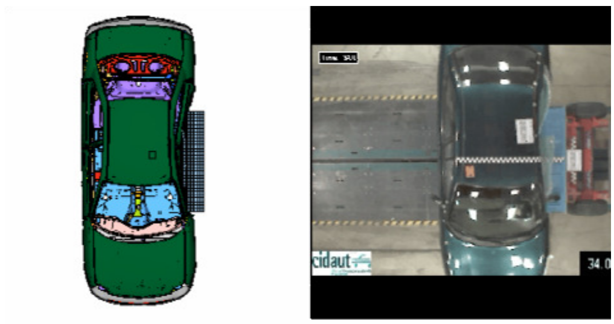


Fig. 6 – A detailed FE simulation of a Euro NCAP side impact

SYSTEM INTEGRATION: When the development of the sensing and actuator system was consolidated, the decision strategy has been fixed and implemented. Using the object information from the sensors, the ego motion and the possible manoeuvres the crash probability and the time-to-collision (TTC) are calculated. The calculated crash probability and the TTC are compared with threshold values and the decision for activation of the actuators is taken. The decision module decides adaptively, if and in which configuration the actuator system is deployed prior to a crash. The module supplies the actuator system with the actuator activation (fire) trigger latest at 200 ms in advance to a crash. Optional, following triggers can be supplied:

- actuator preparation trigger at 400 ms before a crash;
- cancellation of activation at 100 ms before a crash.

SYSTEM EVALUATION: The sensor and actuator systems and decision logic are currently integrated into several experimental setups. The performance of the sensing system and the performance of the actuator system have been evaluated at several stages. In addition, a complete system evaluation will be performed, largely based on the methodology developed by APROSYS Work Package1.3. Within WP1.3, a generic evaluation methodology has been developed for the evaluation of advanced safety systems (Eggers & de Lange, 2006). This end user oriented evaluation methodology is characterised by a partitioning of the holistic evaluation process into the following assessment clusters:

- pre-crash performance;
- crash performance;
- driver-in-the-loop performance (influence of the driver);
- normal driving performance.

For the different assessment clusters, accident and/or traffic scenarios are used to develop system specific test conditions resulting in a test plan for the assessment of the pre-crash and the crash performance and, if necessary, the driver-in-the-loop behaviour.

Pre-crash performance tests: Pre-crash tests have to be done to assess the performance of the sensing system and decision algorithm. Test conditions are derived from the seven scenarios shown in Table 3 and Table 4, taking into account the possible limitations from the test facility and the implications on the expected system effectiveness. This could for instance limit the maximum velocity in the test. It should be noted that performance characterization of sensor systems is based on statistical measures. For this reason a number of scenarios must be run through repeatedly and tests need to be non-destructive.

The theoretical assessment criterion is the required system-in-function time, which is the time needed for a full deployment of the system. As for the pre-crash side impact protection system the actuators should be in position at the moment the impact starts, the required system-in-function time is equal to the start of the collision. If the time is expressed as a time-to-collision (TTC), with a TTC = 0 at the start of the impact, the required system-in-function time can be specified as:

$$T_{system} = T_{trigger} + T_{actuator}$$

With:

- T_{system} = total system-in-function time;
- $T_{trigger}$ = time the trigger signal is given to the actuator;
- $T_{actuator}$ = time needed to activate the actuator.

Since in SP6 the vehicle is in a prototypical stage, the system-in-function time is difficult to measure accurately, the actuator trigger time ($T_{trigger}$) is obtained via the vehicle CAN system. The maximum activation time of the actuator is specified to be 200 ms, thus the trigger time should be at least 200 ms before the start of the impact (TTC $\geq$ 200 ms). Based on the above definitions, tests are:

- Passed if the trigger time is $\geq$ 200 ms TTC;
- Failed if the trigger time is < 200 ms TTC or if there is no trigger at all.

A first series of non-destructive evaluation tests has been performed. During these tests, the experimental vehicle was stationary and an object representing a small vehicle was approaching the experimental vehicle (see Fig. 7).

Fig. 7 – Preliminary pre-crash performance tests

The object was stopped before the impact with the experimental vehicle such that TTC was well below 200 ms. Initial conditions as the orientation of both the experimental vehicle and the object, relative velocity and approaching angle were chosen such that the tests represented the scenarios provided in Table 3. Laboratory data was logged synchronously with the vehicle data to be able to calculate the exact actuator trigger time.

<u>Crash performance tests:</u> The crash test to assess the performance of the safety system in the vehicle was chosen to be the Euro NCAP side impact test. The test set-up can be seen in Fig. 8. A trolley fitted with a deformable front is towed into the driver's side of the car to simulate a side-on crash. The impact is targeted at the R-point[1] of the vehicle under test. Impact takes place at 90 degrees (pure lateral impact) and at 50 km/h. The assessment criteria are the maximum intrusion and maximum intrusion velocity.

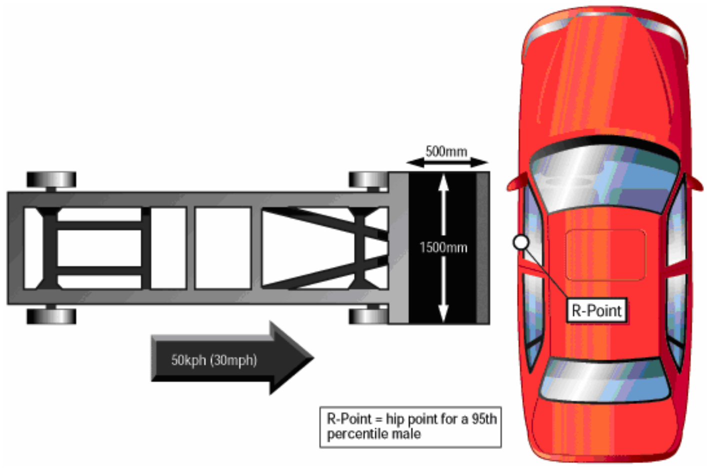


Fig. 8 - The Euro NCAP side impact crash test

During the development of the sensing system, a series of tests have been performed to ensure a good performance of the sensor system in this test set-up. These tests have been performed at a number of different trolley velocities ranging from 10 to 55 km/h. Instead of the full vehicle a specially designed test rig was used to allow for non-destructive testing with both the radar and the video sensing systems mounted at the correct locations.

[1] The R-point is defined as the point where the hip of the 95^{th} percentile male is located.

Driver-in-the-loop performance tests: As the system performance is not significantly influenced by the behaviour of the driver nor the driver is expected to be strongly influenced or distracted by the system function, no driver-in-the-loop performance tests are performed.

Normal driving performance tests: Separate from the pre-crash and crash tests, track tests and field tests are performed. These tests provide relevant information about the performance of the system in typical traffic conditions and in a realistic traffic environment.

Track tests are performed to evaluate the sensor performance in specific traffic situations. These situations are non-accidents, but are considered as typical traffic scenarios that are challenging for the sensor system in terms of distinguishing an accident from a non-accident.

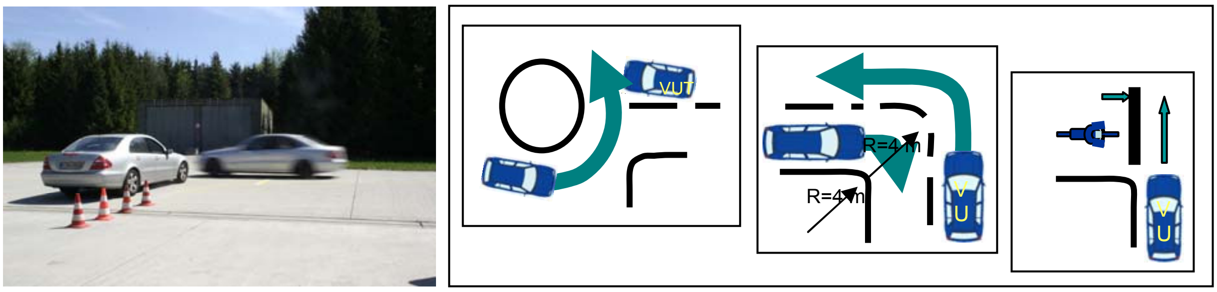


Fig. 9 – Some typical traffic scenarios evaluated by the track tests

The evaluated scenarios are straight road scenarios, crossing scenarios and roundabout scenarios. Some typical examples are shown in Fig. 9. The track tests provide information about the maturity of the system and false alarm rate (the system activates, but shouldn't) related to specific traffic scenarios

Field tests are performed to evaluate sensor performance under normal driving conditions. An 'Around Swiss' route through France, Italy and Germany was selected for the field tests. This route of approximately 2000 km in total comprises different road types, different driving situations and different traffic conditions. Similar to the track tests the false alarms are monitored. If possible these alarms will be related to specific traffic situations or scenarios. The weather conditions during the field test will be reported.

DISCUSSION

For the development and evaluation of systems using environmental sensors, information on pre-crash motion is thought to be valuable. During the definition of the relevant scenarios it was seen that data on what occurs prior to the accident is largely unavailable. The EACS database has some information on pre-crash motion. Fig. 10 shows the effect of the average change speed prior to the accident, for a TTC of 0, 1 and 2 s. This figure indicates that in general the speed prior to the accident is higher than at the moment of impact. However, it has to be noted that the accuracy is limited due to the small amount of pre-crash information available.

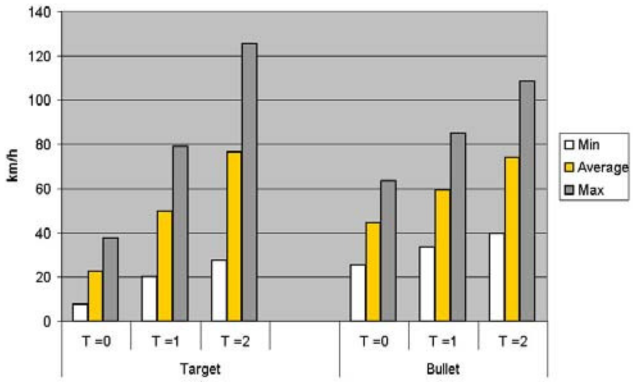


Fig. 10 – Velocity of the target and the bullet vehicle versus TTC

New initiatives as for instance SafetyNet (Thomas, 2004) do include more and more pre-crash information, existing accident databases contain only very limited information on pre-crash motion.

Within APROSYS SP6 it was chosen to develop a pre-crash side impact protection system. As the side looking application is relatively new, it imposes new challenges to both the radar and the video subsystem. E.g. phases of the radar sensor antennas had to be adjusted to achieve the required field of view. Furthermore, the system has to cope with large azimuth velocities, when a potential bullet vehicle just passes by the sensor host vehicle. Also the video system does not have the point of expansion of the ego motion in the acquired images (Metzler *et al.*, 2006). These issues were experimentally assessed and appropriate solutions were investigated. During the development of the sensing system special attention was paid to:

- high level fusion of object track data from image and radar processing subsystems;
- correct and fast detection of approaching objects;
- object tracking down to extremely low distances of about 10 cm.

Despite the fact that the environmental sensing techniques are relatively young within the automotive field, the use of environmental sensors offers extended possibilities not only for detection of a possible collision, but also to better estimate the type and severity of the collision. Based on this information, advanced integrated safety systems could use this information for optimisation of the available restraint systems towards the real world conditions for that specific impact. The APROSYS SP6 system is developed to reduce the intrusion and intrusion velocity into the passenger compartment to give other protective devices more time and space to react. As such this system is a good example of an integrated safety system using both active and passive safety measures to increase protection.

Currently the possibilities of systems with environmental sensors are being explored for improved protection of the occupants as well as vulnerable road users. In order to ensure a good performance of these systems under different real world conditions a lot of effort is put into the development of methods for the evaluation of these advanced safety systems. The method used by APROSYS SP6 for the evaluation of the system has been developed in APROSYS WP1.3. As this method has become available only recently, the test results generated with the evaluation of the pre-crash side impact protection system will also be used to evaluate the applicability of this a methodology.

The evaluation of the pre-crash performance of the sensing system in a controlled environment is found to be a challenge. After a first series of tests, the development of a more suitable test set-up for the evaluation of the sensing system is ongoing within APROSYS SP6. This clearly indicates the need for further research and development of dedicated test tools for the evaluation of integrated safety systems.

CONCLUSIONS

APROSYS SP 6 develops an integrated side impact protection system with the aim to develop generic methods and tools for the design and evaluation of pre-crash systems. The sensing system consists of a visible light stereo camera and a 24 GHz short range radar system. The data of the various sensors are combined in a fusion step and a decision module decides adaptively, if and in which configuration the actuator system is deployed prior to a crash.

Shape-memory-alloys are applied within the actuators to meet the demanding timing requirements while maintaining reversibility. Multibody and FE simulations are used for concept choosing, development verification and evaluation.

Currently the actuator and sensor system are tested and integrated into experimental vehicles. Finally, the feasibility of the applied technologies is evaluated by the assessment of the pre-crash performance of the sensing system, the crash performance and the normal driving performance. For this evaluation, the generic evaluation method as developed within APROSYS WP1.3 is used.

As a general outlook, an increasing number of active and passive safety features is implemented in modern road vehicles. To use the full safety potential of both the active and passive safety features, there will be a growing demand for an intelligent integration of both.

ACKNOWLEDGEMENTS

The support of the EC through project TIP3-CT-2004-506503 (APROSYS) was greatly appreciated. The work described here was performed within the APROSYS Sub Project 6 by the partners IST (Pt), Daimler-Chrysler (Ge), CIDAUT (Sp), Fraunhofer Gesellschaft LBF and IITB (Ge), Warsaw University of Technology (Pl), Faurecia (Fr), Siemens VDO (Ge) and TNO (Nl).

REFERENCES

Ambrósio, J., “Improved Protection of Vehicle Occupants in Side Impacts by Using Active Structural Devices”, Proceedings of the II International Conference on Computational Biomechanics, 2005, pp. 989-1002.

Eggers, A., de Lange, R., “Proposed Evaluation Methodology for Advanced Safety Systems”, Public APROSYS Deliverable D1.3.2, Document AP-SP13-0022, 2006.

Lange, R. de, “Proposal of generic procedures for an assessment of Pre-Crash systems”, Public APROSYS Deliverable D6.5.1 (Draft version), Document AP-SP65-0033, 2007.

Matusiak, K., Dziewoński, T., Lozia, Z., Guzek, M., “Assessment of driver’s and passengers behaviour when facing an imminent side crash”, 2005 IRCOBI Conference proceedings, 2005.

Metzler, J., Grinberg, M., Willersinn, D., “Asessment of the FOE for Side Impact Alert”, WIT, 2006.

Tandler, J., Preis, C., Willersinn, D., Grinnberg, M., “Side Pre-Crash System Specification”, Intelligent Vehicles Symposium 2006, 2006.

Thomas, P., “The New European Road Safety Observatory – SafetyNet”, 2004.

Wismans, J., Kellendonk, G., “Advances in European Passive Safety Research: The APROSYS Project”, FISITA World Automotive Congress, 2006.

Relevant internet sites:

European Integrated FP6 Project APROSYS: http://www.aprosys.com

European Integrated FP6 Project PReVENT: http://www.prevent-ip.org

PreScan software: http://www.prescan-tno.nl