特集：安全

33 Rear Vehicle Monitoring, an Award Winning Safety Function

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Summary

Passive safety technology has achieved a very high degree of perfection. In order to further reduce accidents, active safety technologies need to be introduced that avoid accidents rather than mitigate them. Mazda Motor Corporation (hence Mazda) follows this approach to make its products ever safer, aiming for zero accidents.

Mazda developed a safety function called Rear Vehicle Monitoring (hence RVM) that is able to assist the driver, warning him not only about invisible cars in the so-called blind spot of the vehicle, but also about cars that are approaching fast, leaving insufficient time for a safe lane change.

RVM has been presented to the Euro NCAP consortium and the Euro NCAP Advanced Award has been granted to Mazda for introducing RVM into most of its current passenger cars. This report describes the background of this technology and the way to the award.

1. Introduction

Lane change accidents happen frequently on multi lane roads, mainly insufficient observation of lanes and misjudgement of other vehicles' motion path cause them. Mazda developed Rear Vehicle Monitoring (RVM), a radar based technology that helps the driver detect vehicles in the blind spot and warns of fast approaching vehicles on the target lane.

2. European accident analysis as a trigger for safety development

2.1 Basic situation

Mazda has researched traffic situations and accident causation in order to find ways how to avoid accidents. High performance brake systems or electronic stability control systems are found nearly paramount in cars helping to stay in a safe state. Beyond these basic accident avoidance functions, Mazda searched for specific driving scenes that frequently trigger accidents and how safety functions could avoid them.

2.2 Lane changes as a critical driving manoeuvre

On multi lane roads a typical scene can be found: Vehicles approach slower vehicles ahead, face an ending or a blocked lane or merge in from other roads using special acceleration lanes.

In order to continue the journey, a lane change needs to be executed. This can only be done, if no vehicle is present laterally to the "ego-vehicle" on the target lane and there is no vehicle that will occupy to this space within a certain time.

In order to assure this, the driver of the ego-vehicle, aiming at change lane, needs to check the target lane by a view into the side mirror. However vehicles can be invisible in this mirror, if they are located in the so-called blind spot. Therefore the driver should always execute an over-the-shoulder view to confirm the vacant space. If vehicles are approaching from the rear, then the driver must decide, if

- a lane change still is possible, as the approaching car has sufficient time to safely react or
- the lane change should better not get executed in order to avoid a potentially dangerous situation.

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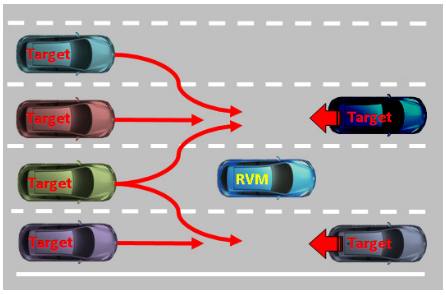

Fig.1 Different Critical Pathways to Enter Blind Spot Area

In parallel to this task, the driver must judge the traffic situation ahead: how much time is left until the lane ends or the car in front be reached.

The criticality of this situation rises with high speed differences of the rear approaching vehicle compared to the ego-vehicle and its speed difference to a vehicle in front or the distance to the end of lane ahead. In Europe high differential speeds occur on highways where passenger cars typically travel at 130km/h (in Germany partly unlimited). Trucks and merging traffic from other roads drive at 80 to 100km/h, so that a ΔV of up to 50km/h can occur frequently.

2.3 Accident causation research and expected effect of RVM to accident occurrence

In Europe various accident statistics on country and EU level exist that count the number of accidents and often assess the severity and causation. The most recent German official accident statistics of Destatis (1) from 2010 show that around 4.4% of accidents with injury happen laterally among cars that travel in the same direction. A *"German In-Depth Accident Study"* database called GIDAS (2) has analyzed about 20,000 accidents with injury in detail and with full reconstruction. GIDAS reports about 4.8% lateral accidents, the British Transport Research Lab (TRL) (3) about 5%. These values need to be corrected by some factors such as cars that did not pursue a lane change but e.g. lost control. Nevertheless it is important to work on these numbers in order to reduce fatality, injury and damage. By considering all factors available and using the GIDAS Database as the information source of highest accuracy, it is possible to extrapolate that annually about 560 lives could be saved in the EU through general introduction of RVM technology, 2,100 severe injury accidents and about 8,300 slight injury accidents could be avoided. The number of accidents with just damage are at least 2 magnitudes higher.

3. Describing the task

3.1 The process of a proper lane change and the task of avoiding its accidents

As already described above, lane change typically should start with a look into the mirror and over the shoulder. (4) In reality drivers often neglect the shoulder view based on carelessness, discomfort or age based physical impairment. This can lead to undetected vehicles in the blind spot area. Also it is reported that based on distraction or other mental occupation drivers look into the mirror or over the shoulder, but do not identify an approaching vehicle.(5) Even if a vehicle gets detected by the driver, the judgement of the relative speed difference can be very difficult, if the other vehicle is extremely fast, has a colour that contrasts little to the road environment (e.g. dark grey) or weather conditions like rain mask it.

The task of a safety device that supports to avoid lane change accidents can be described with the following statements:

- Vehicles in the blind spot area should be confirmed to the driver, even, if he does not detect them based on above mentioned reasons.
- Vehicles that will reach the lateral position to the ego-vehicle on the adjacent lane within a defined short time shall be notified as well.
- Should the driver of the ego-vehicle still indicate his lane change intention, then a warning should be placed, convincing the driver to abstain from lane change.

3.2 The critical area around the vehicle

The above described tasks imply the detection of vehicles in an area, left and right and behind of the vehicle. The blind spot area is depending on the driver seating position and the resulting side mirror aiming. To be sure to detect cars in all possible blind spot geometries, Mazda decided that the detection area should stretch longitudinally from the centre of front side window back to 10m behind the vehicle. The lateral detection should reach from the vehicle to a distance of 3.5m, covering also wide highway lanes. For defining the so-called closing area of approaching cars, the relative speeds of vehicles on different lanes and necessary reaction time for driver of the detected vehicle need to be considered. This lead to the understanding that this zone should stretch 50m behind the blind spot detection zone.

3.3 Detection and classification of issues preventing lane change

Not every vehicle being in the closing or blind spot area is a thread to the safety of the ego vehicle. It is necessary to further classify the target vehicles to judge, if a potential danger is existing. E.g. vehicles that are entering the closing area from rear with a very low differential speed (10km/h) need nearly 20s to progress from border of closing area to the blind spot area. Here a notification should be given to the driver of the ego vehicle, when a Time-To-Collision (TTC) of 5.5s is reached. This value has been developed based on extensive driver tests, considering reaction times, perception of urgency and its latency. However a vehicle entering the blind spot area of the ego-vehicle should always be notified from wherever it enters. Only if the vehicle has completely left this area, the notification can be cancelled.

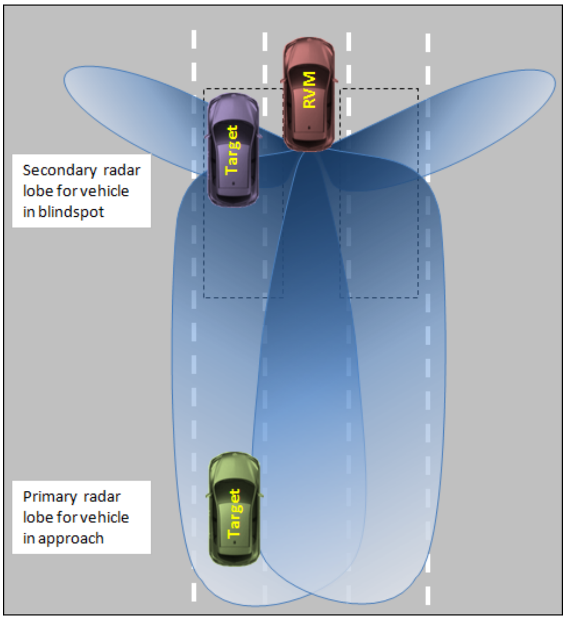

Fig.2 Radar Beam Forms and Vehicle Detection

3.4 Technical solution

In principle a detection of vehicles in the blind spot zone can be done by different sensor types such as camera systems. This has been shown already by some OEMs. Such technical solution shows insufficiencies in terms of weather robustness and especially the detection of vehicles in the closing area. A very robust sensor is a 24GHz short range radar. Mounted well protected behind the bumper fascia at the two rear vehicle corners allows to detect vehicles in the closing and blind spot area. The classification allows to distinguish stationary objects like road signs from moving objects and to analyze their location and relative speed very precisely. Weather influences the performance only very minor, so that a continuous operation can be achieved. The picture on the right shows the beam shapes of the radar sensors of the blue Mazda and the detected vehicles in the blind spot and approach zone.

4. The Human-Machine-Interface (HMI) Concept

4.1 Warning the driver

The HMI should not make the driver give up his checking of mirrors. (Misuse avoidance) Therefore the indication of a vehicle in blind spot area or closing with TTC<5.5s is notified by a LED light in both side mirror areas. This is far out of the primary area of vision so that the driver still needs to look into the mirror direction. In case the driver neglects the notification and sets turn signal for changing lane, an audible warning is given, to prevent action. Mazda followed by this a two step warning procedure using a warning indication based on SAE J 2802 with fast blinking lights for the imminent danger warning.

Fig.3 Indication of Car in Blindspot Area or Approaching to it

4.2 The HMI dilemma

Any lane change support device suffers one key issue: the knowledge about the actual driver intention. Drivers show their intention to change lane differently:

- drivers set the turn indicator to show their will to change lane and await a suitable "gap" on the target lane,
- others set the turn indicator, when the "gap" is present and notify the instant following lane change action,
- finally some drivers do not indicate lane change at all.

Mazda decided to change from notification to warning as soon as the driver sets the turn indicator. This leads to a safe warning of the majority of drivers. To assure that the driver recognizes the warning Mazda introduced a strong blinking of the notification LED and an audible buzzer. The later one (if notification LED and audible buzzer turn on at the same time) can be reduced in volume or switched off to avoid driver annoyance.

Therefore Mazda's RVM fully complies with ISO 17387 that specifies system requirements and test methods for Lane Change Decision Aid Systems (LCDAS).

4.3 Results from external research

Mazda reviewed research of field tests such as the Integrated Vehicle-Based Safety Systems Project (IVBSS) (6) among many others. The IVBSS used more than 100 non-professional testers in a naturalistic, 40 day driving test on vehicles that were equipped with different active safety systems, among them a RVM-type function. The review showed: 25% told they increased their turn signal use. 20% increased their general awareness and 13% had more awareness of the blind spot region. The RVM-type function was rated highest for satisfaction and usefulness in particular when changing lanes and merging into traffic. 7 drivers reported that a RVM-type warning they received prevented them from crashing during a lane change or merging into traffic.

Mazda could confirm similar effects during the prototype test phase done in various locations of the world.

5. The technical performance verification of RVM

5.1 Selection of test scenes

During the development verification tests were used to confirm the production readiness, detection effectiveness, but also the fault free function of RVM. Later tests were carried out with external partners that should neutrally confirm the performance of RVM. In Germany this was done together with BAST, the Federal Highway Research Institute.(7) 17 different scenarios were selected that cover almost all possible configurations for the approach of cars in a target lane in longitudinal and transversal direction with speed differences of up to 50km/h. They represent all typical accident scenarios for lateral accidents with lane change as stated in the GIDAS research. Examples are shown on the right. BAST measured the detection distance L, notifying timing accurateness (5.5s Time-To-Collision) and the possible influence on different turn signal setting timings by the driver. This should give evidence that the expected warn process of detecting a critical approach and warning to the driver should he intend to change lane, was achieved. A further important part was confirmation of the absence of potential false positive or negative detections.

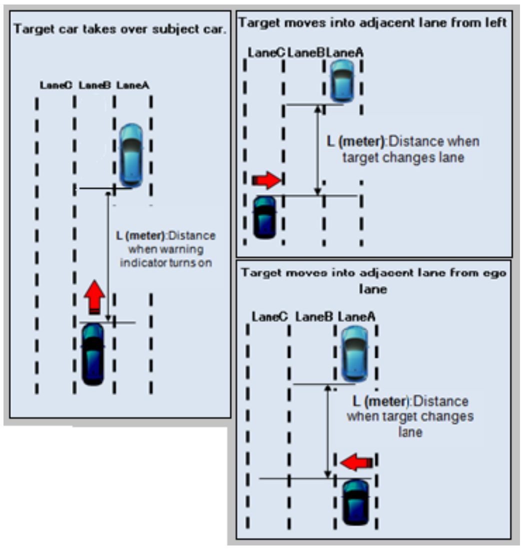

Fig.4 Examples of Test Scenarios for Critical Approach

5.2 Test Results

The test results showed that RVM is able to detect cars fault-free and at required precision within the designed areas. The calculation of the TTC was correct and the warning was issued timely independent of driver behaviour. False positive or negative detections were not present. This is very much in line with the results from the IVBSS project which had found that radar based RVM-type functions have the highest reliability.

6. The application to Euro NCAP Advanced Award

6.1 The application of Euro NCAP Advanced Award

In 2010 the Euro NCAP consortium had started to award automotive OEMs with a **Euro NCAP Advanced Award** for introducing advanced safety systems to the market without any legal obligation. As Mazda had successfully tested and deployed RVM throughout its core models, Mazda decided to apply for this award through developing a comprehensive application report.

6.2 The Award

On 23rd of September 2011 the Euro NCAP Advanced Award for Rear Vehicle Monitoring was handed out to Mazda during the Frankfurt Motor Show acknowledging Mazda's efforts to raise vehicle safety beyond the conventional levels through applying advanced technology.

Fig.5 The Euro NCAP Advanced Award

7. Future outlook to lane change assist systems

7.1 Intelligent detection and function

The next challenge in further improving RVM will be to detect the driver intention, even if the driver does not indicate his lane change wish by using the turn signal. This will only be possible by using additional information from other sensors. It will have another big impact on RVM effect.

Further RVM should distinguish the criticality of the situation in a more differentiated way. Doing a lane change, when a vehicle is already in the blind spot or the TTC is very short, should effect a different, stronger reaction of the vehicle.

Finally the driver of a car is facing the difficulty to judge, if e.g. he better performs a critical lane change or e.g. executes a hazard braking, if a lane is blocked ahead. Here a criticality check and advice by RVM would be a desirable new feature.

7.2 Human Machine Interface HMI

With regards to the HMI we expect also in future a progress. Warning chimes should be restricted for actual, imminent dangers.

As RVM is mostly dealing with less critical situations, the HMI should be adapted. Research projects are scheduled that aim at a lane change assistant that not only detects suitable gaps on an adjacent lane, but also can advice proper speed and steering to reach them.

Should the driver aim at a critical lane change that would lead to a crash, a different interaction of the RVM should be considered. This could be even a steering impulse preventing the driver from lane changing.

8. Conclusions

Mazda has successfully developed and introduced Rear Vehicle Monitoring, which supports the driver to confirm vehicles in the blind spot of his mirror or in approach to that. RVM is assisting drivers in a fact based decision on executing or aborting a lane change. In this way it is possible to reduce typical lane change accidents that are quite frequent on multi lane roads / highways all over the world. RVM has proven its performance and customers put their confidence in its trustworthy recommendation. Mazda is proud to have received the Euro NCAP Advanced Award for introducing this advanced safety technology.

Mazda is continuously developing new safety systems towards the vision of a zero accident traffic.

Ref.

(1) Destatis, Official German Statistics Office, Publication of annual accident statistics, www.destatis.de

(2) Gidas, German In Depth Accident Study, of real accidents that get reconstructed through an expert team by in depth analysis on the accident location. Database with more than 20000 accidents with injury/fatality is already available.

(3) Study on lane departure warning and lane change assistant systems, Transport Research Laboratory, England 2005

(4) Olsen et al, Eye glance behaviour during lane changes and straight ahead driving, Journal of Transport Research Board, USA 2005/ vol. 1937, p.44-50

(5) Review of the "Looked, but failed to see" accident causation factor, Department for Transport, England 2005, Report 60

(6) Integrated Vehicle Based Safety Systems - Light Vehicle Field Operational Test – Methodology and Test Results Report, University of Michigan, USA 2010, UMTRI-2010-30 report

(7) BAST Bundesanstalt für Strassenwesen, Federal German Highway Research Center, www.bast.de is a governmental research organisation for road / transport related research including accidentology.

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