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Advancing active safety towards the protection of Vulnerable Road Users by evolution of ADAS solutions that meet real-world deployment challenges: The project PROSPECT

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Abstract

Accidents involving Vulnerable Road Users (VRU) are still a very significant issue for road safety. ´**PRO**active **S**afety for **PE**destrians and **C**yclis**Ts**´ is a collaborative research project funded by the European Commission. The objective of PROSPECT is to significantly improve the effectiveness of active VRU safety systems compared to those currently on the market by: (i) expanding the scope of scenarios addressed (ii) improving the overall Autonomous Emergency Braking (AEB) system performance (iii) proposing extensive validation methodologies. Concepts for sensors and control systems will be shown in three vehicle demonstrators and a mobile driving simulator and tested with novel VRU dummy specimen. Those systems address the well-known barriers of current AEB systems such as limited sensors field-of-view, fuzzy path prediction, unreliable intent recognition and slow reaction times for the actuation. The findings contribute not only to the augmentation of state-of-the-art knowledge but as well to technical innovations like assessment methodologies and tools for testing.

Keywords: Active safety; Advanced Driver Assistance Systems (ADAS); Vulnerable Road Users (VRU), Autonomous Emergency Braking (AEB)

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Nomenclature

ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking Systems
Euro NCAP	The European New Car Assessment Programme
FOV	Field of View
PROSPECT	Proactive Safety for Pedestrians and Cyclists
VRU	Vulnerable Road Users

1. Introduction and motivation

Traffic accidents involving VRUs are still a very significant issue for global road safety. According to the World Health Organization about 1.25 million people die each year on the world's roads and 22% of those are pedestrians and 4% bicycle riders; (WHO, 2015). These percentages show the importance of further intensified VRU protection activities and the need to take immediate action in order to improve the road safety.

The last decade has seen significant progress on active safety, as a result of advances in video and radar technology. This has recently culminated in the market introduction of first-generation active pedestrian safety systems, which can perform autonomous emergency braking in case of critical traffic situations. Nevertheless there is still high potential for improvement in this field.

In order to address this issue, the project PROSPECT aims at laying the foundation for next generation active safety systems. PROSPECT is a collaborative research project funded by the European Commission under Grant Agreement nº634149. It started in May 2015 and involves many relevant partners from the automotive industry, academia and independent test labs. The objective of PROSPECT is to significantly improve the effectiveness of active VRU safety systems compared to those currently on the market by: (i) expanding the scope of scenarios addressed (ii) improving the overall system performance (iii) proposing extensive validation methodologies. The emphasis is on the two groups with large shares of fatalities: cyclists and pedestrians.

The project pursues an integrated approach comprising an in-depth accidents analysis involving VRUs, combined with results from naturalistic observation studies and HMI guidelines. All relevant VRU traffic scenarios are considered, with a special focus on urban environments, where the majority of accidents with VRU occur. This analysis represents key input for the system specifications, integration and demonstration with a cost-benefit analysis. An overview over the derivation of use cases from accident data can be found in Enhanced Safety of Vehicles conference paper (ESV, 2017) and in the appropriate PROSPECT deliverables (D2.1 2016).

For system development, two main aspects are considered: (i) advanced sensor processing and (ii) actuator strategies including braking and/or steering. These will be extensively tested in realistic scenarios. Special emphasis is placed on allowing systems to react earlier, without increasing the number of false activations.

Focus of this paper is the path from specification of improved VRU sensing and situational analysis functions to the implementation of the envisaged sensors concepts in three vehicle demonstrators and one mobile driving simulator, tested using novel VRU dummy specimen. Each of the demonstrators will have its unique focus:

- I demonstrator is equipped with stereo vision camera and high resolution radars, featuring high dynamic brake system combined with power assisted steering actuator.
- II demonstrator will feature improvements in earlier, accurate and more robust detection of VRUs where sensor fusion with radar / lidar technologies is planned to extract VRU intention-related features.
- III demonstrator integrates enlarged FOV radar sensors including side and rear coverage and avoids critical situations or collisions by steering and/or braking in complex urban scenarios.
- Additionally, one driving simulator will include advanced warning/HMI and control strategies to evaluate interaction between the driver and the vehicle inside PROSPECT.
- Advanced realistic pedestrian and cyclist dummies including platform propulsion system will improve realistic testing by extending dummies trajectories, organic materials, kinematics and physical behavior.

The findings within the PROSPECT contribute not only to the generation of state-of-the-art knowledge but as well to technical innovations i.e. assessment methodologies and tools for testing and next generation VRU active safety systems. Those systems address the well-known barriers of current AEB systems such as limited sensors field-of-view, fuzzy path prediction, unreliable intent recognition and slow reaction times for the actuation.

The PROSPECT results will enhance VRU road safety, contributing to the ‘Vision Zero’ objective of no fatalities or serious injuries in road traffic set out in the Transport White Paper (Vision Zero, 2011). Moreover, test methodologies and tools shall be considered for 2020-2024 Euro NCAP test programmes with final aim to support the European Commission goal of halving the road toll by 2020 (Euro NCAP, 2015).

2. Challenges and general methodology for addressing barriers of current ADAS systems

PROSPECT focusses on active safety solutions, where the vehicle survey surroundings based on video and radar sensing. The developed sensors intend to support a larger coverage of accident scenarios by means of an extended sensor field of view (e.g. frontal stereo vision coverage increased to about 90°, radar coverage increased up to 270° covering vehicle front and one side), high-resolution and sensitive microwave radar sensors with enhanced micro-Doppler capabilities for a better radar-based VRU classification.

For automated driving however, the system should not only detect VRUs, but also predict their trajectories to anticipate and avoid potentially dangerous situations. In this case, advanced algorithms enable safety related decision-making and the systems developed within PROSPECT will take action in case of a critical situation with a VRU, increasing the effectiveness of current active safety systems.

This section provides an overview of the applied methodology pursued in this project in relation to sensor processing, situation analysis, VRU motion detection, path prediction and vehicle control functions.

2.1. General obstacle detection with video and radar systems

“Obstacle Detection” deals with obtaining a spatial representation of the vehicle environment that localises any kind of objects (i.e. VRUs, but also infrastructure and vehicles). In PROSPECT novel video- and radar-based environmental sensors are used. Combining the video- and radar-specific information streams will increase robustness and overall system performance and is the trigger for novel active safety VRU protection features (i.e. extending the vehicle control from braking to steering) and paves the way towards fully automated driving in the near future. While advanced video methods are more and more based on deep learning with convolutional neural networks (CNN) the radar techniques still rely on classical approaches due to the very early development stage. To tackle these issues, the video component within PROSPECT has been developed in close collaboration by Daimler and the University of Amsterdam; the radar component by Bosch and Continental researchers.

For generic video-based obstacle detection, Daimler within the PROSPECT project uses the stixel world (Badino, 2009). Stixels are an efficient and sparse representation of objects having approximately vertical surfaces and thus can be used to represent e.g. VRU and cars. By fusing the depth information along with the results from semantic scene segmentation (Schneider, 2016) the stixel world can be refined based on class specific knowledge. For example, see Fig. 1, where the different colors encode the class of each stixel. The class information supports the stixel generation along the disparity.

Fig. 1: Semantic stixel representation where the image is segmented into drivable road, sky, and vertical "sticks" (Schneider, 2016).

Radar obstacle detection is performed by receiving transmitted electromagnetic waves that are reflected from objects within the sensor’s observation zone. It also utilizes the Doppler method to measure directly the relative speed of the objects. This technology exists for more than 100 years, but the first automotive radars came on the market in the 90´ due to tough commercialization and utilization challenges. The principles and component technologies have significantly changed over the last years and boosted the radar sensor performance from a very simple distance and speed measurement device to a high resolution radar with integrated hardware components and fast increasing computation power. Another important step towards detection and classification of VRU with radar sensor systems in complex scenarios was to extend the FOV of the individual sensor or putting them in different locations in the vehicle and fuse the detection results in one source. For this purpose networks of radar sensors are integrated into the PROSPECT demonstrators (see one of the solutions in Fig. 10).

One of the PROSPECT tests is the “crossing cyclist” use case addressed by Continental demo-car as depicted in Fig. 2. A bicyclist is riding from the left to the right and crossing the FOV of all three radar sensors. Dynamic detections accumulated over time of the single radar sensors are plotted in Fig. 2b-c. Static detections are not displayed in Fig. 2 at all. Finally Fig. 2e shows dynamic detections of all three sensors overlaid, but not yet fused. The trace of the cyclist crossing the FOV of all sensors is clearly visible. Some dynamic detection appears outside the path of the cyclist. These are caused by static parking cars acting as a "mirror" for the radar signals of the cyclist. "Dynamic ghost detections" may appear that can be filtered out by sophisticated algorithms in the later radar signal processing chain.

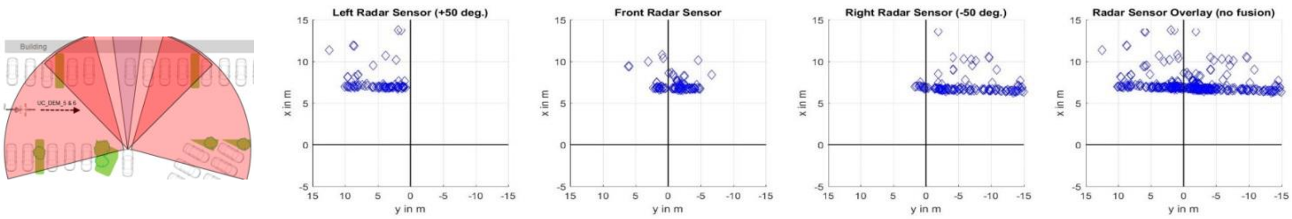


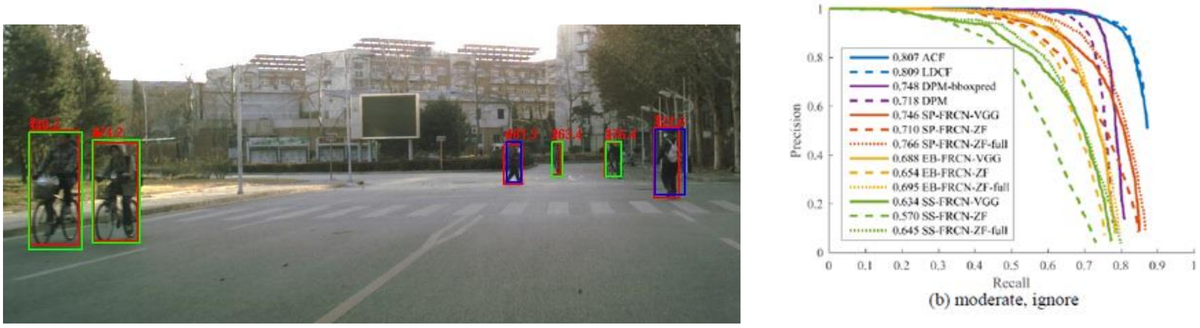
Fig. 2: Potential radar sensor setup to cover PROSPECT VRU use cases at the vehicle front.

In Fig. 2 (a) PROSPECT test scenario for "crossing cyclist" use case. A bicyclist is riding from left to right through the FOV of all three sensors; (b-d) Dynamic detections of each sensor accumulated over time to show the trace; (e) Overlay of dynamic detections of all sensors from (b-d) accumulated over time.

2.2. Video and radar-specific VRU classification and tracking

Object instance information is inferred by a classical bounding box detection. For most box detection methods an accurate box proposal generation is crucial. Daimler within PROSPECT presented an efficient stereo proposal generation similar to the one described in (Enzweiler, 2012) that meets both the runtime requirements and a high detection performance with the used classification methods. In (Li, 2016) it was shown that the recall of the stereo proposal method is significantly higher than the recall of other well know proposal methods (e.g. Selective Search (Schneider, 2013), Edge Boxes (Zitnick, 2014)). Fig. 3 shows qualitative and quantitative detection results on the public available Tsinghua-Daimler Cyclist Detection Benchmark Dataset (Li, 2016).

At each time step the set of object detections is compared with the set of already known tracks. The association scores are computed using the multi-object data association technique Joint Integrated Probabilistic Data Association (Musicki, 2004). This method is further extended to also take similarity measures into account, which are computed based on the learned appearance model for each object. During the filter process different motion models (Constant-Position, Constant-Velocity) are employed within the IMM filter (Mazor, 1998).



(b) moderate, ignore

Fig. 3: Results shown on the public available Tsinghua-Daimler Cyclist Detection Benchmark Dataset (Li, 2016)

In Fig. 3 a) Qualitative results show bounding box proposals (red), cyclist (green) and pedestrian detections (blue). b) Quantitative results are shown in comparison to other state-of-the-methods. While the proposed methods with a stereo proposal generation (SP-FRCN-VGG/ZF/ZF-full) perform slightly worse than well-tuned ACF or LDCF methods, they are able to run with >15Hz and thus meet real time requirements for the application.

On the other hand, the evaluation of the so-called micro-Doppler signature and the exploitation of multiple input, multiple output (MIMO) systems, was the subject of the work performed by Bosch. The introduction of these two new measurement techniques in the last few years caused significant improvements in automotive radar sensors. Especially, the new modulation scheme "Fast Chirp Sequence" that is capable to exploit the Micro-Doppler signals received from moving objects enables VRU classification and tracking by radar sensors. In the so-called range-velocity representation the reflection of each traffic participant has its characteristic Micro-Doppler signature that mainly depends on the individual movements of the radar-illuminated parts.

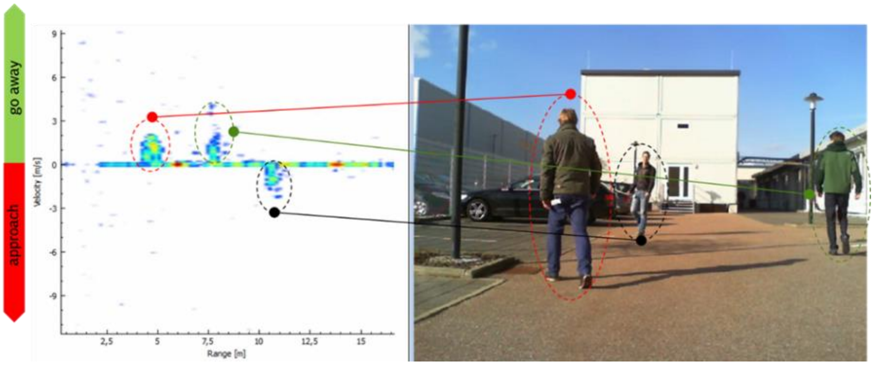


Fig. 4: Micro-Doppler signature of three walking pedestrians

In Fig. 4 the micro-Doppler signature of three walking pedestrians is sketched. The limb movements while walking generate a specific speed-distribution pattern that can be recognized and used for classification and intent prediction (e.g. when a pedestrian is slowing down to stop at the road curb). Road users with wheels (i.e. cars, trucks, bicycles) have wheel-specific radar signatures as shown in Fig. 5.

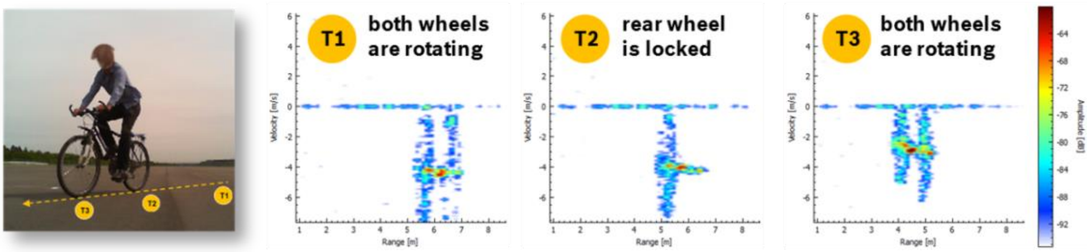


Fig. 5. Micro-Doppler signature of a braking bicycle

The wheel's Micro-Doppler signature typically ranges from zero (contact point on the road where the backward rotation speed and forward movement speed cancel) to the double target ego-speed (top of the wheel that rotates with the forward ego speed and adds up with the forward movement speed). In naturalistic observation studies and individual test campaigns, conducted by the PROSPECT partners, the specific motion patterns of pedestrians and pedaling cyclists were recorded and analyzed in depth (D5.1, 2017).

2.3. Video- and radar-based VRU intent-related feature extraction

The wish to know already in advance where pedestrians or other traffic participants are in the near future is obvious and can be realized with intent-related feature extraction. Gait patterns and limb speed profiles are good indicators that can be evaluated by video and radar sensors. While the underlying physical principle for intent-related feature extraction is identical for both, video and radar sensors, the evaluation techniques used are completely different and adapted to the video- and radar-specific processing methods.

With Pose-RCNN (Braun, 2016) Daimler has added an additional orientation estimation task to extract the object orientation jointly with the object detection based on a single CNN. Most other approaches use simple L1 loss functions for orientation regression. As orientation angles are discontinuous and periodic values such approaches can be problematic. Therefore a carefully designed loss function based on a biternion representation (Beyer, 2015) is used. Besides the object orientation Daimler extracted skeleton cues (similar to the ones described in (Cao, 2017)) as a base for higher-level intention cues and/or human gestures (e.g. arm signal of a cyclist). Fig. 6 shows examples for the intent-related features (orientation, skeleton) which are extracted.

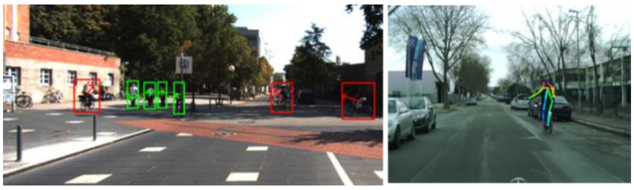


Fig. 6. Video-based intention-related features which help to better predict the behaviour of the VRU

In Fig. 6 a) Orientation information inferred jointly with the detection from a single CNN. b) Detailed body skeleton and part information extracted for capturing body gestures (e.g. turn-signal of cyclist).

Similar to video-based intent recognition, as described above, radar-based intent recognition is also possible by evaluating the same metrics like gait speed variation with radar-specific means. In Fig. 7 the Micro-Doppler distribution of the gait speed and its variance are plotted for a pedestrian that either stops or continues to cross.

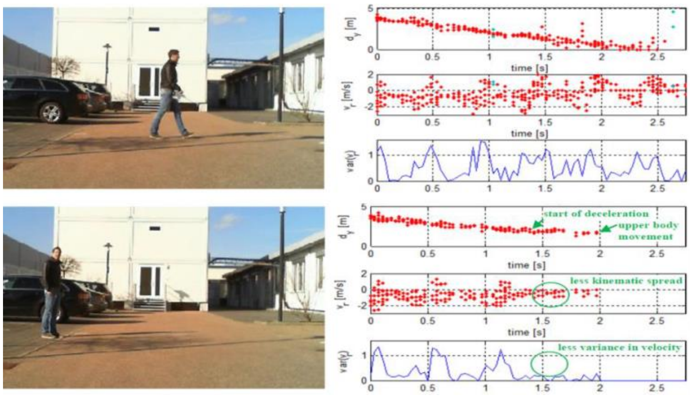


Fig. 7. Intent recognition of a pedestrian at the road curb (stop or cross over)

500 milliseconds before the pedestrian comes to a complete standstill a decrease of the gait speed (and even more visible in the variance of the gait speed) can be observed. This information is useable to predict the intention of a pedestrian up to half a second in the future. AEB-VRU safety systems can thus trigger much earlier and mitigate or avoid VRU crashes in a better way.

2.4. Video and radar-specific VRU Path Prediction and Intent Recognition

Detailed and exact information on the location and moving directions of the VRUs around the target vehicle is needed to conduct appropriate warnings and control actions. Together with Daimler, the University of Amsterdam (UoA) worked on a Dynamic Bayesian Network (DBN) to combine the various behavioural indicators extracted from the video system. Based on the work in (Kooij, 2014) the DBN estimates the motion model transition probabilities (cyclists either going straight or turning) by considering if the cyclist is near or at the intersection, if the cyclist had raised his/her arm, and if the situation is critical. Parameters of the DBN are estimated from manually annotated ground truth values for all states and indicators. Fig. 8 shows the DBN architecture and an example result from a sequence recorded by the Daimler demonstrator car.

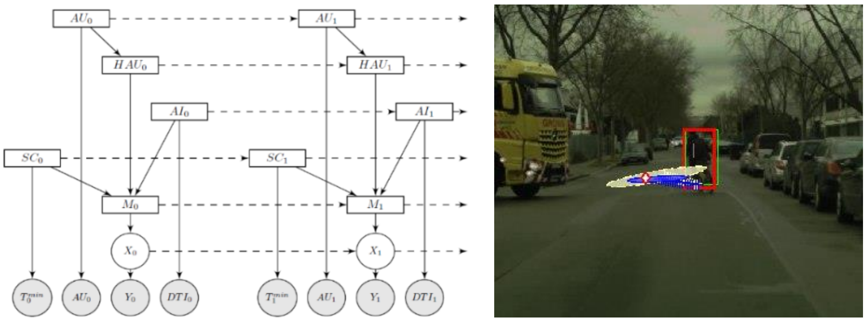


Fig. 8. The DBN architecture and an example result from a sequence recorded by the Daimler demonstrator car

In Fig. 8 a) The DBN for cyclist path prediction, shown for two time indices t = 0, t = 1. The discrete latent variables used are Arm-Up (AUt), Had-Arm-Up (HAUt), Situation-Critical (SCt), At-Intersection (AIt), and the current dynamic Model (Mt). The SC latent variable is based on the minimal time required to reach and hit the cyclist, Ttmin. b) An example frame of the current state of the model. The blue oval represents the prediction of the DBN, the white oval shows the prediction of an LDS. The bounding box of the detected cyclist is shown in red.

Radar-based path prediction and intent recognition is mainly based on the evaluation of a grid-based environmental model of static (i.e. fixed, roadside objects) and dynamic (i.e. the moving traffic participants) obstacles and the evaluation of characteristic motion patterns by Micro-Doppler measurements. The principle concept of radar-specific path prediction is sketched in Fig. 9.

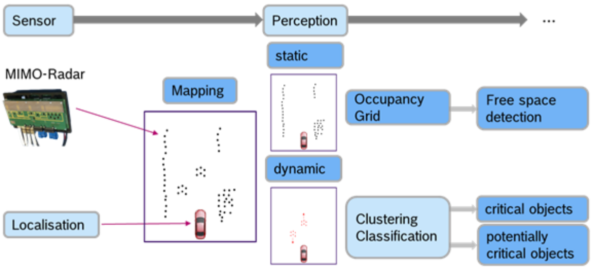


Fig. 9. Radar-based occupancy grid with static and dynamic obstacles - the new perception concept

In Fig. 9 the surrounding perception is conducted on a feature level with a separation between static (road side) and dynamic (moving) objects.

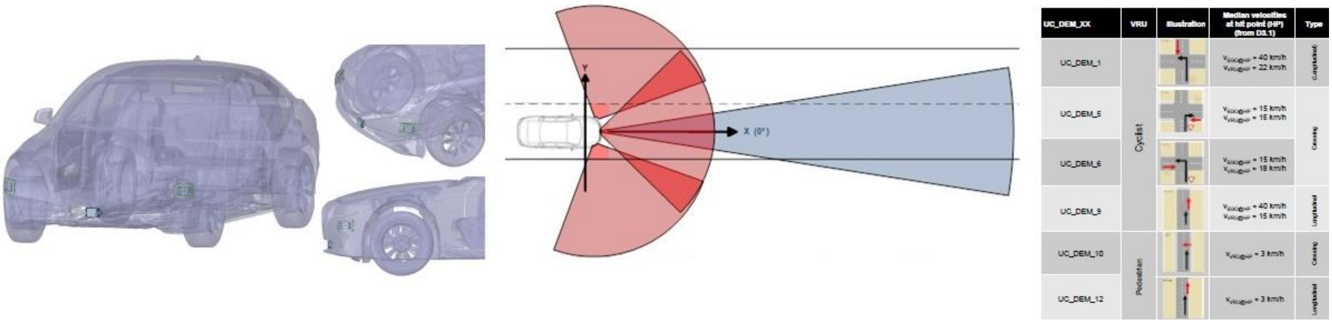
3. Project results

3.1. Demonstrator vehicles and functions

Improved VRU sensing and situational analysis functions (enlarged sensor coverage; earlier and more robust VRU detection and classification; sophisticated path prediction and reliable intent recognition) will be shown in three vehicle demonstrators at the final project event at IDIADA proving ground (Spain) in October 2018. All vehicles will be able to automatically steer and / or brake to avoid accidents. Special emphasis will be placed on balancing system performance in critical scenarios and avoiding undesired system activations. Information about the demonstrators developed in the project is available in the appropriate PROSPECT deliverables (D3.2, 2016).

3.1.1. Demonstrator car I

Demonstrator car I is able to quickly detect and classify VRU from -90° to 90° with respect to the vehicle center line with three RADAR sensors, additionally detect the lane markings with a lane camera. There are actuators for the steering and the brake. Especially the brake actuator can increase brake force much quicker than current production brake systems (approx. 150 ms from start of braking to fully cycling ABS). Due to shorter reaction time a prediction horizon can be reduced and the prediction error is lower. The reduction of false activations improves overall driver acceptance and usability. The Fig. 10 shows the addressed use cases and utilized sensors of the demonstrator. The resulted field of view is presented in Fig. 2 (left).



UC_DEM_XX	VRU	Illustration	Median velocities at hit point (HP) (from D3.1)	Type
UC_DEM_1	Cyclist		$v_{EGO@HP} = 40$ km/h $v_{VRU@HP} = 22$ km/h	Longitudinal
UC_DEM_5			$v_{EGO@HP} = 15$ km/h $v_{VRU@HP} = 15$ km/h	Crossing
UC_DEM_6			$v_{EGO@HP} = 15$ km/h $v_{VRU@HP} = 18$ km/h	
UC_DEM_9			$v_{EGO@HP} = 40$ km/h $v_{VRU@HP} = 15$ km/h	Longitudinal
UC_DEM_10	Pedestrian		$v_{VRU@HP} = 3$ km/h	Crossing
UC_DEM_12			$v_{VRU@HP} = 3$ km/h	Longitudinal

Fig. 10. Demonstrator car I - vehicle with functional setup and addressed use cases

In Fig. 10 a) Sensors integration site RADARS b) Overview Radar sensor setup (3x Long Range Radar for VRU detection & classification over >180°) c) Use Case selection (cyclists and pedestrians at day and night).

3.1.2. *Demonstrator car II*

To handle the defined use cases (e.g. car moving straight with VRU crossing/moving straight, car turning right/left with VRU crossing) the II demo-car is equipped with a front facing stereo camera and two side-mounted cameras. By this camera setup a horizontal FOV of approx. 210° is covered, which is suitable for most of proposed use cases (see Fig. 11 with the sensor setup). In the near range (longitudinal distance up to ~ 40 m) a more detailed analysis of the VRUs will be executed. Based on this detailed information intention recognition can be performed. The correct estimation of VRU’s intention helps to increase the possible prediction time horizon, allowing much earlier warnings and interventions without increasing the false-positive rate.

Still unsolved in literature and always a challenging task is to gain an accurate intrinsic and extrinsic calibration of the lidar and the camera systems. A semi-automatic workflow was developed which makes it possible to use a totalstation along a calibration checkboard to get a first initial guess of the extrinsic sensor parameters. The final position and orientation is then estimated based on this initial guess by an iterative approach.

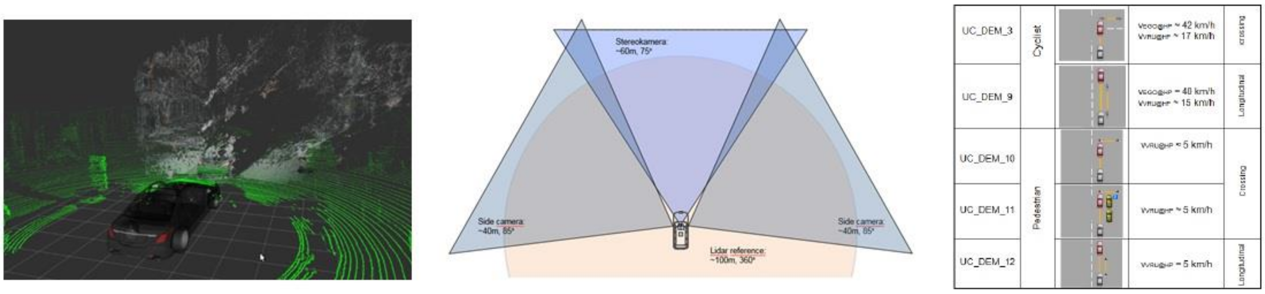


Fig. 11. Demonstrator car II - calibrated and synchronized stereo camera and lidar system and addressed use cases

In Fig. 11 a) Calibrated and synchronized stereo camera and lidar system. b) Sensor setup consisting of one front facing stereo camera (~60m, 75°) and two side-oriented cameras covering a horizontal FOV of roughly 210°. c) The addressed use cases (cyclists and pedestrians, crossing and longitudinal where car can have high speed and early detection needed).

3.1.3. Demonstrator car III

Demonstrator car III will focus on high resolution RADAR sensors with a coverage of the regions in the front, rear and at least at one side of the vehicle: especially accidents with crossing or rewards approaching, quick-running bicycles in combination with a relatively slow or stopped car require a sufficient large field-of-view zone for a sound detection and appropriate vehicle action (e.g. for a stopped car in a parking lot and an approaching cyclist from the rear a warning or even the blocking of the door is needed to avoid an accident).

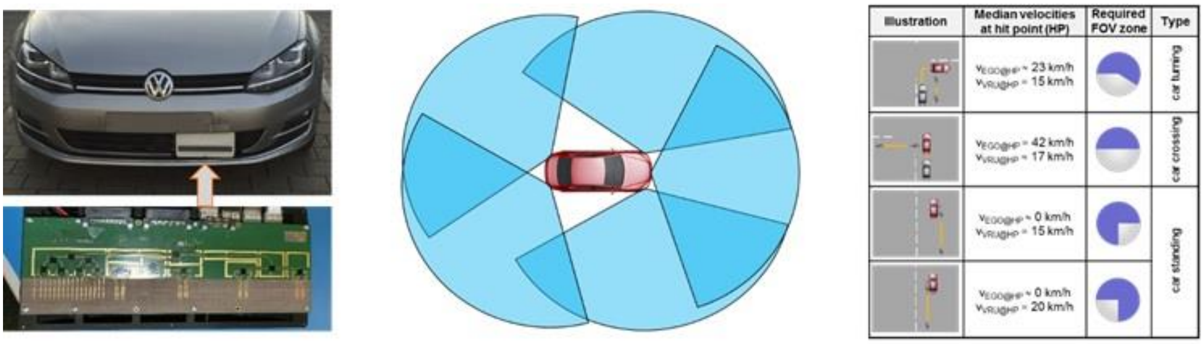


Fig. 12. Demonstrator car III - high resolution radar sensors and addressed use cases

Fig. 12 shows a) the demo-car equipped with radar sensors b) Radar sensor mounting positions and FOV and c) the addressed use cases (car turning right with cyclist approaching from behind, car crossing with cyclist coming from the left side, car standing and cyclist risks to hit the opening door - either left or right).

3.2. Mobile driving simulator

Within the project, a mobile driving demonstrator is used to present and evaluate the results of PROSPECT in a realistic setting applying a real car as a mock-up. Based on the results of the accident analysis (D2.1 2016) it was possible to integrate common accident scenarios between car drivers and cyclists into the Audi driving simulator in order to demonstrate the circumstances of car-to-cyclist-accidents. Moreover, the results of the accident analysis contributed fundamentally to the establishment of hypotheses which outlined why car drivers fail to manage these common crash situations with cyclists.

As a next step, studies will be carried out with Audi driving simulator in order to evaluate these hypotheses. One of the planned studies deals with the role of sensory conspicuity of cyclists within the detection of cyclists in specific scenarios by car drivers. The results of these studies will account for a better understanding of possible reasons why car drivers often fail to handle such situations properly. Fig. 13 shows the Audi driving simulator, which was equipped with two additional monitors (for a better side view in order to improve the demonstration of crossing cyclists) with Audi Simulation Tool (side view and drivers view).

Fig. 13 Audi Mobile driving simulator presentation during PROSPECT technical meeting at BASt, Cologne

3.3. Realistic pedestrian and cyclist dummies

Finally, in the context of testing tools development, advanced articulated dummies - Pedestrian and Cyclist - prototypes are already completed by partner 4activeSystems to obtain higher degrees of freedom (head rotation, torso angle, pedaling, side leaning, etc.) and an improved behavior during the acceleration- and stopping-phase (see Fig. 14). The demonstrator vehicles will make use of novel realistic VRU dummy specimen features for a better object classification and prediction of intended VRU movements. The dummies are mounted on fully self-driving platforms to take into account even complex test scenarios with different arbitrary movements.

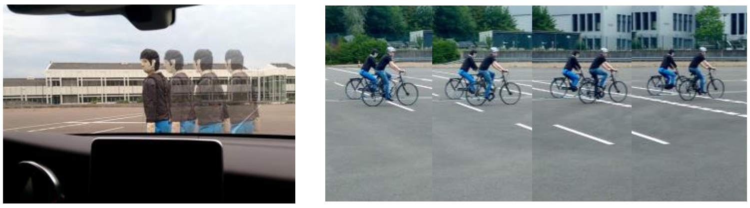


Fig. 14 Examples of advanced dummy features

Fig. 14 shows a) Pedestrian dummy full stop and rotate head towards approaching car. c) Pedaling cyclist dummy with rotating wheels.

3.4. Other project results and findings - test results, methodologies and assessment protocols

Apart from technology demonstrators that will help to maintain and extend the leadership of European car manufacturers in intelligent vehicles and for autonomous driving, PROSPECT will take a step forward in defining test and assessment methods for Euro NCAP AEB VRU systems. Euro NCAP will directly benefit from the project’s findings and results, especially by being supplied with deliverables including test protocol as a proposal for consumer testing (final deliverable under preparation), the above mentioned dummy and verification testing. Since Euro NCAP is the leading NCAP in the world regarding active vehicle safety, this helps to keep the European automotive industry in the pole position of active safety.

At this stage, Euro NCAP has published a roadmap document that outlines the strategy for the timeframe 2016 to 2020, however more important with respect to PROSPECT will be the roadmap 2020 to 2024 (expected to be published in the fourth quarter of 2017) which announces several requirements for e.g. steering intervention and cross-junction AEB systems that need specifically conditioned VRUs. PROSPECT results will be an early input for the definition of all these requirements.

Moreover, the test results will be used for benefit estimation of the PROSPECT systems. User acceptance is crucial for the success of all active safety systems - if the systems are not accepted by the drivers (e.g. annoying), they could be permanently turned off and would then have no effect on traffic safety. Moreover, if interventions of active systems are rare, they may lead to unpredictable reactions from non-aware drivers.

4. Concluding remarks and next steps

The proliferation and performance of ADAS systems has increased in recent years. PROSPECT's primary goal is the development of novel active safety features to prevent accidents with VRUs such as pedestrians and cyclists in intersections. The know-how obtained in the accident analysis and the derivation of the PROSPECT use cases enable the development of improved VRU sensing, modelling and path prediction capabilities. These facilitate novel anticipatory driver warning and vehicle control strategies, which will significantly increase system effectiveness without increasing the false alarm/activation rate. Disruptive AEB systems will be finally demonstrated to the public in three prototype vehicles with the use of realistic dummy specimen during the final PROSPECT event in October 2018.

A sound benefit assessment of the prototype vehicle's functionality requires a broad testing methodology which goes beyond what has currently been used. A collection of 'test scenarios', representative for all accident scenarios, was required to be defined and specified within the project, resulting in a preliminary test protocol (D7.4, 2016). A key aspect of the test methodology is the provision of exact copies of natural driving styles on the test track with driving robots.

In July 2017 a pre-testing event was organized at BASt testing tracks in Germany. The idea was to give all demo-car developers (Continental, Bosch and Daimler) the opportunity to get an impression of the new dummy design. Furthermore, they could verify whether the methods for "hiding" the dummy from vehicle sensors at the beginning of the various test scenarios perform as expected.

What now follows is the first baseline tests according to the PROSPECT test methodology that will start in September 2017 with four most advanced production vehicles from Audi, BMW, TME and VCC. These tests represent the baseline for the state-of-the-art of AEB systems and will focus on testing dummy-vehicle interactions. The other objectives of testing production vehicles against the first PROSPECT draft test program are to generate not only baseline data but as well to refine the test procedures (D7.4, 2016). In the final stage of the project, these results will be compared with the prototype performance. The hypothesis that will be deeply studied is that current vehicles from the market are able to address only a limited number of PROSPECT scenarios.

The final tests of the three prototype vehicles developed within PROSPECT will be conducted in the first half of 2018; in surroundings and conditions as realistic as possible to real urban roads.

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