Development Platform for Safe and Efficient Drive

VRU protection functions solution design

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Workpackage	WP 4.3	Vulnerable road user protection functions	
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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
ARTEMIS	Advanced Research and Technology for Embedded Intelligent Systems
DESERVE	DEvelopment platform for Safe and Efficient dRiVE
DSI	Disparity Space Image
HiL	Hardware in the Loop
HW	Hardware
PC	Personal Computer
ROI	Region Of Interest
SiL	Software in the Loop
SW	Software
VRU	Vulnerable Road Users
WP	Work Package

1. EXECUTIVE SUMMARY

According to the DESERVE's Description of Work, the **scope of WP4.3** is the definition, design and development (up to the stage of working prototypes) of the test case functions for the DESERVE platform, addressing the vulnerable road users (VRU) protection. These functions will be part of the DESERVE platform, and therefore, feedback from the related WP must be taken into account.

The first step of the work that was carried out within this WP has been the analysis of the scope of the VRU collective. There are a lot of definitions regarding what the VRU word means that, sometimes, are significantly different. Vulnerable road users usually comprise pedestrians, cyclist and motorised two wheelers. However, as each categorisation entails a certain degree of arbitrariness, depending on the point of view, some of the above mentioned groups could be too wide for being considered as a vulnerable road user (if all the possibilities within that group are taken into account). In fact, non-motorized users are always the weak part in an accident whereas motorised vehicles (including powered two wheelers) typically create a greater risk in the traffic than the non-motorised ones.

The inherent arbitrariness of the VRU definition has been taken into account and, finally, within the WP4.3 the most vulnerable user among the vulnerable road users: pedestrians, will be addressed as the main target of the VRU protection functions, that will be developed within the scope of WP4.3.

The **deliverable D4.3.1** is a document that contains the analysis of the specific requirements for the VRU detection and protection functions that will be designed and developed within WP4.3. Indeed, the content of this document will be the basis for the remaining tasks (T4.3.2 and T4.3.3) that belong to WP4.3.

This report is structured with the following sections:

- Section 1 (current one) contains an introduction and provides an overview of the different sections in the document.
- Section 2 provides an overview of the scope of the document.
- Section 3 describes the main test cases and scenarios that should be taken into account within the scope of WP4.3.
- Section 4 introduces the requirements for VRU detection and protection functions that have been analysed within task T4.3.1.
- Section 5 describes the methodology that would be undertaken within the task T4.3.2 and T4.3.3 devoted to the development and testing of VRU detection functions.
- Section 6 introduces briefly how the testing of the developed function should be carried out.
- Section 7 summarizes the content of the present document.

2. INTRODUCTION

The **purpose of task T4.3.1** – *Requirement analysis and solution design* – is to collect the specific requirements for the VRU (focusing on pedestrians, as it has been commented on the previous section) detection and protection functions that will be designed and developed within the scope of the WP4.3.

This deliverable summarizes the work carried out during the above mentioned task. In particular, this document is meant to be a compilation of the minimum requirements that the functions that will be developed within the scope of tasks 4.3.2 should accomplish.

Hereunder, the approach that has been considered within the task T4.3.1 is summarised:

- The information gathered in the deliverables D1.1.2 and D1.2.1 of the DESERVE SP1 [1][2] has been taken into account in order to have in mind the basic requirements and specifications of the DESERVE development platform and try to embrace them whenever possible.
- Also, deliverable D1.3.2 [4] has been consulted to be aware of the defined methodology for the ADAS application development based on DESERVE platform before defining requirements or an specific methodology for WP4.3 tasks.
- Information coming from Fiat Research Center (CRF) regarding their demonstrators and use cases has been assessed, as it is expected that the functions that will be developed within the scope of WP4.3 are integrated on a vehicle demonstrator, if it is possible.
- In order to define the solution design and the requirements of the VRU protection functions, several discussions between the partners have taken place.
- Finally, the present document has been created thanks to the information gathered in the above mentioned points.

3. TEST CASES AND SCENARIOS

As it has been commented throughout this document, pedestrians are the most vulnerable road users, whilst also being the most difficult to observe for the car drivers, both in day and in night conditions. Pedestrians in the vehicle path or walking into the vehicle path are in danger of being hit causing severe injury both to the pedestrian and potentially, also, to the vehicle occupants.

An assistance system for protecting pedestrians in road traffic shall be developed starting from the pedestrian detection device/tool. The pedestrian detection device supports such a system by detecting and classifying pedestrians in front of the vehicle. The assistance systems that use the pedestrian detection could **deduce the following measures** from the fusion of the sensors adopted in the vehicle:

- Warnings
- Brake interventions
- Steering interventions
- ...

The pedestrian detection functions should **send the necessary object information** (related to the pedestrian) such as:

- Position
- Direction of movement
- Speed
- Confidence level (Detection quality)
- Time to collision
- ...

From the general definition, a pedestrian is a traffic participant that does not use any means of transportation. However, for the pedestrian detection device/tool, it should be considered that a pedestrian can transport loads with hand cart or wheel barrows.

Then, the pedestrian **detection must be able to detect also pedestrians drawing or pushing** objects such as:

- Baby carriages
- Wheel chairs
- Hand carts
- Wagons
- …

Moreover, the pedestrian **detection has not to be sensitive to the pedestrian clothes**. The pedestrians can wear any type of normal clothing or wear various accessories as it is shown on Table 1.

Table 1. Types of clothes or accessories related to pedestrians

Normal clothes	Accessories
- Unisex clothing - Women's clothing (dresses & skirts) - Short, medium and full length overcoats - Rain capes - Sports clothing - Clothing with reflective strips - Work wear - Exotic clothes: Kaftans, djellabahs, sarongs, etc. - Pedestrians can be partially undressed. - Pedestrians can wear hats / caps. - …	- Suitcases - Bags - Handbags - Rain umbrellas (closed, open) - Canes - Backpacks - School bags - Safety flasher lights - …

It is important to remark that the pedestrians in the vehicle path or walking into the vehicle path are in danger. Because of that, every individual, walking in front of the vehicle, with a variable **speed within the range from 0 to 10 ms^{-1} must be detected as pedestrian**.

The **pedestrian must be in contact with the road surface** to be considered in the vehicle path. So, if the base point of the person is more than 50 cm above the road surface, the person has not to be classified as pedestrian.

In order to define which pedestrians have to be detected by a pedestrian detection device/tool, it should be noted that the **pedestrian must be visible to the system** (in relation of their projection surface in the camera image), but a pedestrian occlusion of about 20% is acceptable. So a person fully visible or partially occluded (up to 20%) must be detected and classified as pedestrian.

Regarding the pedestrians' main features, the **person's height must be between 100 cm and 200 cm** to be classified as pedestrian. Besides, the system must also be robust to various pedestrian postures. Also, the **detection must be insensitive to the varying positions of legs and arms** (e.g. opened ,closed, pacing, switching,...).

In general, the detection must be robust to:

- Pedestrian rotation (front position, side, back,...)
- Pedestrian inclination (up to 30°).
- Pedestrian in crouching position
- Pedestrian bucked \ ducked from the hips to 40°
- ...

Groups of people must be detected as a pedestrian, except if there is no obstruction between people. In this case, each person (not obstructed by another person) has to be detected as pedestrian.

The vehicle speed is an important factor for defining when the pedestrian detection must be enabled. The pedestrian detection must be enabled with **vehicle's speeds ranging from** 5km/h to 75km/h.

Also, the detection must be **insensitive to any transversal accelerations** occurring in road traffic. And the pedestrian detection must function in all normal pitch, rolling and yaw movements of the system vehicle occurring in road traffic.

Regarding the environment where the VRU detection functions should work, below some **requirements for the environment** are listed:

- The pedestrian detection must be performing in all light conditions (in all light ratios), and the detection must be insensitive to the fast light variation:
    - Day
    - Sunny day
    - Night
    - Tunnel
    - ...

- In the same way the weather conditions should not disturb the pedestrian detection performance. The detection must function under all weather conditions. An exception is the weather conditioned by the limitation of the maximum visual range (strong fog). In this case, the pedestrian detection must function without restrictions in the available visual range.

4. REQUIREMENTS FOR VRU DETECTION AND PROTECTION FUNCTIONS

In the previous section an overview of the test cases and scenarios where the VRU protection functions should be tested has been provided. That information mainly defines the VRU protection functions' targets and, under which conditions those functions should work. So, taking into account that information, and also, information coming from some DESERVE deliverables [1] [2], that have been consulted for considering, whenever possible, the general DESERVE platform needs and the development platform requirements, throughout this section specific requirements for the VRU detection and protection functions will be addressed.

Specifically, the requirements that will be addressed in this section are the following:

- Component layout
- Testing scenario
- Platform
- Functions communication
- Functions inputs
- Functions outputs
- Target definition
- Approach
- Performance
- Detection area

The definition of the scope of each one of the above mentioned points will help to specify the minimum requirements that should be undertaken by the VRU protection functions to be developed within the WP4.3 of DESERVE.

Component layout:

The DESERVE project aims to design and build an ARTEMIS Tool Platform with the objective to reach a standardization of the interfaces, SW reuse, development of common non-competitive SW modules, and easy and safety-compliant integration of standardised HW or SW from different suppliers.

Below, the general DESERVE Platform Framework is shown:

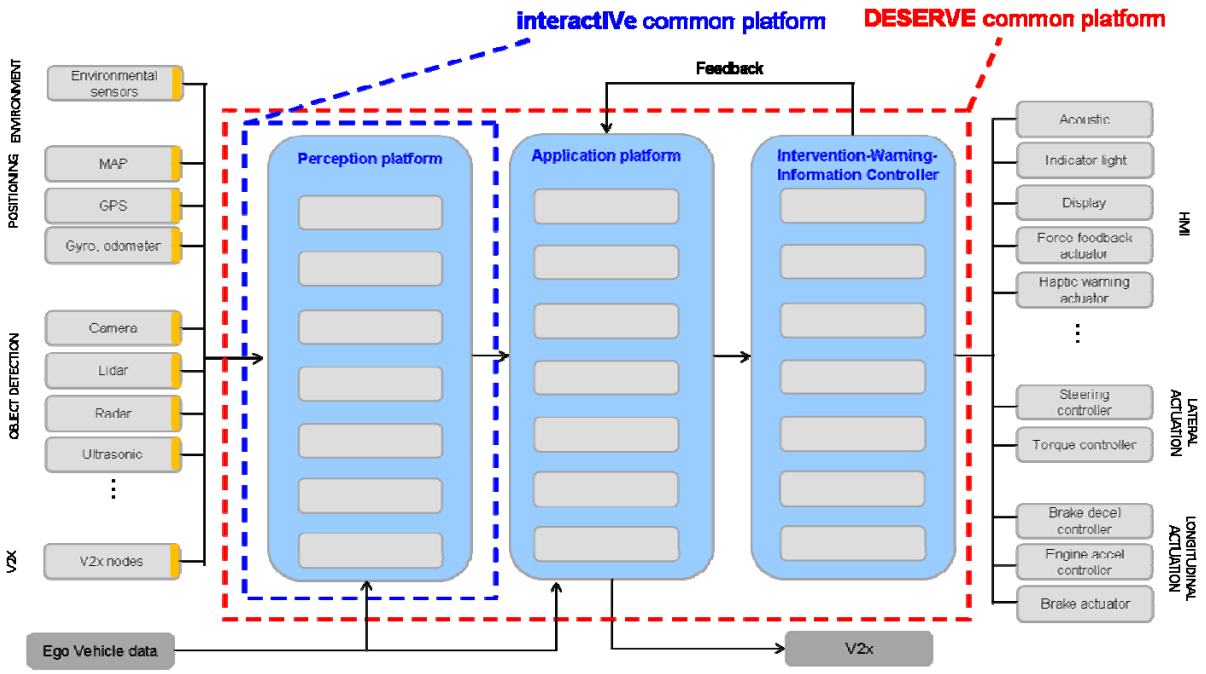

Figure 1. DESERVE Platform Framework. The VRU module belongs to the Perception Platform

As is it shown on Figure 1, the DESERVE platform will be formed by 3 distinct platforms. Within the 3 platforms that forms this platform, the Perception Platform will contain all the VRU protection functions that will be developed in the sphere of WP4.3. In Figure 2,

the detail of the modules that form the DESERVE Perception Platform are shown, in order to clarify the role of the VRU functions within the previously mentioned platform.

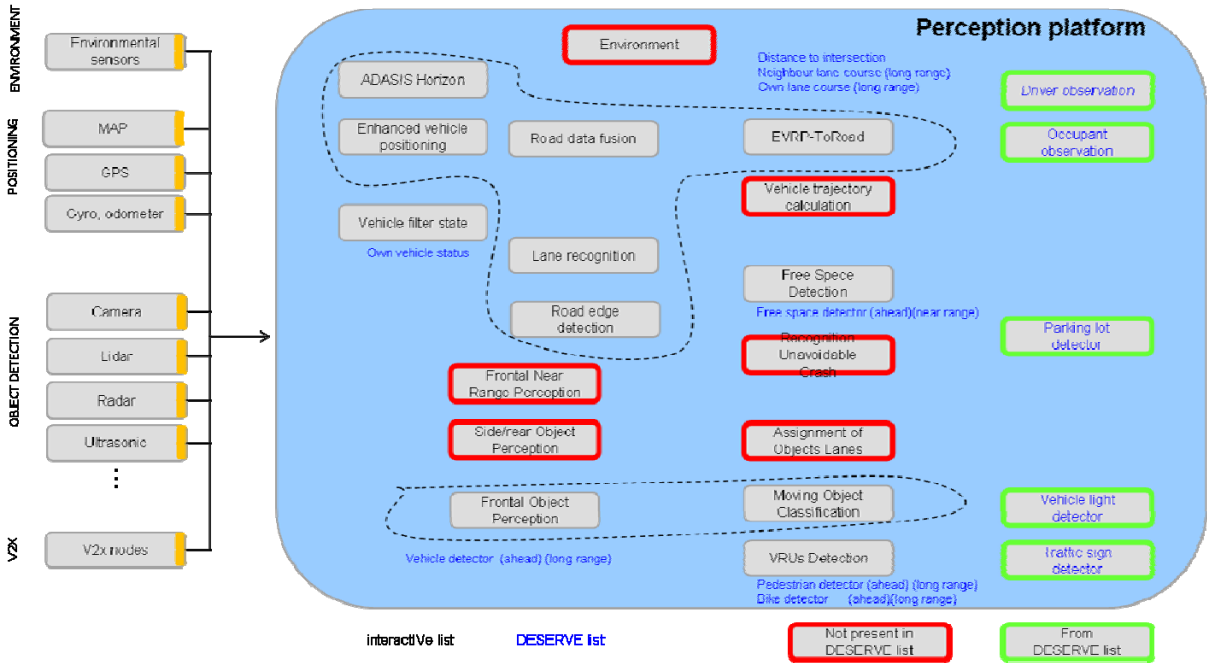

Figure 2. DESERVE Perception Platform. VRUs Detection module represents the functions that will be developed within WP4.3

So, as shown in the previous figure, the VRU protection functions will be gathered around the VRUs Detection module. This module will contain all the functions that will be developed within the scope of the WP4.3. It is expected that the VRUs Detection module will need the output of other DESERVE modules as its own input, and, in the same way, the output of the VRUs Detection module will be used as input by other DESERVE modules.

Testing scenario:

Due to the duration of the work package and the early maturity of the development platform, the development carried out within the scope of WP4.3 should focus on intermediate development of pedestrian detection, with laboratory and virtual testing. The laboratory and virtual testing of the VRU functions will be treated in Section 6.

However, it is also expected that the VRU perception module, developed and partially tested in WP4.3, will be integrated in the architecture of one of the Fiat Research Center (CRF) demonstrator vehicles. That architecture is represented in the following image:

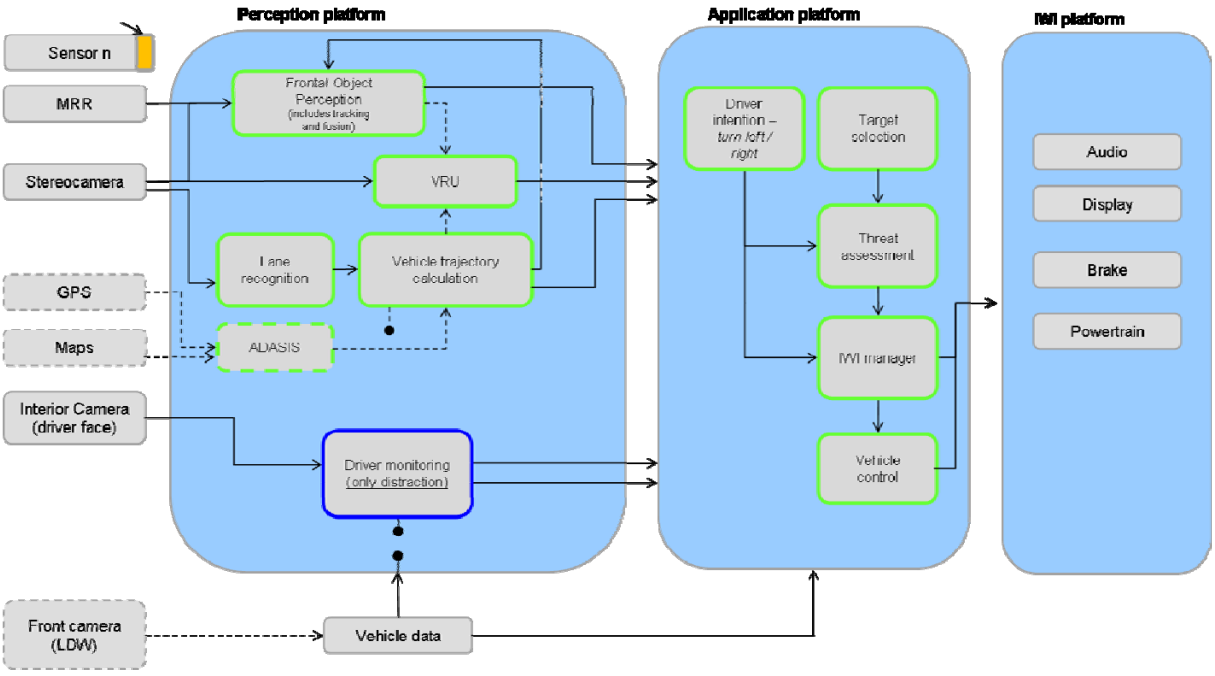

Figure 3. CRF demonstrator architecture for AEB pedestrian

Platform:

As stated on D1.3.2 [4], regarding the method and tools specifications, the DESERVE platform system may work at least on three different development stages:

- Fully PC-based HW platform
- Mixed PC and embedded controller platform
- Embedded and custom ASIC HW-framework

Due to the need of progressing within the development of the functions that will run over the DESERVE platform, the development of the VRU protection functions will be done, at least at the beginning, in a fully PC-based HW platform. Moreover, all the DESERVE specifications [2] regarding the development process will be taken into consideration whenever possible.

Functions communication:

The DESERVE platform has to be based on state-of-the art tools which are typically used for the development of ADAS applications.

As the VRU protection functions will be developed by more than one partner, it is necessary to establish a methodology for interfacing all the functions. Partners have agreed on using RTMaps (see Figure 4) for the development of the VRU protection functions.

Functions inputs:

In order to have information about the environment and being able to detect pedestrians, the VRU module will use a color stereo camera as a primary input device. The two cameras have to acquire synchronized images of the scenario in order to enable a sufficiently detailed 3D reconstruction of the environment.

As it can be deduced of the test cases and scenarios presented on the previous section, other vehicle data, as speed and trajectory, are necessary to enable or disable the processing and to compute the area in which pedestrians must be detected.

Moreover, if it is available, a radar could be used as a secondary input sensor. Information coming from the radar could be fused to the stereo camera data at a low level to enter the processing at an early stage or used at a higher level for validation, to improve reliability of the system.

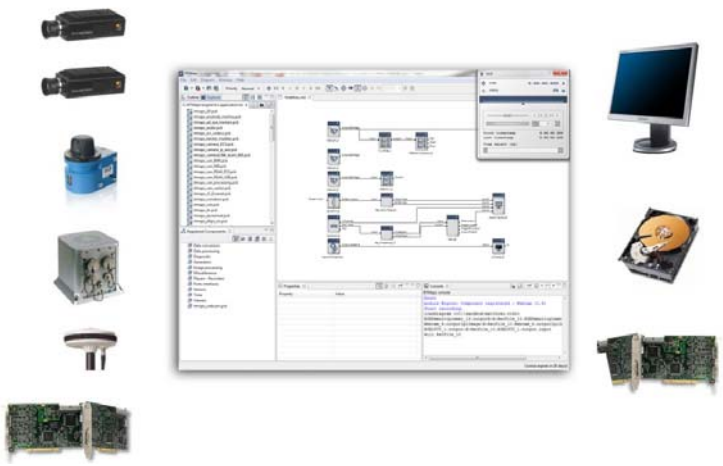

Figure 4. RtMaps Studio and its capabilities for supporting different sensors and actuators

Functions outputs:

The output of the VRU module will be a list of the detected targets that have been classified as pedestrians. This list will be used by those DESERVE modules that need to have information about pedestrians in front of the ego-vehicle.

The content of that list will be defined together with the rest of the partners involved in the Perception Platform (or even in the Application Platform, see Figure 3), as the output of the VRU module will be the input of other modules, and therefore, it is necessary to define as a group, which one is the minimum required information that should contain the output list of the VRU module.

Target definition:

It has been agreed that the aim of Vulnerable Road Users protection system will be the detection of pedestrians or bicyclists, namely the non-motorized road users according to the EU ITS directive [3]. This decision has been made after assessing the different groups that could be gathered under the VRU definition.

Moreover, as it has been stated previously in this document, the VRU module will be developed focusing specially on the detection of pedestrians, as it has been considered that within the VRU, pedestrians are the most vulnerable collectible and, therefore, specially interest in the protection of this group should be taken.

Approach:

As it has been commented previously, one of the tasks within WP4.3 is directly related with the development of vulnerable road user detection functions. After assessing several possibilities to carry out this development, it has been decided to divide the VRU module in two main layers:

- Region Of Interest (ROI) detection layer
- Region Of Interest (ROI) analysis layer

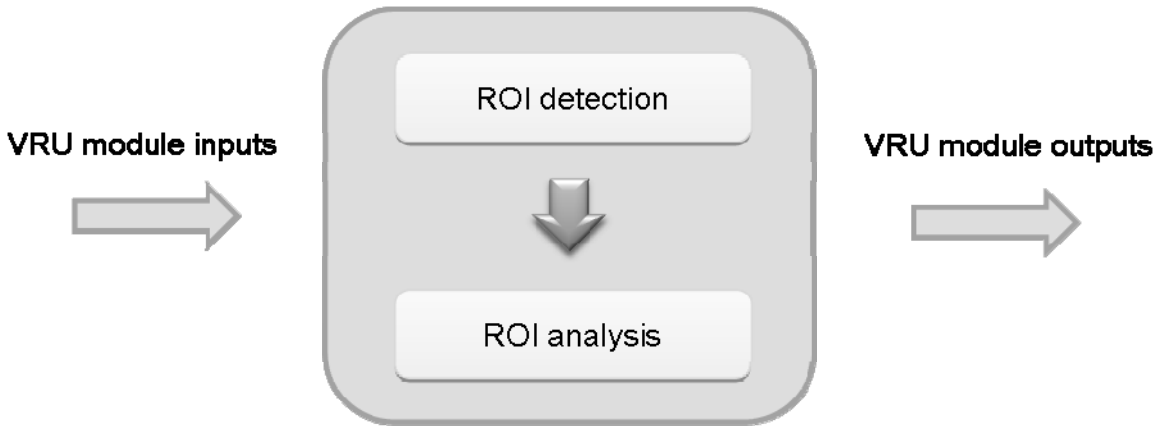

Figure 5. Main layers of the VRU module that will be developed within the scope of WP4.3

The University of Parma will develop a system for detecting a list of Region of Interest in images acquired by a stereo camera. The main idea is the use of a color stereoscopic system to acquire images. Then, a dense disparity space image (DSI) will be computed to determine the distance of different portions of the images. The DSI will be used to discriminate between obstacles in the scene and background. Using specific size, distance, and position constraints this list of objects will be filtered producing a list of objects that can be potentially pedestrians. This list will be passed to another layer for a further investigation and validation approaches. The use of radar will be evaluated to improve the reliability of the detection and therefore reducing the number of ROIs to be passed to the following layer.

CTAG will be in charge of classifying the ROIs provided by the University of Parma. The ROI analysis will combine shape restrictions, texture-based classification and tracking. The size and aspect ratio of the pedestrian ROIs will be studied considering the pedestrians body size, the distance to the car, and the camera model. The ROIs that do not fit the size and the aspect relation constrains will be filtered to eliminate the obstacles without pedestrian shape. The remaining regions will be classified using state of the art texture classifiers. These classifiers will evaluate different image features, like the edge and intensity patterns, in order to decide if the ROI corresponds to a pedestrian or not. Moreover, the pedestrian position could be used to improve pedestrian classification through statistical based tracking.

Performance:

Regarding common performance requirements and criteria for the functions developed in SP4, there are not required or established performance requirements on the functional level. The main request is that the developed module fits the specifications and requirements elaborated in SP1 and the general DESERVE platform idea of SP2 [1] [2].

Nevertheless, 3 sets of videos will be used during the development stage in order to measure in an objective way the performance achieved by the developed functions. The behavior of the system with the third set of videos (reserved for validation purposes)

should show that the VRU module functionality is reliable enough according to the state of the art. See Figure 6 for more details.

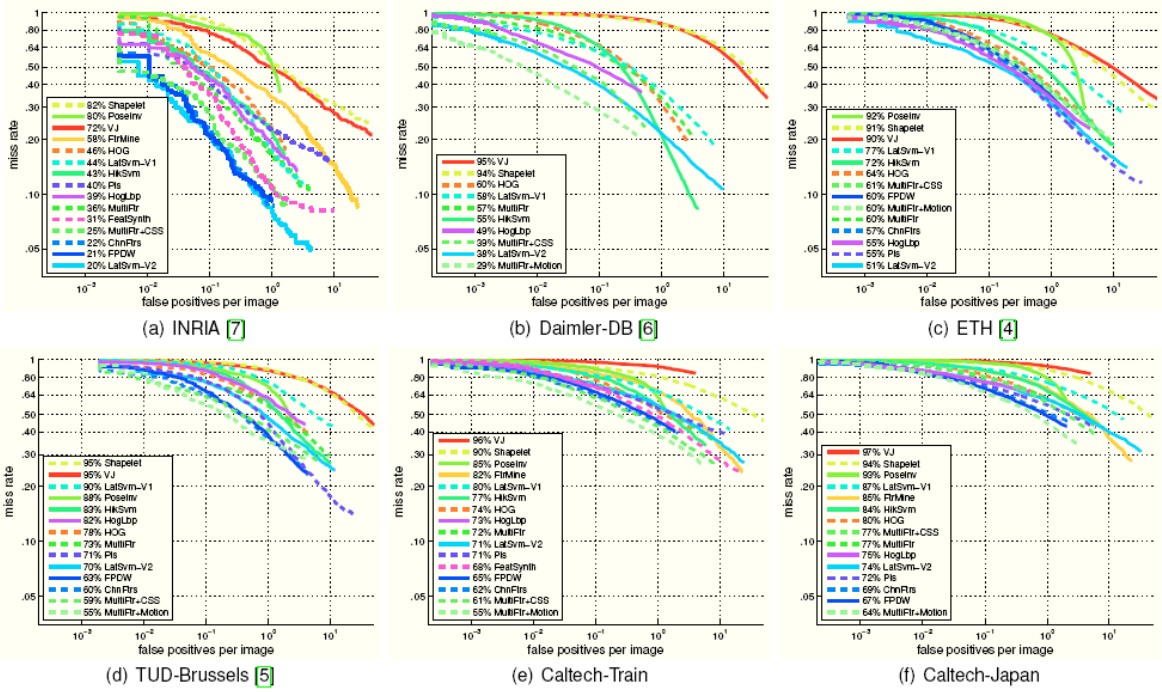

Figure 6. These figures show the performance on six datasets of several algorithms for pedestrian detection. Image from reference [5].

Detection area:

Regarding the detection area where the VRU module will look for vulnerable road users, the VRUs detection module has to take into account the trajectory and the speed of the vehicle in order to limit the detection to the part of the scenario in which the presence of a VRU is potentially a danger. This area is not limited to the specific trajectory of the vehicle (usually the road surface) but, it must include also road sides to enable the detection of VRUs that can potentially impact to the vehicle trajectory. Anyway, the limit relative to the portions of images to be processed can lead to a more fast or a more accurate detection.

In addition, according to pedestrian detection requirements, the processing of portion of images that correspond to artefacts too high or too close to the sky will not be taken into account.

Throughout this section, several requirements related to the VRU detection functions have been addressed. These requirements will be used as a starting point for the development that will be carried out within the scope of task T4.3.2, and, they will be updated whenever required during the development process.

5. METHODOLOGY

Within the general framework of the DESERVE project, the methodology for application development has been specified in D1.3.2 [4]. This deliverable describes the main phases of the development process of ADAS applications and, it also defines the specifications of the development tools to be used in the DESERVE platform. For that reasons, whenever possible, this methodology will be taken into consideration within the developments of the WP4.3.

Apart from the above mentioned general methodology, due to the fact that within the scope of the WP4.3 is necessary to develop and/or adapt SW, it is necessary to establish a specific working methodology, to be adopted by all the WP4.3 partners, in order to organise, plan and monitor the development phase.

Usually a conventional approach does not produce the expected results and it makes difficult to control the development. Because of that, minimum guidelines will be followed during task T4.3.2 and T4.3.3 in order to ensure the correct development and finalizations of the tasks. Those guidelines consist on:

- As the University of Parma is on charge of the ROI detection layer, they will be responsible for the video data acquisition.
- Those videos will be divided into 3 different sets, as it would be explained throughout the following section of this document.
- Videos from different sets will not be mixed, so videos should be correctly labelled in order to avoid combine them by mistake.
- As the VRU module is formed by 2 different layers, RTMaps will be used for the general communication of those modules (data exchange, synchronization…)

- Periodic meetings and phone conferences will be hold in order to monitor the status of the development phase and establish the necessary measures in order to detect any deviations or issues.

6. TESTING ENVIRONMENT

Testing will be carried out for the selected and developed VRU detection and protection functions. In this case, a two-step validation phase will be undertaken:

- Virtual testing, using SiL (Software in the Loop) elements by feeding the developed SW with recorded logs of different driving scenarios previously recorded. It is important to highlight that a log database should be created, with three different sets of logs:
    - One set of logs for training purposes
    - A second set for development purposes
    - The third set, the largest one, devoted to testing
- Laboratory testing of the final HW platform for VRU detection and protection, using HiL (Hardware in the Loop)

Regarding the virtual testing phase, it is important to remark that it should be recommendable to annotate the video datasets in order to know the ground truth and being able to get an objective measurement of the performance of the developed functions. In case of not having the possibility of getting annotate datasets, only a subjective measurement of the performance could be provided.

For virtual testing purposes, SW tools such as RTMaps could be used.

In relation with the laboratory testing, the final HW platform is going to be needed for being able to carry out this step of the task T4.3.3. In case of not being possible, the virtual testing phase would be enforced.

7. CONCLUSIONS

The present report contains an analysis of the minimum requirements that should be accomplished by the DESERVE's VRU having in mind the test cases and scenarios where the module will be tested.

Test cases and scenarios described throughout this document have been used as starting point for defining the minimum requirements of the VRU module. Moreover, other requirements coming from several previous deliverables of the DESERVE project (see references [1] [2] and [4]) have been taken into account.

If needed, requirements will be updated during the running of the project based on the needs of the development activities.

Finally, regarding the testing environment, it would be defined more in detail once the task T.4.3.3 - *Laboratory and virtual testing* – begins.

8. REFERENCES

[1] DESERVE D1.1.2 Platform needs

[2] DESERVE D1.2.1 Development platform requirements

[3] ITS Directive. (Directive 2010/40/EU)

[4] DESERVE D1.3.2 Method and Tools Specifications

[5] P. Dollár, C. Wojek, B. Schiele and P. Perona. *"Pedestrian Detection: An Evaluation of the State of the Art"*, PAMI, 2012