Development Platform for Safe and Efficient Drive

Vehicle Control Solutions

Deliverable n.	D24.1– Vehicles Control Solutions (first release)		
Sub Project	SP2	ADAS development platform	
Workpackage	WP2.4	Arbitration/Control	
Tasks	T2.4.1	Analysis of existing vehicle control solutions	
Authors	Joshué Pérez Fawzi Nashashibi	INRIA	
File name	D24.1_Vehicle Control Solutions_v4.0 - CRFchanges.docx		
Status	First release		
Distribution	Public (PU)		
Issue date	15/10/2013	Creation date	30/06/2013
Project start and duration	1st of September, 2012 – 36 months		

ARTEMIS

REVISION CHART AND HISTORY LOG

Ver	DATE	AUTHOR	REASON
0.1	2013-05-15	Joshué Pérez (INRIA)	Table of contents and structure of the document
0.2	2013-06-19	Joshué Pérez (INRIA)	Explanation of subsection. Searching information.
1.0	2013-07-03	Joshué Pérez (INRIA)	Finalization of the first Draft
1.5	2013-07-12	Alfred Hoess	Peer review of D2.4.1 "Vehicle control solutions"
2.0	2013-08-27	Joshué Pérez (INRIA)	Modifications suggested (improvements) by CRF.
3.0	2013-10-12	Nereo Pallaro (CRF)	Second peer review of D2.4.1 "Vehicle control solutions"
4.0	2013-10-15	Joshué Pérez (INRIA)	First delivery

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
AEB	Autonomous Emergency Braking
AFL	Advanced Front Lighting
ASV	Advanced Safety Vehicle
AVCS	advanced vehicle-control systems
BSW	Blind Spot Warning
CAS	Collision Avoidance System
CSW	Curve Speed Warning

CWS	Collision Warning System
DPP	Dynamic Pass Predictor
FIR	Far-infrared
HMI	Human Machine Interface
ITS	Intelligent Transportation Systems
LCA	Lane Change Assistance
LCDAS	Lane Change Decision Aid Systems
LDW	Lane Departure Warning
LKAS	Lane Keeping Assistance systems
LSCAS	Low Speed Collision Avoidance System
NIR	Near-infrared
NVS	Night Vision Systems
SLI	Speed Limit Info
SOTA	State of the art
SVM	Support Vector Machine
TSR	Traffic Sign Recognition
VRU	Vulnerable Road User

INTRODUCTION

The aim of the Advanced Driver Assistance Systems (ADAS) is mainly linked to aid drivers in safety critical situations rather than to replace them. However, in recent years, many research advances have been done in this field, giving to understand that fully autonomous driving is closer to be daily reality. In the literature, the control of autonomous vehicles is separated in lateral and longitudinal, for this reason in the Arbitration and Control work package (WP24) of DESERVE project both controllers will be considered in order to have a natural and shared behaviour between the driver and the ADAS system.

1.1 Objective and scope of the document

The purpose of D241 deliverable (output of work package 2.4, dealing with the development of Arbitration and Control strategies and algorithms) is to analyse the existing vehicle control solutions for the DESERVE platforms. Both longitudinal and lateral control will be addressed, and these perspectives will consider the driver in the control loop in the next developments of the DESERVE project.

2.1 Structure of the deliverable

This document is structured as follows: section 1 describes the vehicle control solutions in ADAS applications. Therefore, different control levels are defined in section 2. Further on, some of the most relevant and related previous works (research level) are presented in section 3. A general description of key factors for vehicle control applications (based on ADAS) in the market is presented in section 4. Then, based on the contributions of the SP1, specifically in the D11.2 and D12.1, section 5 explains the applications and platform needs to be used in the different demonstrators and their relation with requirements defined in previous sections. Finally, conclusions are given in the last section.

1. VEHICLE CONTROL IN ADAS APPLICATION

Some research groups and vehicle manufacturers around the world are technologically ready to provide fully autonomous driving [2]. However, the complexity of traffic scenarios, some legal constraints and the driver's acceptance allow as forecast a soft transition between manual and fully autonomous driving. In this context, the control capacities in Advanced Driver Assistance Systems (ADAS) have a very important role.

In this section, a classification and explanation of the most relevant aspects for the control functions in the DESERVE platforms will be defined. Moreover, an identification of the basic control modules of the DESERVE platform will be considered, based on the deliverable D1.2.1 Development Platform Requirements (SP1).

The baseline for DESERVE project is represented by the results of past and on-going research projects, and in particular of interactIVe addressing the development of a common perception framework for multiple safety applications with unified output interface from the perception layer to the application layer. DESERVE moves towards the standardisation of a wider software architecture including the Application and the Information Warning Intervention (IWI) platforms, in addition to the Perception platform already developed within interactIVe.

1.1 Perception of the environment

The perception platform is in charge of analysing all the information from different acquisition modules. This includes: external devices (cameras, laser, radar, GPS, IMU, biosensor, among others) and internal buses (odometry and CAN information- speed, angle position and operating signals-).

The perception modules that will be developed in DESERVE are explained in D12.1 Development Platform Requirements report [36]. Most of these functions are related to different perception sources, object recognition and lane keeping. Five of the most important perception modules used in DESERVE platforms are explained, as follows:

- ***Frontal object perception (FOP)***: this module detects stationary and moving obstacles in front of the vehicle. It will be developed and tested in **Volvo** and **CRF** platforms.

- ***ADASIS Horizon (ADA):*** this module gives the description of the road (lanes, curvature, landmarks, and slopes, among others). It will be developed and tested in **CRF** and **Daimler** platforms.

- ***Vulnerable road users (VRU):*** this module detects, classifies and tracks vulnerable obstacles, such as: bicycles, pedestrian and motorcycles in front of the vehicle. It will be developed and tested in **CRF** platform (focus is only on pedestrian).

- ***Driver monitoring motorcycle (DMM):*** this module monitors the rider/driver in motorcycles, using one or several cameras. It will be developed and tested in **Ramboll** platform.

- ***Vehicle trajectory calculation (VTC):*** this module anticipates the future trajectory and speed based on the current performance of the vehicle. It will be developed and tested in **Volvo** and **CRF** platforms.

The information provided by perception software modules is highly important for the vehicle control, allowing the definition of use cases of control functions in DESERVE platforms [37].

1.2 Application platform

a. Driver behaviour

To infer the driver intentions is playing an increasing role in the development of vehicle control functions in ADAS applications, because the driver behaviour (e.g. distraction or concentration) is one the most sudden causes of fatal accidents [12].

Some researchers are focused in the developing of human-centric intelligent driver assistance systems, which can be based on cognitive knowledge. Usually this techniques use data base information from expert drivers, and then the driver models previously validated are compared with current driver behaviour [32].

These aspects are also considered in DESERVE, as follows:

- Driver Intention Detection (DID): this module gives information about the intention of the driver based on vehicle performance and vehicle sensors. It will be developed and tested in **CRF** platform with **ICOOR**.

- Threat Assessment (TA): this module determines the risks associated to the current situation of the vehicle. It will be tested in **Volvo, CRF and Daimler** platforms.

b. Arbitration

The arbitration in the driving process involves the necessity of sharing the control of the vehicle, between two decision makers: fully autonomous and only driver. The level of assistance provided by the autonomous vehicle to the driver might change depending on the driver’s state and on the situation to handle (imminence of danger).

The Application platform in the DESERVE architecture processes the perception horizon data in order to develop control functions and to decide the actuation strategies.

The arbitration actions and control functions can be defined in:

-IWI manager (IWI): this module will determine the action to be taken by the driver or the vehicle. The Driver Assistance Systems involve two main decision makers: when is the driver who takes the control or when the automated systems. It will be developed and tested in **CRF, Volvo** and **Daimler** platforms.

- ACC control (ACC-C): This module uses an adaptive cruise control system to keep a safe distance to other vehicle ahead. Automated brake will be activated when the vehicle detect an obstacle in the trajectory of the host vehicle. It will be developed and tested in **Volvo** platforms.

More details about arbitration will be available in D24.2 deliverable report focused on Control Strategies for sharing vehicle control between driver and ADAS systems.

1.3 Information Warning Intervention (IWI) platform

The IWI platform informs the driver in case of warning conditions, and it also activates the systems related to the longitudinal and/or lateral actions. The functional descriptions of each module are linked to: HMI, lights, lateral and longitudinal actuations. Most the actions are warning signalizations and some control functions.

a. Light control

The external lights increase the attentiveness of the drivers in unlighted or emergency situations. There are several regulations for the usage of external lights in automotive vehicles with regards to e.g. colour and illumination [36]. Light control is part of the IWI platform, and it will be tested in **Daimler** platform.

b. Lateral Control

Lateral control concerns the action on the steering wheel. The software architecture and the specific modules defined Deliverable D12.1 allow to address applications based on lateral control too, e.g. autonomous parking in which it is always necessary to have predefined trajectory.

c. Longitudinal control

Longitudinal control has been more implemented (compared with lateral control) in commercial vehicles, acting on throttle and brake pedals. Most of the longitudinal controllers read the vehicle speed and acceleration to achieve the cruise speed desired. The longitudinal control in terms of actuator control is part of the IWI platform, and it will be tested in Autonomous Emergency Brake (**CRF**) and ACC (**Volvo**) applications.

2. CONTROL LEVELS

Modern ADAS functions help drivers in different tasks or situations in the driving process. Some studies show that nowadays there are many distractions for drivers, causing multiple task overloads (e.g. GPS, panel recognition, security alarms, among others) [33].

One of the most common causes of driver distraction is the monotonous driving. It causes mental underload, which decreases the vigilance on the route and then it generates dangerous situations. Moreover, the stress, mental overload and highly difficult situations are important factors to be considered in the definition of the interaction between driver and fully autonomous functions.

The project HAVEit has obtained a pragmatic approach for the levels of assistance and automation in vehicles. Figure 1 shows the five levels defined in this project, considering driver actions and fully autonomous vehicle functions [9]. The stepwise transfer of the driving task forms the basis for optimum task repartition in the fully autonomous driving system. These levels are defined as follows:

- **Driver only**: the driver has the full control of the vehicle without any warning or assistance from the vehicle, e.g. vehicle without ADAS installed.
- **Driver assisted**: the driver still is in full control, but one co-system supports with lights or acoustic assistances, e.g. during lane change maneuvers.
- **Semi-automated**: it can integrate partial control of vehicle in some specific scenarios and/or conditions, e.g. ACC (only throttle and brake pedals) or parking assist systems (specific configurations).

- **Highly automated**: the co-system does most of the driving, but the driver is still in the loop and can take over the driving task anytime, e.g. Lane departure warning system.
- **Fully automated**: the vehicle is completely autonomous, even is difficult situations. So far, most of the systems are highly automated; therefore the driver has always the last decision.

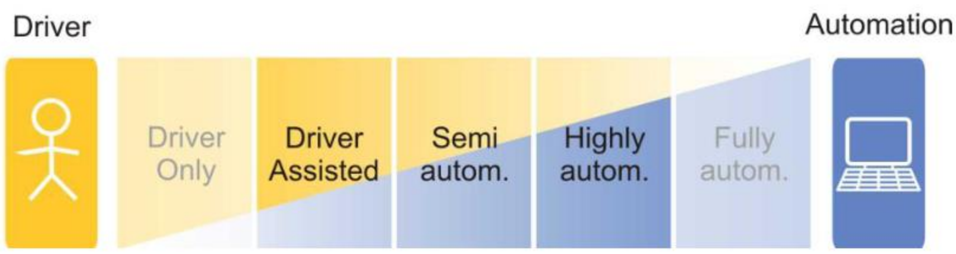

Figure 1. Automation levels considered in HAVEit project-

3. STATE OF ART

In the recent years, many safety and comfort improvements have been implemented in commercial vehicles through the ADAS, which are one of the systems most studied into the Intelligent Transportation Systems (ITS) field [1][2]. Most of these implementations are focused on constrained scenarios (e.g. Intelligent Park Assist), warning systems (e.g. Blind Spot Warning Systems or Night Vision Systems), and some partial control systems, such as Adaptive Cruise Control (ACC), Pre-crash systems and Low Speed Collision Avoidance Systems (LSCAS), among others. So far, only partial executions on driverless vehicles are available.

The last decade has been the most dynamic in the autonomous vehicle field. It is beyond of the scope of the document to explain all the projects and researches carried out. However, some of the most relevant researches and initiatives developed in Europe are mentioned as follow:

- **Project VIAC (2007-2010)**: *International travel with autonomous vehicles from Parma to Shanghai (Vislab, Parma University).*
- **Project SPITS (2008-2011)**: *Communication among intelligent vehicles. More than 100 vehicles involved in the final demonstration (TNO, Helmond - Holland).*
- **Project HAVEit (2008-2011)**: *Energy efficiency, driving comfort and control. Some of the partners are working in Deserve (7th Framework program).*
- **Cybercars-2 and CityMobil (2005-2008 and 2008-2011):** *Cooperation between autonomous, manual vehicles and Cybercars. Other projects have been started in Asia (Inria).*

- **Initiative e-Safety (2002-2013)**: *Development of intelligent vehicle safety. This initiative is working for a quicker development of smart road safety and eco-driving technologies.*
- **GCDC Competition (2009-2011)***: it was the first European completion among autonomous vehicles. More than 10 teams, from different countries.*

Other initiatives have been undertaken in the United States, such as the Grand DARPA challenge 2005 and the Urban DARPA challenge 2007, and most recently the Google Driverless Car [10], one of the most disseminated experiments with autonomous vehicles [11]. Another important demonstration was carried out by Vislab group (University of Parma), in the framework of the PROUD-Car Test 2013 event. An autonomous vehicle was guided in a mixed traffic route (rural, freeway, and urban) open to public traffic [35].

Since today international laws do not allow fully automated driving, some recent projects have started to consider the driver into the control loop. It means that the drivers can take over control in order to avoid accidents. The 7th Framework Program (FP7) HAVEit project describes highly automated driving as the next step towards the long-term vision of safe, comfortable and efficient transport for people and goods [9]. The project developed, validated and demonstrated important intermediate steps towards highly automated driving for passenger cars, buses and trucks. The architecture was scalable in terms of safety. This project is one of the pioneers considering mental overload and under load in automated assistance.

However, some non-trivial issues remained open, e.g. manage between manual and fully autonomous driving. For this reason, other concepts and problems, such as longitudinal and lateral control strategies, and their integration in the same platform, as well as an arbitration and control module, have to be included in the control architecture of the DESERVE project. This is the goal of the work package 2.4 Arbitration and Control.

Research in autonomous driving is starting to be taken also into account from automotive companies (Tier1, OEMs). For example Bosch has developed an autonomous vehicle to solve the door to door problem in urban and highways scenarios. The vehicle has the capability of switch between automated and manual driving modes. They use different ADAS in the same platform, such as: Lane Keeping Assistant, Adaptive Cruise Control e Lane Changing Assistant. Figure 2 shows a demonstration in real urban scenarios [34].

Figure 2. Bosch Automated driving

4. KEY FACTORS FOR VEHICLE CONTROL IN THE MARKET

The Advanced Driver Assistance Systems are one of the objectives of the ITS along with intelligent infrastructure and autonomous driving developments. The green, safe and supportive transportation, in particular to the accident free mobility scenarios is the major motivation for the development of ADAS systems.

Recently, the ADAS are more accepted by consumers. In [17] a study of awareness and interest of the Driver Assistance Systems and Active Safety Features on vehicle is described considering: *driver warning*, assistance and map enabled systems, *HMI* preferences and user-friendliness of current safety systems, *perceived benefits* of integration with chassis and powertrain and other future safety systems and technologies(V2V or V2I communications etc.)

Some the most demanded ADAS are: Driver Warning and Awareness systems, Driving Assistance and Collision avoidance Systems, Vehicle Stability Systems and Exterior Lighting Control, among others.

Some other motivations to the development and improvement of these systems are:

- ***Legislation***: different initiatives like European New Car Assessment Programme (Euro NCAP) have been developed recently. The most relevant advanced safety technologies are rewarded for the Euro NCAP, such as: Blind Spot Monitoring, Lane Support Systems and Emergency braking, among others [31].
- ***Cost***: Studies show that customers are willing to pay more for avoidance systems than other ADAS in their vehicles[17].
- ***Market indicator***: some of them show that the ADAS will have a high influence in market in recent years [17]. For example, in 2016 the overall

annual market for Lane Departure Warning systems is expected to reach over 22 million units/year (corresponding to 14.3 billion dollars).

- ***Safety***: on board Electronics systems have become critical to the functioning of the modern automobile, as mentioned by the national research council report [29].

The individual functions of the ADAS are designed from the beginning in such a way that they operate within a common environment. Different ADAS functions will not simply live together, nevertheless coexist and deeply cooperate by providing their assistance to the drivers simultaneously. Some of the technology availability is:

- ***Interconnections***: electronics systems are being interconnected with one another and with devices and networks external to the vehicle to provide their desired functions [29].
- ***Fusion***: new vehicle capabilities have to be adapted to the human behaviour in the driving process, and electronics, perception system information and HMI inputs become relevant in order to handle the best decision in each situation.
- ***New infrastructures***: a recent study report from the European Commission explains the need of vehicle and infrastructure systems designed for Automated Driving [30].
- ***Sensor technologies***: are becoming more sophisticated and varied, especially to support the functionality of many new convenience, comfort, and safety-related electronic systems. Some of the sensors technologies used in ADAS developments are:
  - ***Ultrasound*** (parking assist …).
  - ***Inertial sensors*** (stability control, air bag deployment …).
  - **Radar** and **Lidar** technologies (ACC, AEB …).
  - **Cameras** (Lane Keeping, ACC …).
  - **GPS** (Advanced ACC, speed advice …).

- ***HMI***: it is interaction interface between humans and ADAS functionalities. It must be understandable and easy to use, otherwise the advantages can be misunderstood by customers.

Many efforts have been recently done by different manufactures and also ARTEMIS Sub-program related to methods and processes for safety-relevant embedded systems [12]. The aim is to improve functional safety in ADAS embedded systems.

Furthermore, a special attention requires the **Human Machine Interface** (HMI) evolution. Recently, the popularization of smartphones and communication systems allow customers to be more familiar to handle touchscreen and interactive HMIs. The graphic capabilities are most demanded with real-time information in new generation vehicles. One the most remarkable is the HMI solution presented by Mercedes-Benz, focused particularly on two topics: safe operation and optimum readability of the displays in order to minimize additional driver stress during top priority driving tasks.

Manage of the over-information (board panel, smartphones, GPS, road panel, among others), when the driving process is being executed, is a challenge that all manufactures (Tier1, OEMs) are dealing with. For example, in Continental -Instrumentation & Driver HMI business unit- are developing the integration of monitoring systems to detect different driving situation. However, an arbitration that covers most ADAS solutions is needed, which is one of the contributions of the WP24 Arbitration and Control.

The wider diffused ADAS system is the ultrasonic park assist [17]. It is followed by the Adaptive Cruise Control and Stop & Go. In these systems the longitudinal control is managed only by the throttle pedal. In other low speed safety systems such as Low Speed Collision Avoidance systems the brake action is implemented too. So far, the ACC is not considering steering wheel actions. A good summary of the List of ADAS systems is presented in the Annex, Figure 8 [17].

5. ADAS APPLICATIONS FROM CONTROL PERSPECTIVE

In this section the existing control vehicle solutions are described. Each subsection is based on the requirement provided in the deliverables D11.1 Application Database and D11.2 Platform needs of the DESERVE project.

10 groups of DAS with 33 applications have been identified in D11.1 that are currently available or will be soon introduced in the automotive market:

- Lane change assistance system
- Pedestrian safety systems
- Forward/Rearward looking system (distant range)
- Adaptive light control
- Park assistant
- Night vision system
- Cruise Control System
- Traffic sign and traffic light recognition
- Map supported systems (Note: only DAS scope, no driver information)
- Vehicle interior observation

5.1 Lane Change Assistant System

The Lane change manoeuvre is one of the most dangerous situation for the drivers. Only in 2009, 13% of all accidents on German freeways (injured persons) were caused by vehicles driving laterally in the same direction, that is during a lane change manoeuvre [13]. Many manufactures develop Lane Change Decision Aid Systems (LCDAS). This system warns the driver about the dangerous lane change situation when the turn indicator is activated [14] by visual elements in the outer mirror, haptic warning signals at the steering wheel [38] or acoustic signals.

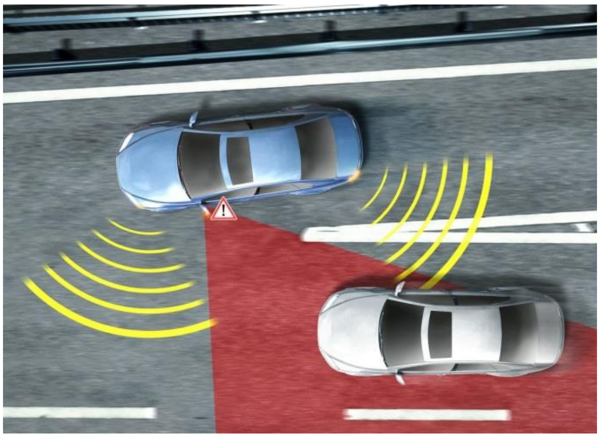

Figure 3. Blind-spot assistant ultrasonic sensors for safe lane changes

Some of the implementations of LCA systems are the Lane Departure Warning (LDW) and Blind Spot Warning (BSW) systems (Figure 3). The LDW helps the driver to stay in the same lane by alerting him of any unintended lane departure. The BSW system prevents potential dangerous situations during the lane change process, alerting the driver of unseen vehicles in his blind spot. The Lane Keeping Assistance systems (LKAS) have been developed in laboratory platforms, being the goal of manufacturers in short and medium term.

From the vehicle control point of view, both *lateral* and *longitudinal* controllers are considered. These systems are depending on sensor information (*perception of the environment*) and the arbitration control based on the *driver behaviour*.

5.2 Pedestrian Safety Systems

Pedestrian detection systems are mostly used for urban environment. The pedestrians are considered vulnerable road users, since they are not protected and even not aware about the dangerous situations.

The first pedestrian detection systems were based on stereo-vision cameras [15][16]. Different techniques were used: motion-based object detection and pedestrian recognition, which provide suitable measurements of the time to collision (TTC). The pedestrian detection can be classified like a Collision Warning System (CWS). However, since the reaction time of the driver is slow (around 2 seconds), these systems usually have access to the brake system (*longitudinal control*).

Recently, Volvo has implemented this system in many vehicle models: the new Volvo V40, S60, V60, XC60, V70, XC70 and S80. The vehicle can stop when a pedestrian or cyclists is detected in the vehicle path ahead.

These systems use Information Warning Intervention platforms to warn the driver before acting on the pedals.

5.3 Forward looking system

These systems are related to forward detection, mainly using radars, lasers, cameras, infrared sensors and, in some cases, fusing different sensors. Although most of them have automatic actions, it is not mandatory. The Forward looking system involves, at least, three main modules: object detection, decision making and actuation [15]. The first one is related to perception tasks, it means, the analysis of the environment information obtained by one or more sensors. The decision-making system estimates when and how collisions can be avoided, or what kind of object is detected. Finally, the actuation stage adapts the target commands generated by the previous stage and transforms these commands to low-level control signals needed by the respective actuators. In some ADAS applications, the action of the steering is recently considered. However, most of them use only access to the brake.

The most known and implemented forward looking systems are the Collision Warning System (CWS) and Low Speed Collision Avoidance System (LSCAS). A brief description of CWS and LSCAS is presented in annex (Figure 8, [17]). The

LSCASs available in the market are usually limited to 30 Km/h. Other Forward looking systems are as follows:

- Pre safe system
- Collision Avoidance System
- Ahead emergency braking
- Electronic emergency brake light
- Intelligent intersection (Emergency vehicle detection)
- Rear approaching vehicle (although the rear view camera is most common in park assistant systems)
- Queue warning

Perception of the environment is one of the most important aspects of the forward looking system for the vehicle control.

5.4 Adaptive Light Control

The systems are recently used in commercial vehicles. The main advantage is that the lights can be adapted to the scenario (straight and curve roads). For example, Adaptive High Beam can turn in the sense of the curves, anticipating to possible undesirable obstacles (e.g. a bicycle or pedestrians) (Figure 4).

The map supported frontal lightings are based on the ability to adapt the headlamps dynamically, turning the reflectors, according to the environment condition and using GPS information.

Continental launched an updated integrated camera-LIDAR module, the SRLCAM400. It can be adjusted to three levels: “Entry”, “Basic” and “Premium”, depending on the number of front windshields ADAS features (Adaptive Front-lighting System, Distance Warning or AEBS, LDWS and Traffic Sign Recognition).

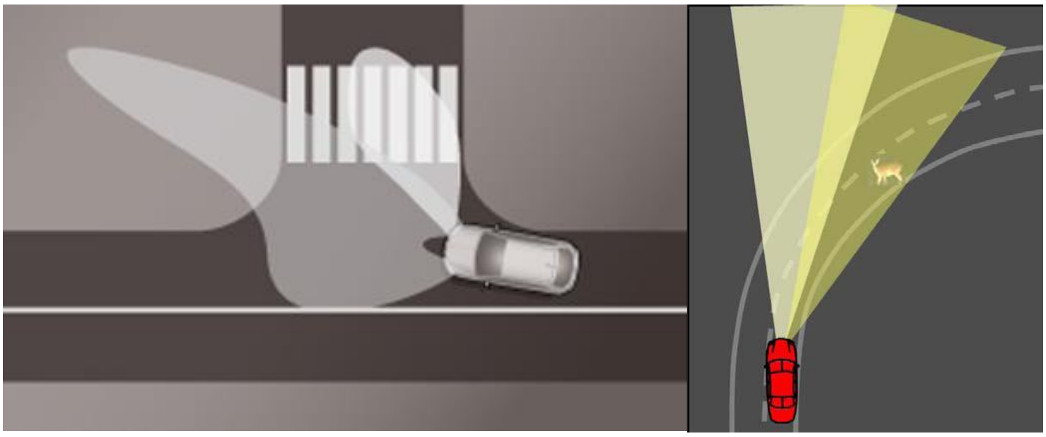

Figure 4. Example of the Adaptive Light Control

This Adaptive lights are a new control systems on-board in the vehicles to prevent dangerous situations.

5.5 Park Assistant

It is probably the most used (and demanded) ADAS today. Ultrasonic park assist systems have evolved from high-end to ordinary vehicles in few years. These systems can help in the parking manoeuvre in close-fitting spaces, by alerting the driver of rear obstacles and their distance to the vehicle.

The intelligent park assist provides easy parking by identifying sufficient parking spaces and steering the car into it. The system is always supervised by the driver, who can override the operation pushing the accelerator pedal or the brake pedal. Other parking assistant systems use rear view camera instead of, or in addition, the ultrasonic sensors. They provide a video image from the rear area of the vehicle. *Lateral* and *longitudinal* controllers are used simultaneously in these systems.

5.6 Night vision system

Night Vision Systems (NVS) permit the drivers to see in low or difficult light conditions. When weather conditions are extreme, these systems can see beyond the range illuminated by the headlights of the vehicle. The technology is based on near and far infrared cameras, which permit to illuminate the road ahead, along a spectrum invisible to the human eyes.

Many manufactures are using these technologies (Mercedes-Benz, Toyota, Audi, BMW, among others). Recently, the light vision system came off second-best in preference for car consumer option in Europe [20].

The night vision system has three basic functions: pedestrian detection, pedestrian collision warning, image display and sound warning. These systems use the information from an image which is composed with thermal radiation of objects.

Many premium vehicle brands offer different night vision systems. Most recent generation night vision systems have added pedestrian detection as a feature to assist drivers to avoid potential collisions. These are classified in near-infrared (NIR) and far-infrared (FIR) according to the regions of the electromagnetic spectrum [19]. Figure 5 shows the different models of existing night vision systems since 2000.

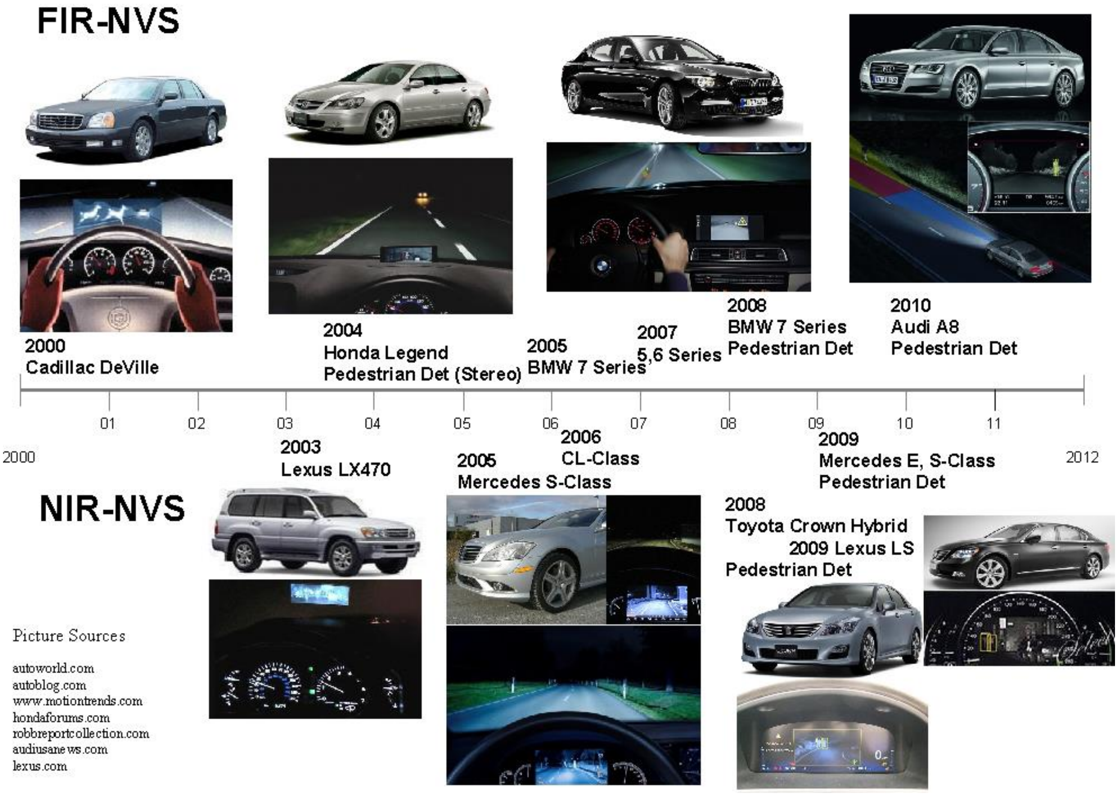

Figure 5. Night Vision System Competitive Landscape – FIR vs. NIR [19]

Perception of the environment is one of the most important aspects of the night vision system for the vehicle control in emergency situations.

5.7 Cruise Control System

The Cruise Control systems are capable to keep automatically the speed of the vehicle. Firsts CC implementations were based on controlling the accelerator pedal only (*longitudinal control*).

Adaptive Cruise Control (ACC), one of the most conventional forms of ADAS, was developed some years ago. It acts on the longitudinal control of the vehicle, permitting it to follow a leader – acting on the throttle and brake pedals autonomously – and to maintain a predefined headway with the vehicle in front.

The next step in the evolution of this technology is based on cooperation among different vehicles in order to reduce this headway between vehicles and the accordion effect in traffic jams. This is known as cooperative ACC (CACC), and it is based on Vehicle to Vehicle (V2V) and in some cases Vehicle to Infrastructure (V2I) communications.

A feature of the ACC is to maintain constant speeds in motorway driving and continuously monitor the vehicle in front, depending on traffic conditions, and start following the traffic automatically. These kinds of systems are also known as Stop & Go for low speed or urban applications.

Recently, some manufactures (e.g. Volvo) have implemented the ACC in many of their models. The goal of this system is to maintain a set time interval (or speed) to the vehicle ahead. It is primarily intended for use on long straight roads in steady traffic, such as on highways and other main roads. This system has some limitation at lowest speed than 18 mph (30 km/h). The distance to the vehicle ahead (in the same lane) is monitored by a radar sensor. Your vehicle speed is regulated by accelerating and braking (Figure 6).

Figure 6. Volvo S60 Full Speed Range Adaptive Cruise Control and a Collision Warning and Mitigation system

5.8 Traffic sign and traffic light recognition

Traffic sign and traffic light recognition deals with outdoor images, considering different techniques used in image processing and segmentation (i.e.: colour analysis or shape analysis) for the recognition of traffic signs with daylight conditions in real scenarios [23] (*Perception of the environment*).

Artificial Intelligence techniques (such as neuronal networks and fuzzy logic) have been widely used in the recognition and classification processes of the Traffic signs. Some other techniques such as template matching or more classical learning based techniques using classifiers (Adaboost, Support Vector Machines,…) were also used. Road and traffic sign recognition is one of the important fields in the ITS, due to visual language that drivers can understand on the road. Sometimes, these signals may be occluded by other objects, and may suffer from different problems like fading of colours, disorientation, and variations in shape and size, especially in images captured at night, in the rain and in sunny day conditions [22].

Different Traffic Sign Recognition (TSR) products were available since 2008 on the BMW 7 Series based on a vision system or GNSS (Global Navigation Satellite Systems) or the fusion of both [27]. The system can help the drivers to maintain a legal speed, obey to local traffic instructions, or urban restrictions. Some typical obtained information are: speed limit, no-overtaking, prohibited access, among others. The information is shown in control panel of the vehicle (Figure 7).

Figure 7. Traffic sigh recognition

5.9 Map supported Systems

Recently, another tendency is the use of digital map to support the driving process. The architectures of Map-Supported ADAS are described in [18]. They explain that Digital Map data can be classified in three levels: Non-map ADAS, Map-Enhanced ADAS and Map-Enabled ADAS*.* An example of the first one is the ultrasonic parking distance control, whereas those for the second ones are the ACC and Speed Limit Info (SLI). These systems work without Digital Map information, but their functionalities can be improved with the addition of Digital Map data. Curve Speed Warning (CSW) and Dynamic Pass Predictor (DPP) are examples of systems that need digital map inputs.

One of the commercialized applications is the map supported for Advanced Front Lighting Systems (AFLS). These are based on the ability to adapt the headlamps dynamically, by means of turning reflectors, according to the current driving situation and the environment using data stored in the map database. The other are the CC Map adaptive, which consider the automatic speed and distance control, based on the preceding vehicle in the same lane and also based on predictive information from the navigation system. Finally, the map supported Lane Keeping System (Departure Warning System) allows to keep the car within the existing lane, based on on-board sensor inputs as well as navigation system.

Map supported systems are used to inform and warm to the driver (*IWI platform*).

5.10 Vehicle interior observation

Driver drowsiness is one of the major causes of road accident. For this reason, several driver drowsiness detection systems have been implemented to warn the driver in this dangerous situation. Some of them are based on iris (eye) detection and also gaze detection (direction) [28].

Vision based eye tracking is one of the most common used technique. Other researches use electrooculogram (EOG) as an alternative to video-based systems in detecting eye activities caused by drowsiness [25]. The problem of the EOG is the difficulty to install it on the driver face (or on head) every time that they drive.

For this reason, the driver drowsiness warning systems that are available in the market are based on vision (camera) systems that monitor the driver’s eyelids to detect signs of weariness or drowsiness and alert the driver.

Other manufactures are using biomedical signals (e.g. FICOSA), which permit to characterize the driving process in order to setting different fatigue and somnolence alarms depending on the driver (it is called somnolence) [26]. These systems will be used in the DESERVE platform (see D12.1 Development Platform Requirements) for the arbitration and IWI platform.

6. REQUIREMENT FOR CONTROL STRATEGIES

Table 1 shows the requirements for longitudinal and lateral control concepts currently used for the relevant ADAS systems, based on the description presented in the previous section.

This parameter will be discussed in SP4, especially in WP 42 –Control functions- and WP44 –Control functions-, in order to select the definitive control commands to be used in DESERVE demonstrators.

ADAS application	Input Control signals	Vehicle system parameters
5.1 LCAS	Time-to-collision. Differential time-to-collision. Relative velocity. Time gap to a vehicle ahead. Speed-dependent performance of the vehicle. Desired velocity level of congestion. Average velocities.	Longitudinal acceleration. Warning signal to abort the manoeuvre. Lane Allocation.
5.2 Pedestrian Safety Systems	Time-to-collision. Pedestrian detection and tracking. Distance to the pedestrian.	Emergency braking system. Steering angle. Warning signals.
5.3 Forward looking system	Object detection. Time-to-collision. Decision making.	Warning signals. Brake system. Steering angle (recently).
5.4 Adaptive Light Control	Map supported. Vehicle position. Steering wheel position.	Adapt the headlamps dynamically. Turn the reflectors.
5.5 Park Assistant	Distance to obstacles. Vehicle position. Rear area of the vehicle	Brake pedal. Accelerator pedal. Steering wheel.
5.6 Night vision system	Near and far infrared cameras information.	Warning signals. Emergency braking system. Steering angle (recently).
5.7 Cruise Control System	Cruise speed Longitudinal acceleration Inter-vehicle distance	Longitudinal acceleration
5.8 Traffic recognition	Speed limit.	Longitudinal deceleration Longitudinal acceleration
5.9 Map supported Systems	Map supported. Vehicle position. Speed Limit Info.	Turn the reflectors. Warning signals.
5.10 Vehicle interior observation	Bio-signal acquisition fatigue state	Arbitration and control shared driving Lateral control Longitudinal control

Table 1. Requirements for longitudinal and lateral control concepts for each ADAS application.

7. CONCLUSION

This deliverable provides an overview of **existing vehicle control solutions** applied in the field of Advanced Driver Assistance Systems (ADAS), from the functional requirements point of view of DESERVE project.

In particular the main **vehicle control software modules** have been identified within the basic software architecture to be addressed by the DESERVE development framework and based on three layers: Perception, Application and Information Warning Intervention (IWI) platforms.

A classification of the **different control levels**, based on the driver actions and fully autonomous vehicle functions, was presented in section 2.

The **advances in vehicle control applications** were described, considering the 10 groups of DAS with 33 applications that are currently available or will be soon introduced in the automotive market.

The next step is to define a **Generic ADAS Control architecture** to be used in the DESERVE demonstration platforms. The lateral and longitudinal control will be considered in the next deliverables (D24.2, D24.3 and D24.4) of Arbitration and Control Work-package. Most of the solutions consider the driver in the control loop, therefore the next activities will focus on modelling of the shared control between the vehicle and the driver (semi-automated and highly automated control level).

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ANNEX

Collision Warning System	*The system provides audio and visual warning in the event of an impending collision*
Low Speed Collision Avoidance System	*This system automatic brakes in case of driver inaction at low speeds typically below 30km/hr*
Blind Spot Warning System	*The system prevents potential hazards during lane changes by alerting the driver of unseen vehicles in his blind spot*
Lane Departure Warning System	*The system helps the driver to stay in the lane by alerting him of any unintended lane departure*
Driver Drowsiness Warning System	*A camera based system that monitors the driver's eyelids to detect signs of weariness or drowsiness and alerts the driver*
Ultrasonic Park Assist System	*The system helps manoeuvring in tight spaces easier by alerting the driver of invisible obstacles and their distance to the vehicle*
Intelligent Park Assist	*Provides easy parking by identifying sufficient parking spaces and steering the car into it – the driver can override at all time and operates acceleration and brake.*
Rear View Camera System	*Provides a video image of the area behind the car enriched by the vehicle's predicted path and data from park assist sensors superimposed to the image.*
Night vision system	*A feature that provides an image of the road in front of the driver, in a display mounted on the vehicle dashboard*
Tyre pressure monitoring system	*A system that alerts the driver in the event of low tyre pressure or a flat tyre, thus averting any accidents*
Adaptive cruise control	*A feature that maintains constant speeds in motorway driving and continuously monitors the vehicle in front, thus slowing down or bringing the vehicle to a complete stop depending on traffic and the vehicle in front, and start following the traffic automatically*
Anti-lock braking system	*A system that prevents wheel lock enabling you to keep control of the car*
Curve Warning System	*A system that warns driver in advance of an approaching sharp corner based on the information stored in digital maps*
Speed alert	*Informs the driver of the current speed limit by reading traffic signs*
Map supported Advanced Frontal Lighting	*Is based on the ability to adapt the headlamps dynamically, by means of turning reflectors, according to the current driving situation and environment using data stored in the map database*
Adaptive Cruise Contro - Stop & go	*The system helps the vehicle moves forward without any action on the part of the driver, adjusts its speed and, if necessary, brakes to a halt in a speed range 0-200Km/hr*
Map supported Adaptive Cruise Control	*Automatic speed and distance control, based on the preceding vehicle in the same lane and also based on predictive information from the navigation system*
Map supported Lane Departure Warning	*Warning-based informative support assistance to keep the car within the existing lane, based on on-board sensor inputs as well as navigation system-based safety attributer input*
Seatbelt Pre-tensioners	*During a crash, seatbelt pre-tensioners restrain the occupant before the peak crash load so that the load on the occupant is reduced during the violent crash.*
Occupant Detection and Classification Systems	*Occupant classification system (OCS) not only detects the occupant but also classifies the occupant according to its weight and size. The system is also capable of detecting whether the occupant is out of position*
Dual stage airbags	*Multi stage airbags usually deploy according to the size of the occupant and/or the intensity of crash. For instance, if the crash is of low intensity, then low-risk deployment will be done.*
Seat Belt Pre-Tensioners	*Pretensioner tighten up any slack in the belt webbing in the event of a crash*
Anti-lock Braking System	*The function of an ABS system is to prevent wheel lock-up, by controlling the brake force on the wheel, in the event of a panic or emergency braking action by the driver.*
Tyre Pressure Monitoring	*System The function of a TPMS is to warn the driver in case one of more tyres are under-inflated or loosing pressure.*
Fuel Economy Systems	*Makes use of information from digital maps like curves, slopes and the positions of crossings or other stoppage points to employ a predictive strategy for optimum energy utilization*
Seatbelts	*A seat belt, sometimes called a safety belt, is a safety harness designed to secure the occupant of a vehicle against harmful movement that may result from a collision or a sudden stop*
Side Airbag	*Side-impact airbags or side torso airbags are a category of airbag usually located in the seat, and inflate between the seat occupant and the door*
Whiplash Protection	*Systems Whiplash protection system, in case of a rear-end collision, the energy is created in order to mitigate the injuries to the neck.*

Figure 8. (Figure 18 of DoW) List of ADAS systems.