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The modularisation design approach applied to the ADAS domain: the DESERVE project experience

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Abstract

The paper focuses on the innovative strength that the DESERVE platform has brought on the Advanced Driver Assistance Systems (ADAS) market in terms of major safety and economic affordability. DESERVE is a project aimed at designing and implementing a low-cost, integrated platform for ADAS: the creation of innovative software and hardware modules to be integrated in ADAS applications will pave the way to a standardization of the single components in order to achieve a full integration of diversified models despite their complexity. The achievement of such objective will end up in an increase of the reliability level of the system and in a cost reduction for ADAS functions and for development costs as well. In this paper the results of the application of the modularisation philosophy to the DESERVE platform architecture and to the HMI concepts will be presented.

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Keywords: ADAS; automotive; HMI; modularisation; safety; user interface; software architecture

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1. Introduction

Advanced Driver Assistance Systems, or ADAS, are systems that help the driver in his/her driving process: this kind of application are able in fact to detect dangerous situations and to consequently provide the driver a safety warning suggesting accident-avoiding manoeuvres, or in case of particularly sophisticated ADAS, directly implementing them. This can be considered as an issue of collaborative control between the human and the system during the supervisory control (human perception and cognition) without requiring time critical or situation critical response from the human – it can still function if human is not available (Fong 2001) (Sheridan 2002).

These applications include wide-know systems as anti-collision systems, lane change support and blind spot detection, pedestrian detection, night-vision enhancement, driver impairment monitoring and adaptive cruise control.

Is a matter of fact that nowadays the popularity of ADAS is quickly increasing among manufacturers, customers and for the whole society as well. In reason of their complexity, due to the inclusion of several heterogeneous functions provided by different manufacturers, their development requires a long time and high costs. Low cost car drivers are then discouraged of installing them. This is the reason why the DESERVE project (2012) is focused on a radical improvement of the ADAS market by means of an holistic approach for an easy integration of different software and hardware solutions as well as a redesign of the Human-Machine Interface.

Recent market studies have put into evidence that ADAS have a relevant potential for the improvement of road safety, thanks to their specific features to support the driver in critical situations.

According to a recent forecast published by ABI Research (2013), a fast growth of the ADAS market is foreseen in the next five years. At the end of 2012, the global market for ADAS systems was estimated to be around US$16.6 billion, and analysts at ABI Research forecast that the market will increase to more than US$261 billion by the end of 2020. This market growth will be possible only through the reduction of costs of components as well as the seamless integration of different functions in the same architecture (Calefato et al. 2015).

The trend towards multifunctional solutions is already fulfilled by the vehicles that are currently available on the market; however, the aspects and constraints related to functional safety and to the co-existence of driving support content (regarding the HMI aspects, for instance) require reconsideration of the overall approach adopted so far to implement these functions.

The problem faced by today automotive industry is that solutions implementing these ADAS-functions are becoming numerous, heterogeneous and provided by different suppliers, since different functions are using different sensors and vehicle actuators. It is necessary that the individual functions are designed from the beginning in such a way that they operate within a common environment, with shared resources, where the different ADAS functions will not simply “live together”, but coexist and deeply cooperate by providing their assistance to the drivers simultaneously and in an interrelated way. In this way, DESERVE will strongly contribute to make a step forward in the state of the art.

The actual “reuse” of software and platforms relies on the above concepts, which put in evidence the reasons for the DESERVE project: in the embedded platform that will be developed in the project, the addition of new functionalities will not imply the need to restart each step of the development chain from the beginning, which is currently one of the most time consuming task in the design and engineering phases. On the contrary, most of the activities, from the design up to the integration will be already available and provided at the platform level, in terms of high level “services” or “API” for the applicative layers of the new functions (Calefato et al. 2015).

2. Overview of the DESERVE project

DESERVE – Development platform for Safe and Efficient dRIVE is a research project, started on September 2012, that will finish on February 2016 and is coordinated by VTT (Technical Research Centre of Finland). It has been co-funded by the European Commission under the Artemis Joint programme and national funding agencies. The project is a joint effort of major vehicle manufacturers (Volvo, Daimler, Fiat), component suppliers (Continental, Ficosa, AVL, Bosch, NXP, Infineon, dSPACE, TTS, Technolution, RE:Lab), research institutes (VTT, ICOOR, INRIA, CTAG) and universities (VisLab, IRSEEM, ARMENIS, IKA, INTEMPORA, University of Hannover) to develop modern advanced driver assistance systems (Deserve 2012).

DESERVE aims to design and develop a tool platform for embedded Advanced Driver Assistance Systems to exploit the benefits of cross-domain software reuse, standardised interfaces, and easy and safety-compliant integration of heterogeneous modules to cope with the expected increase of function complexity and the urgent need to reduce costs (Kutila et al. 2014). These are ambiguous but highly relevant targets since number of software code rows in the modern cars is increasing exponential over the next 10 years. The DESERVE platform will provide the environment for ADAS design, development, pre-validation and even pre-certification of software and hardware modules to be integrated in ADAS applications. With safety-critical requirements considered in the design and systems development, integrated, trusted, interoperable tools and tool-chains will become available.

2.1. DESERVE innovation

The DESERVE project (2012) will provide a low cost, highly reliable, standardised Tool Platform, that can seamlessly integrate different functions, sensors, actuators and HMI to enable the development of a new generation of ADAS applications. Such a platform will be validated on emerging risk-prone use cases for the next generation vehicles, including full electrics and hybrids, as well as the integration of existing safety functions.

Since the purpose of ADAS functions is also to support the driver, an advanced human-centred design strategy will be integrated in the Tool Platform. Therefore, the developed applications will provide natural and friendly support to the driver, with proper levels of overall functional safety also during complex or emergency manoeuvres.

The benefits of the Tool Platform will be demonstrated to the stakeholders by developing different types of prototypes: urban vehicles (passenger and freight), passenger car, and long distance freight transport vehicle. These demonstrators will implement next generation ADAS such as low speed manoeuvring assistance, urban driving support, pedestrian detection and avoidance, collision mitigation, adaptive cruise control and lane keeping integration, driver monitoring, eco driving and cooperative applications.
The DESERVE key innovation aspects are briefly summarised as follows:

- A standard platform for development of a new generation of ADAS
- Natural active support as the standard intervention
- Vehicle-Driver sharing control
- Actual deployment of model-based approach including holistical driver-vehicle scenario
- Easy extension towards cooperative systems
- Flexibility at sensors/actuators/vehicles/architecture/HMI levels
- High reliability and Fail Safe
- Low cost via SW reuse and sharing of HW (i.e. standard components and interfaces)
- Decision support on heterogeneous system-on-chip-architectures (cost modelling on basic building blocks for next generation implementations)
- Virtual testing of the applications

Some of these innovation aspects are completely new, as is the virtual testing of the application; other aspects have been already considered in research projects, but only DESERVE is integrating everything in a single development platform. The advantages of the DESERVE approach are not limited to the ease of composing different applications in one single application, but in the availability of common resources, in particular related to the driver interface. This will further reduce the development cost, but it will increase also driver acceptability, since all functions will have a natural, homogeneous behaviour. The driver request to have more (because he/she is tired) or less support could be easily extended in natural way to all support functions, without requiring a specific set up of each one.

Furthermore, the support will be adapted to driver needs, state and behaviour, considering also the environmental conditions (weather, visibility, traffic, type or road, road condition, etc.).

DESERVE will allow safe evolution of the ADAS solutions towards full driver support, including autonomous manoeuvres in specific scenarios, such as automatic parking, supervised autonomous driving on highways or Stop & Go in congested traffic. Due to the safety requirements the current approach is to build monolithic solutions, completely closed, and extensively tested to fulfil such safety requirements. The aim of DESERVE project is to avoid such a scenario, with the development of a safe architecture together with safety-qualified components. Modern methods for efficient modular software development such as model-based design are not yet available for advanced driver assistance systems. DESERVE modules will be developed on a reusable and easily extensible rapid-prototyping development platform. To get reusable and hardware independent software modules some meta information about the HW characteristics of the software modules must be added to the module description already in an very early stage and a high abstraction level.

3. DESERVE architecture

To master the complexity of multiple driver assistance and driver task automation functions in one in-vehicle platform and to come to seamless integration of new functions, DESERVE takes a highly modular approach in the software architecture for the in-vehicle platform. The project will not provide open libraries for automotive industry but rather the common methodology to reach the modularisation aims for reducing development costs. The modularisation of the in-vehicle platform is approached from two perspectives: streaming data perspective (data model) and activity perspective (activity model).

The first perspective on modularization is the streaming data perspective (Figure 1). Data streams from sensors in raw and/or pre-processed form to software modules that build the perception of the vehicle state and status and the theatre the vehicle is driving in (perception layer). Perception related data streams to software modules that assess the vehicle state and status and the theatre, and generate and execute plans. Application related data streams to software modules that transform decisions into actuation strategies and the corresponding actions. The action generate for informing the vehicle driver in case of warning conditions and activating the systems related to the longitudinal and/or lateral dynamics.

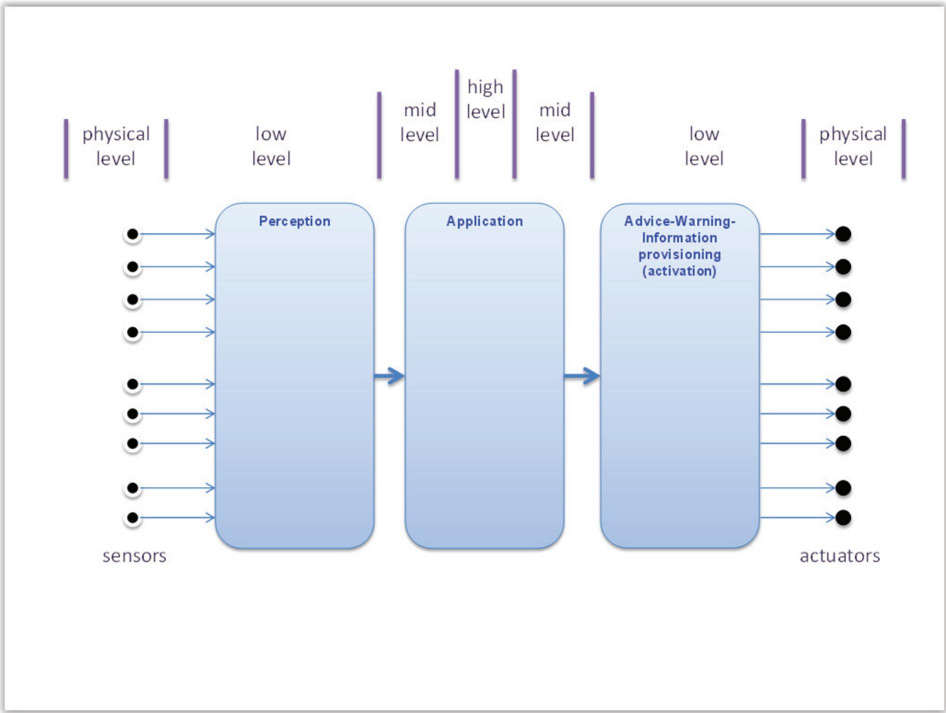

Fig. 1. Modularisation of ADAS functions from streaming data perspective.

The second perspective on modularization is the abstraction in reasoning by the software modules. As depicted in Figure 1 already, four abstraction layers can be distinguished: 1) Physical level: processing sensor data and controlling actuators; 2) Low level: animate the physical world and collect its dynamic state; 3) Mid-level: execute driver assistance; 4) High level: capture and meet the dynamic driver assistance objectives.

The abstraction in reasoning perspective is illustrated in Figure 2.

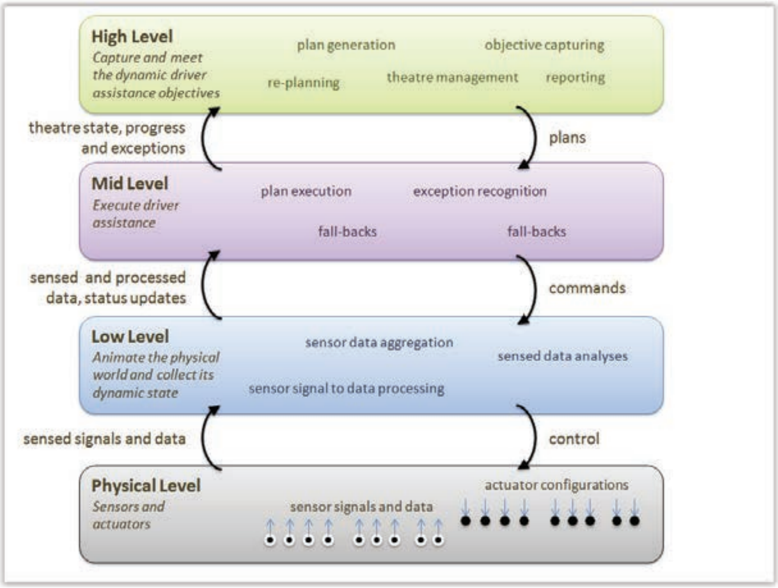

Fig. 2. Modularisation of ADAS functions from abstraction.

Fitted in the vehicle both approaches give us modular software architecture for the in-vehicle platform, as depicted in Figure 3.

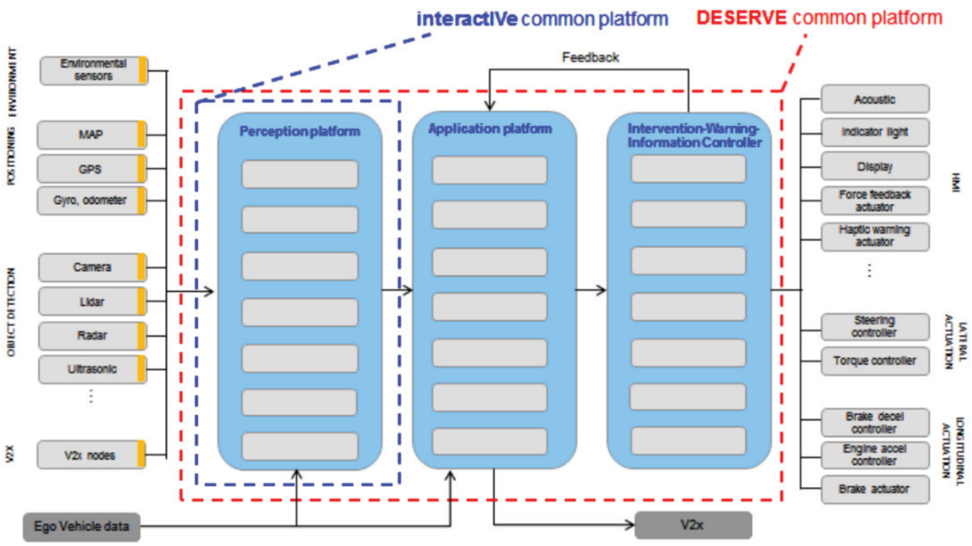

Fig. 3. DESERVE's in-vehicle platform software architecture.

Another advantage of modularisation of the software architecture is the possibilities to reduce development time and the overall costs of components. Developing new ADAS functions comes with two main cost drivers: (i) developing software for the new function and (ii) transferring the new software to target hardware. New or enhanced driving assist functions have to be tested on dedicated prototype hardware, due to the underlying real--time-conditions of a (pre)developing and testing phase. Afterwards the algorithms have to be transferred to the series product specific target hardware, entailing a redesign and recoding to the new hardware structure. Again very expensive test and verification cycles have to be performed with these implementation levels before start of production occurs (Calefato 2015).

Modularisation increases the possibilities to reuse well tested and proven modules in the software for the new function. It also increases the possibilities to reuse existing, fully industrialised sensors and – especially on the levels of drive train control (physical level) and drive command generation and validation (low level) – embedded ECU components, as illustrated in Figure 4.

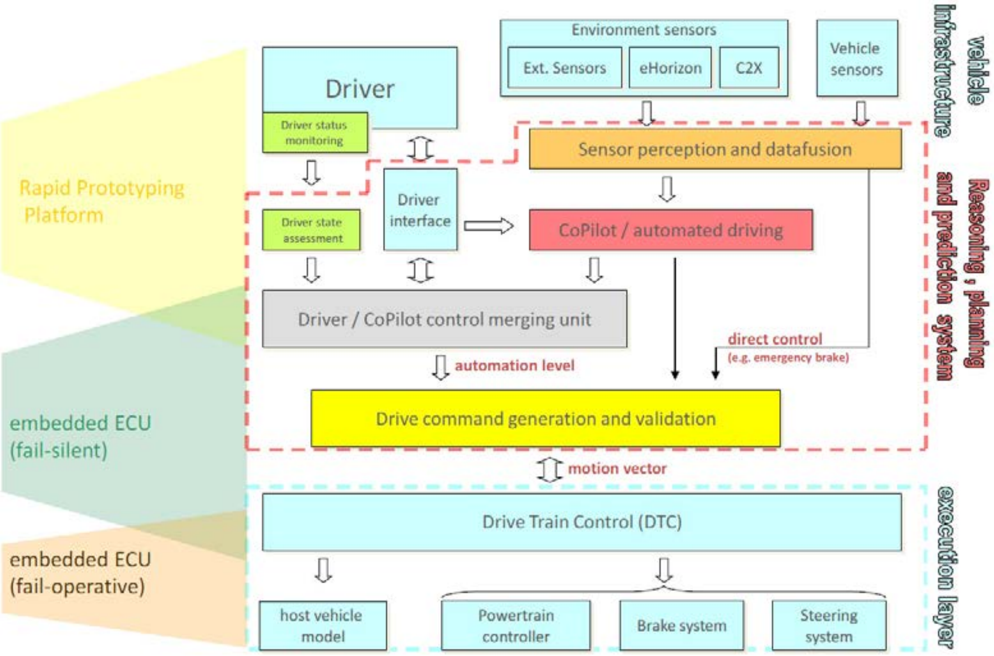

Fig. 4. Reuse of ECU components on ECU components on the levels of drive train control and drive command generation and validation (HAVEit, 2011).

4. DESERVE HMI concept

The modularisation design philosophy has been applied also to the HMI concept. The user interface of sixteen ADAS and safety-related functions has been designed in a modular way, in order to define an HMI concept able to support different function configurations. The encompassed functions are: Lane change assistance system; Night vision system with pedestrian detection; Rear view camera system; Surround view; Lane departure warning; Pedestrian safety system; Collision warning system; Emergency braking ahead; Rear approaching vehicle; Adaptive high beam assist; Adaptive cruise control; Curve warning system; Intelligent park assist; Traffic sign recognition; Driver impairment warning system; Navi/Map info; Setting menu.

This study led to design three HMI concept, each of them with different modularization features. A focus group with target users allowed to assess the different HMI concepts having a general evaluation with perceptions about utility, facility to use, facility to learn the concept, if it is clear, intuitive, if its functions are accessible and if they think it can annoy drivers.

4.1. Concept 1: Holistic HMI

In the Holistic HMI concept all the HMI elements (I/O) are centralized in front of the driver. The Instrument Panel Cluster (IPC) is the main visual output channel, while the steering wheel (SW) is the main input channel.

The HMI elements are listed as follows: i) IPC display 12"; ii) SW commands; iii) Left stalk commands; iv) Buttons; v) Knobs.

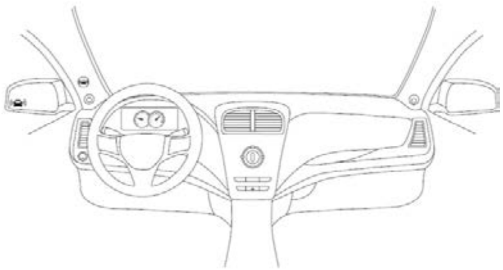

Fig. 5. Holistic HMI concept.

4.2. Concept 2: Immersive HMI

The second concept is totally different from the previous one. While the Holistic HMI Concept centralizes all the info and the interaction with the driver in front of him/her, the Immersive HMI Concept distributes the interaction along the dashboard and the windscreen.

The HMI elements of concept 2 are listed as follows: i) The HMI elements of concept 3 Display 3.5" in the IPC; ii) Touch Display 8.5" in the dashboard; iii) Head-up display for the windscreen; iv) SW commands; v) Left stalk commands; vi) Buttons; vii) Knobs.

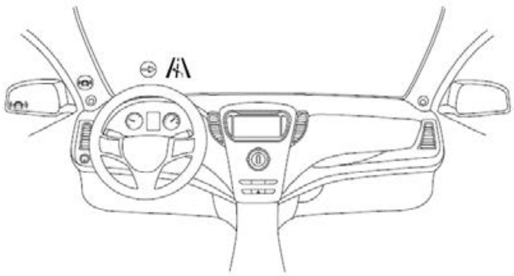

Fig. 6. Immersive HMI concept.

4.3. Concept 3: Smart HMI

The third concept replaces the dashboard display with a nomadic device (ND – i.e. smarthpone/tablet). The HMI can reconfigure itself according to ND size.

The IPC display has the same structure of that one of Concept 2. The difference is that in the Smart HMI concept the 3.5" display of concept 2 was integrated by adding, for example, a 7" tablet (as in Figure 7) seamlessly connected with the car system. Drivers just connects the phone with a cable and immediately s/he gains access to ND applications using dashboard/steering-wheel buttons. The ND can provide also the access to further automotive applications. Driver can define what kind of information has to be shown in the ND: the ND is able to manage the infotainment functions and some ADAS applications.

The HMI elements of concept 3 are listed as follows: i) Display 3.5" in the IPC: ii) Touch Display of the nomadic device set into the dashboard; iii) SW commands; iv) Left stalk commands; v) Buttons; vi) Knobs.

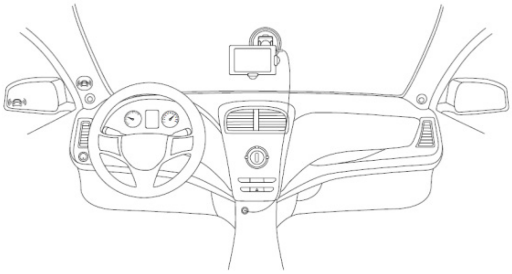

Fig. 7. Smart HMI concept.

4.4. Focus Group results

Participants rated the degree of utility and the easy to learn aspect for each HMI concept. The first proposal got the best average score, Concept 2 had the second best score, while Concept 3 was considered just acceptable.

Visual clarity is one of the most important issues to have in mind when talking about HMI concepts: evaluating this aspect, users expressed their preference for the first proposal, but Concept 2 was not far away. Concept 3 had the worst value. About intuitiveness the most appreciated concept was Concept 2, while concerning the degree of accessibility the first option excels over the others possibilities. Concept 1 was also considered the less intrusive (Assessment of the degree of Driver Annoyance).

After having in mind the previous issues, participants scored the global concept and Concept 2 is the first option chosen followed by Concept 1. Concept 3 obtained the lowest scores.

Summing up users comments and feedbacks, the most positive aspect of Concept 1 was that information was located in a defined zone. On the other hand users expressed the doubt that having all the information condensed in the same site could distract the driver, requiring extra attention to manage it. Moreover, it should be necessary to have in mind if providing the information in the same area could be a problem if steering wheel hides part of the information.

Main positive issues for Concept 2 were to include HUD information and have secondary information separated from primary information. But at the same time, having information in different positions could be a drawback too. Mainly, some participants pointed out that having information like night vision in central column or move controls regarding driving to the central column was not a good idea.

Users appreciated flexibility of the configuration available in Concept 3, because you could place tablet wherever you wanted. Moreover, the surface to show information in the windshield was bigger. Nevertheless, this concept was the less appreciated and it was considered not very pleasant from an aesthetically point of view.

5. Conclusions and future works

This papers describes the modularisation approach in the design of the DESERVE tool platform and HMI for the development of embedded Advanced Driver Assistance Systems. The aim of the DESEVE platform is to exploit the benefits of cross-domain software reuse, standardised interfaces, and easy and safety-compliant integration of heterogeneous modules to cope with the expected increase of function complexity and the urgent need to reduce costs. To meet this goal, the specific needs of stakeholders (OEMs, suppliers, developers, end users), together with the safety critical requirements, have been taken into consideration during the design and system development process. Deserve findings will pave the way to the creation of a European standard reference technology platform and an innovation ecosystem for European leadership in ADAS embedded systems, based on the automotive R&D actors, with possible applications in other industrial domains.

The platform has been designed in compliance with the human-cantered design methodology and the consideration of human factors in the design process will result in an application compliant to the end users' needs.

The expectations of the development of the DESERVE integrated platform is a growth of the ADAS market, thanks also to the definition of a smoother, user friendly HMI and a consequent more popular use of integrated safety functions. At this aim different HMI concepts have been designed and preliminary evaluated by target users during a focus group. The focus groups results let us to identify the most effective concepts (namely "Concept 1: Holistic HMI" and "Concept 2: Immersive HMI") that are going to be tested in next weeks by an in-depth usability test. The usability test will involve 24 users that will be engaged in executing four driving tasks at the driving simulator that will allow them to assess the effectiveness of both HMI solutions.

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References

ABI Research, 2013. *Forecasted US$ 260 Billion Global Market for ADAS Systems by 2020*, London, United Kingdom – 17 Apr 2013, available at: https://www.abiresearch.com/press/forecasted-us-260-billion-global-market-for-adas-s consulted on the 14th January 2015.

Calefato, C., 2011. Designing the Trustiness: Driving and Driver Models for the Design of a Cognitive Framework Supporting Adaptive Safety--Critical Applications (Supervisor Prof. L. Console), PhD Thesis, University of Turin, available at http://www.di.unito.it/~phd/documents/tesi/XXII/calefato.pdf.

Calefato, C., Ferrarini, C., Kutila M., Landini E., 2015. Development of cost efficient ADAS tool platform for automotive industry, in *Proceedings of 22nd ITS World Congress, 5–9 October 2015*, *Towards Intelligent Mobility – Better Use of Space*, Bordeaux, France.

DESERVE Project, 2012. *Development platform for Safe and Efficient dRIVE*, project co-funded by the European Commission under the Artemis Joint programme and national funding agencies, http://www.deserve-project.eu/.

Fong, T., Thorpe, C. and Baur, C., 2001. Collaboration, Dialogue, and Human-Robot Interaction, in *Proceedings of the 10th International Symposium of Robotics Research*, November, Lorne, Victoria, Australia.

HAVEit Project, 2011. *Highly Automated Vehicles for Intelligent Transport*, European-funded project within the 7th Framework Program, www.haveit-eu.org, 2011.

Kutila, M., Pyykönen, P., van Koningsbruggen, P., Pallaro, N. & Pérez-Rastelli, J., 2014. The DESERVE project: Towards future ADAS functions, in *Proceedings of the International Conference on Embedded Computer Systems: Architectures, MOdeling and Simulation (SAMOS XIV)*. Samos, Greece. 14–17 July 2014. p. 308–313.

Sheridan, T., 2002. Humans and automation: System design and research issues. New York: Wiley.