HoliDes newsletter

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Intro

HoliDes addresses development and qualification of Adaptive Cooperative Human-Machine Systems (AdCoS) where many humans and many machines act together, cooperatively, in a highly adaptive way. This means that they adapt to each other and to the context to guarantee fluent and safe task achievement. Such systems with higher levels of automation are urgently needed to enhance safety and to increase the confidence of human operators. However, adaptiveness is still limited in many domains and Automotive is one of them.

In this second number of the HoliDes newsletter, we focus on the HoliDes results and objectives in the Automotive domain. We present two of our Automotive demonstrators, the Lane Change Assistant AdCoS and the Adapted Automation AdCoS. Such AdCoS are conceived to adapt not only to the external environment (e.g., to road and traffic conditions) but, most importantly, to the current driver state and behavior. Indeed, one of the main distinctive traits of our project is to bring adaptiveness to human factors aspects in embedded systems. We then provide some details of an innovative technique for the real time detection of the cognitive state of the driver. Finally, we present an integrated architecture for designing, simulating and testing AdCoS in the Automotive domain, the Virtual Human Centred Design platform, which is under development in our project.

Enjoy!

In this issue:

The Lane Change Assistant AdCoS

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In the Automotive context, one of the HoliDes AdCoS to be developed is a **Lane-Change Assistant (LCA) system**. Such a system (the machine agent) is able to suggest an "optimal" maneuver, by means of specific warnings, advice and information, according to the visual or cognitive state and intentions of the driver (the human-agent), as well as to the external environment. Figure 1 illustrates the lane change scenario to be addressed.

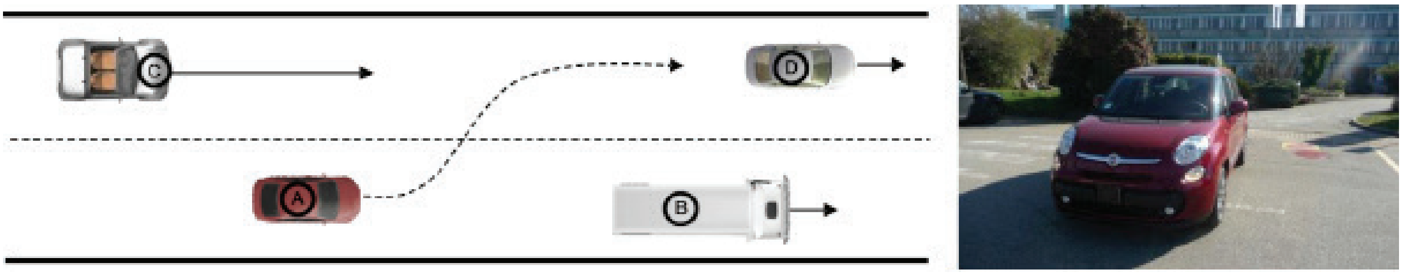

Figure 1. Representation of a Lane Change scenario. The precondition is that agent A is driving faster and approaching a slower vehicle (B) on a straight road. The successful end-condition is that the Lane-Change (LC) maneuver, and then the overtaking, is performed without risks and taking into account the driver's state.

The Lane Change Assistant system is implemented on the CRF (Centro Ricerche Fiat) test-vehicle, which is a Fiat 500L (see the right part of Figure 1), with the following sensors installed on-board:

External camera to detect the edges of the lanes on the road and the relative position of the ego-vehicle in the lane.
Internal camera to detect the head position of the driver (and where he/she is looking at).
Laser-scanner sensors (four in total: one in the front, one in the rear, one in the left side and another one in the right side of the vehicle) to provide a real-time estimation of the current traffic situation.

The following functionalities are implemented:

- **Lane-Change Assistant (LCA)** and **Overtaking Assistant (OA)**.
- **Forward Collision Warning (FCW)**, including assisted braking.

The principle is to model the AdCoS of CRF as an MDP (Markov Decision Process), where the classification of distraction is the "trigger" for the adaptation, in order to construct optimal Warning and Intervention Strategies (WISs). In fact, depending on the cognitive state of the driver (if he/she is distracted or not) and on his/her intentions (the will to change lane), the strategies of the AdCoS are modified.

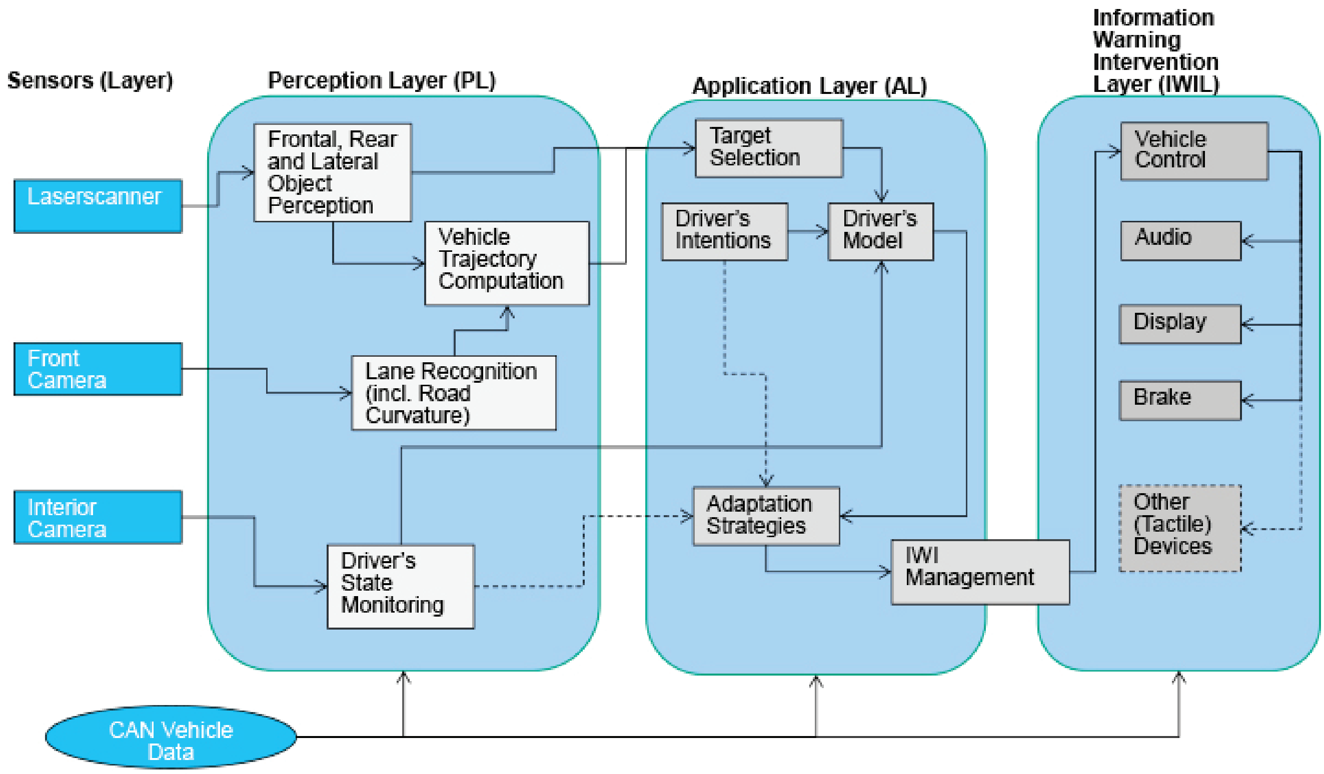

Figure 2. Architecture of the LCA system implemented in CRF demonstrator.

The architecture of the LCA system is shown in Figure 2. The elaboration process of such a system can be broken down in four stages:

the perception of the traffic environment around the host vehicle in real-time,
the assessment and interpretation of the current traffic situation,
the planning of appropriate maneuvers and actions and
the action to control the vehicle and guide it safely along the planned trajectory

In particular, the **Driver's State Monitoring module** classifies if the driver is visually distracted or not (determining distraction of the driver from vehicle dynamic data). On the other hand, the **Driver's Intentions module** estimates the driving characteristics and intentions (e.g., the wish to change the lane and to overtake, based on Bayesian Dynamic Networks model). These two inputs are used by the **Driver's Model** block – named **"Co-pilot"** – which is the artificial intelligence able to adapt its behavior, minimizing the risk of a required take-over. Thus, the focus of development is on the adaptation of the assistance system, according to the distraction and intentions of the human driver.

The last part of the system architecture of Figure 2 illustrates the Human **Machine Interface (HMI)**, which aims at presenting the information to keep the driver informed about the interpretation of the traffic situation, as well as the planned and suggested maneuvers.

Finally, all these modules (or MTTs – Methods, Techniques and Tools) are integrated together through RTMaps, which is a software framework, allowing to easily and efficiently interconnect data streams of the different tools and models. At this global level, RTMaps software is also able to support and integrate data processing algorithms, with capacities for synchronized recording and playback functions, of any kind of streams.

The Adapted Automation AdCoS

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Many research institutes, universities and car manufacturers and suppliers have presented prototypes of automated vehicles that are capable of guiding themselves, even in complex traffic situations. Nevertheless, there are quite a few remaining challenges to solve before this technology is brought to mass production and to bring these systems from a technological showcase to an ergonomic product.

Figure 3. Aspects of Intuitive Driving in the Adapted Automation AdCoS

Improving the usability and the user acceptance is the main focus of the HoliDes research performed for the **Adapted Automation AdCoS**, to be developed within Ibeo Automotive Systems GmbH. A human-centered design of the interaction between the driver and the machine agent is addressing these issues in order to move towards the "**Intuitive Driving**" paradigm. We are targeting four main aspects of our AdCoS, as illustrated in Figure 3:

1. **Fluent Task Transition.** A fluent transition between manual and automatic driving allows the driver to shift lateral and longitudinal control to and from the machine independently, at any time. The driver uses the traditional control elements – pedals, steering and indicators – to interact with the machine agent.
2. **Intention anticipation.** The machine agent anticipates the intention of the human driver from minimal interactions on the control elements. It allows the driver to interact with the vehicle at a maneuvering level and leaves the low level vehicle control to the vehicle.
3. **Adaptation.** During periods of manual driving, a driver model estimates the characteristics of the human and adapts the automation accordingly. Also the automated driving is adapted according to the situational awareness of the human in order to minimize the risk of a required take-over while the driver is distracted.
4. **Advanced HMI**. An HMI keeps the driver informed about the interpretation of the current traffic situation and planned maneuvers. It allows the driver to confirm or reject planned maneuvers and creates transparent behavior of the automated system. Information is presented to the driver dependent on the current traffic situation and the awareness of the driver.

The reference architecture of the Adapted Automation AdCoS is illustrated in Figure 4. The *Human Driver* and the *Machine Agent* act in parallel. At any time, either of the two agents controls the vehicle fully or partially. The Machine Agent (the red part of Figure 4) represents the artificial intelligence to guide the vehicle. It provides a real-time estimation of the current traffic situation based on laser scanners, an interpretation of the situation, planning of suitable maneuvers as well as the control of the vehicle. Research in this field focuses on the development of a motion planning that allows for adaptation to the state of the human driver and the external situation context.

Three dedicated modules are implemented to achieve a convenient interaction between the Human Driver and The Machine Agent:

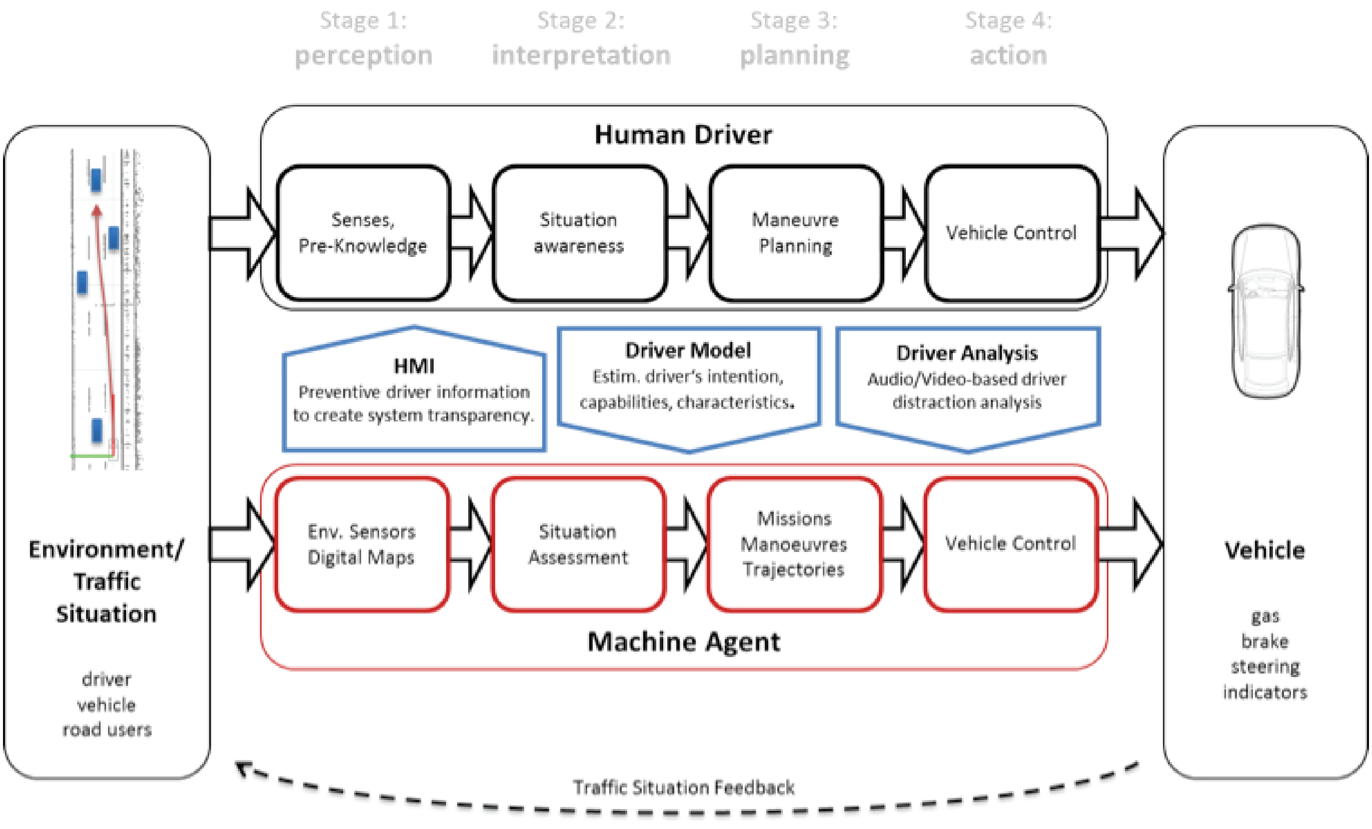

Figure 5. The Adapted Automation AdCoS architecture

1. The **HMI** presents situation-dependent information to keep the driver informed about the interpretation of the traffic situation and planned maneuvers.

2. The **Driver Model** estimates the driving characteristics and intentions from manual control inputs of the human driver and provides these to the artificial intelligence. Maneuvers are selected accordingly and the driving style is adapted to the individual characteristics of the driver. The focus of development is on the adaptation of the automated vehicle according to the manual driving style of the human driver.

3. The **Driver Analysis** estimates the distraction of the driver. The distraction estimation is used to adapt the machine agent's behavior in order to minimize the risk of a required take-over. The distraction estimation is based on inner-vehicular audio and video analysis. Research in this area focuses on determining distraction of the driver from inner vehicular sensors.

Real-time detection of cognitive distraction of the driver based on in-car recordings

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Figure 6. Unconscious shifts of attention can happen easily during driving due to cognitive distraction.

Imagine you are driving a car. You are on the highway, take your hands off the steering wheel, which signals the car to drive autonomously. You lean back and while your car overtakes several other cars and subsequently steers you back to the right lane. At your preferred speed of 140 km/h you actively observe the scene and your car's behaviour and are ready to take back the control over your car at any time. Suddenly, one of your children in the back seat starts to cry; she seems to be sick. You shortly turn around trying to help her relying on the car's autonomous function. While you are looking at the street, trying to visually attend to the traffic, you think about how you can help your daughter and you weigh several possibilities in your mind assessing the pros and cons of each alternative. Your car notices that you are distracted, not only visually but also cognitively. Therefore it now abstains from overtaking and keeps somewhat more distance to the car in front in order to assure more reaction time in case you abruptly need to step in into the driving activity.

How did your car notice that you were cognitively distracted at that moment and how could it use this information to ensure a safer driving?

TWT GmbH Science & Innovation is investigating the question *how to detect the level of cognitive distraction of the driver in real-time*, with the aim to develop a **computational cognitive distraction detection model**. Distraction is inattention to a primary task (e.g., driving), due to the presence of a triggering event or activity, (e.g., a crying child in the back seat or a conversation with a co-passenger). When people perform two complex tasks simultaneously, these tasks might be competing for cognitive resources available. The brain then shifts its focus, which might also occur unconsciously. *Driving performance can thus be affected when filtered information is not encoded into working memory and therefore critical warnings and safety hazards can be missed* (Figure 6). This kind of cognitive distraction of the driver might visually not be obvious and therefore sophisticated technology is necessary for its detection.

Figure 7. Cognitive distraction is computed based on driver's audio, face-tracking, and behavioural data

In order to detect these subtle differences in everyday driving situations, TWT analyses in-car **audio signals** (i.e., voice data) and combines this information with **head pose** and **face tracking** information as well as **behavioural driving data** (in case the driver him/herself is driving and not the autonomously driving car) (Figure 7).

In a number of experiments using a driving simulator, behavioral driving, video and audio features correlating with the level of the driver's cognitive distraction are collected (Figure 8). In the first phase, subjects have the task to solve mathematical problems while trying to keep the driving distance to the pace car constant. From these experiments, specific features will be extracted that have a high prediction rate for the distraction degree of the driver. E.g., blink rate is a promising feature, because it is known to increase when someone is cognitively distracted. These features will be used to train the model in estimating the degree of the driver's distraction. In the second phase, we will train and test the model during conversations of the driver with co-passengers during active driving. This more natural condition will enable a more thorough acoustic analysis based on features such as the number of speakers, information about the driver's involvement in the conversation (e.g., whether the driver him/herself is speaking), and possibly the degree of emotional content.

The overall aim of the cognitive distraction model is the development of a mobile user profile computing the individual distraction degree. Additionally, the model can be applied in other systems. For example, **the Adapted Automation AdCoS developed by Ibeo** (see previous section of this newsletter!) adapting it's driving style in order to drive less risky when the driver is distracted, by leveraging the model herein described and developed by TWT in the Driver Analysis module. Adapting the behaviour of a system to the operator's cognitive state enhances the cooperation between humans and machines and should lead to less accidents and overall increased safety on the road.

Figure 8. The TWT driving simulator, used for experiments to assess features correlating with the cognitive distraction degree of the driver.

A Virtual Human Centred Design (V-HCD) platform of Adaptive and Cooperative Systems (AdCoS) for Automotive

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We aim to support the virtual design process of future AdCoS for Automotive in charge of monitoring risks due to visual distraction. In this context, the challenging design issue in HoliDes is to develop an integrative platform interfacing (1) *a human driver model* (using a "virtual eye" for road scene scanning) able to drive (2) a *virtual car* equipped with (3) a *virtual AdCoS*, for progressing in (4) a *virtual road environment*.
From this approach, it is expected to better integrate end-users' needs in the design process: that's why we called such an integrative architecture **"Virtual Human Centred Design (V-HCD) platform"**.

Figure 9 provides the platform overview. Actually, the V-HCD platform resembles an example of a tailored Human Factor – Reference Technology Platform (HF-RTP) dedicated to the automotive domain, developed in HoliDes to the aim of supporting the virtual design of advanced adaptive and cooperative driving aids.

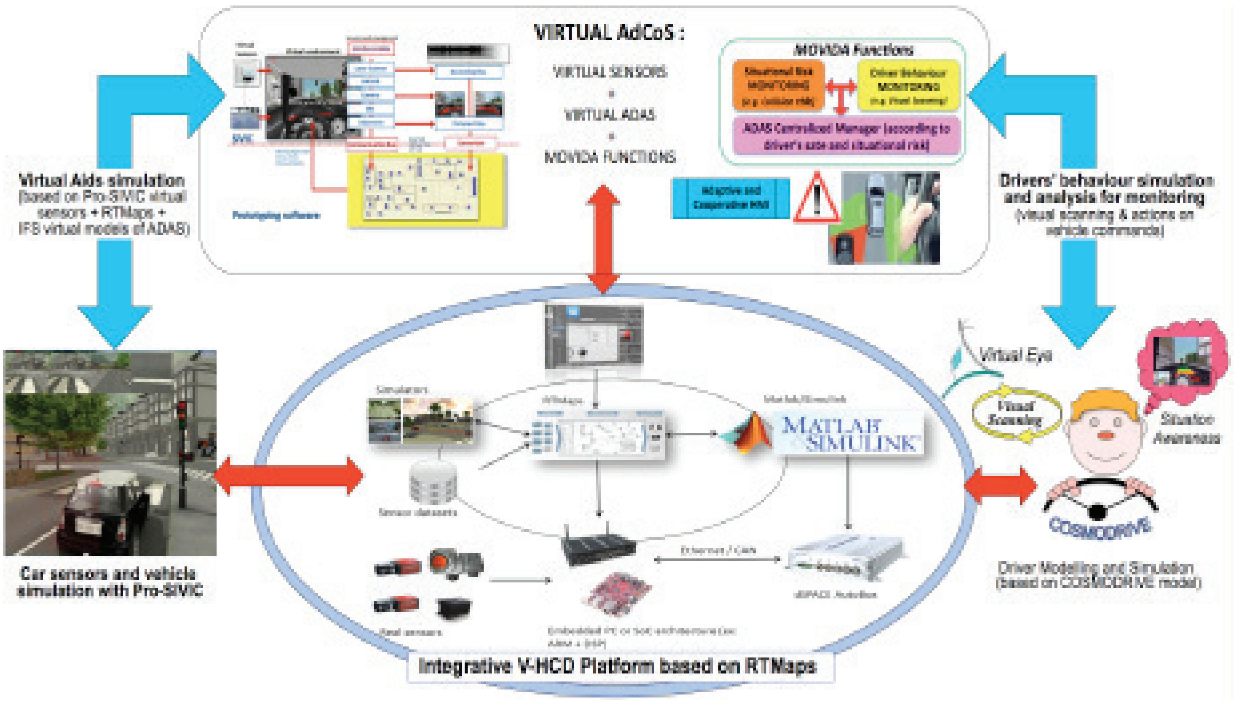

Figure 9. The V-HCD Platform as a tailored HF-RTP in HoliDes for the automotive domain

The actual human-centred part of this integrative platform is represented by the **COSMODRIVE** model (**COgnitive Simulation MOdel of the DRIVEr**), on the right part of Figure 9. COSMODRIVE is in charge of simulating human drivers' visual strategies, cognitive processes and driving behaviours (including errors). This driver model is able to drive a virtual car in a 3D road environment simulated with the **Pro-SIVIC®** software (see the left part of Figure 9). Pro-SIVIC® is also used to simulate car embedded sensors that are connected, by means of RTMaps, to a virtual AdCoS. **RTMaps** (the core of Figure 9) is a software allowing to easily and efficiently interconnect data streams of the different tools and models, such as simulators, car sensors or actuators, simulated HMI or end user models, already introduced in the above

newsletter sections. As it can be seen by looking at the top of Figure 9 (and detailed in Figure 10), the **AdCos** considered by the V-HCD platform involves a set of virtual Advanced Driver Assistance Systems (**virtual ADAS**) developed by IFSTTAR with Pro-SiVIC® Research. Examples of the considered virtual ADAS are *Collision Mitigation/Avoidance* systems, *Lane Keeping Assistant* and *Lane Change Assistant*. Besides the aforementioned ADAS, there is the **MOVIDA** module (**MOnitoring of VIsual Distraction & risks Assessment**). MOVIDA is in mainly in charge of monitoring and assessing the driver behaviour and the current situational risk. Thanks to such a functionality, it is possible to have the AdCos interacting with the driver in an adaptive and cooperative way, i.e., according to the situational risk and driver's errors. In a virtual simulation environment, the driver is represented by means of the COSMODRIVE model.
When using a driving simulator, the driver is the actual simulator user.

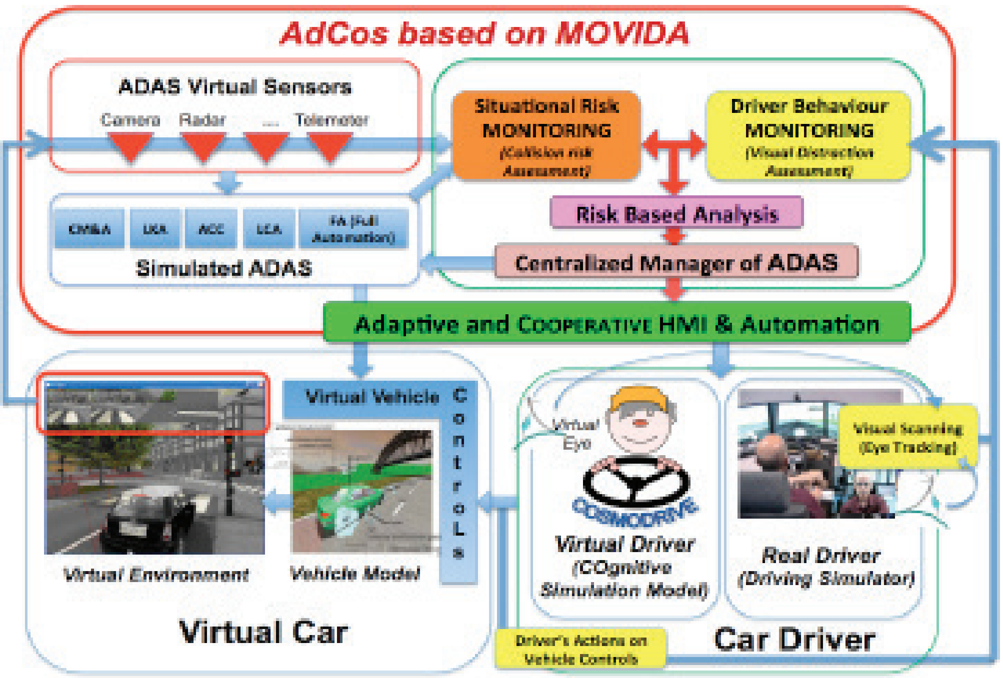

Figure 10. Functional architecture of the AdCoS based on MOVIDA

From the technological point of view, the core advantage of the V-HCD platform is to support the virtual prototyping and simulation of ADAS and then AdCoS in a very realistic way (from car sensors to fully fledged adaptive and cooperative systems simulations). From the Human Factors point of view, thanks to the exploitation of the COSMODRIVE model of the driver, the core advantage of the V-HCD platform is to allow for a better integration of end users' needs in the AdCos design process. That benefit can be seen at two main levels.

First, at the earliest stages of the V-Cycle design process (Fig. 11), COSMODRIVE-based simulations can be used to assess driving performances and situational risks due to visual distraction, for example in case of unassisted driving. Through these simulations, it is possible to identify some critical driving scenarios and to provide ergonomics specifications of real human driver needs in the form of a set of use cases that need to be, at last, avoided or solved by the future AdCoS. Both critical driving scenarios and future use cases are stored in a so-called "Reference Database".

Second, during the virtual design process of the AdCoS, the reference database can be used to progressively increase the efficiency of the AdCoS, in accordance with the different variations of the critical scenarios previously identified. Such simulations will allow the designer to assess the potential effectiveness of ADAS and MOVIDA functions, before developing a final integrated prototype of the AdCoS, and then testing its effectiveness among real human drivers through full scale tests with end-users implemented on driving simulator (final stage of the V-Cycle design process).

In addition (Figure 12), connection with other WP4 MTTs of HoliDes (like Djnn from ENAC or GreatSPN from University of Turin) may be also used to support AdCoS verification and validation at a virtual level, in association with RTMaps dynamic simulation functionalities and/or through shared databases of collected/ simulated driving data. RTMaps could also support the transfer of the virtual AdCoS toward real cars, and/ or for empirical data sharing with the HoliDes automotive demonstrators shown in the previous sections.

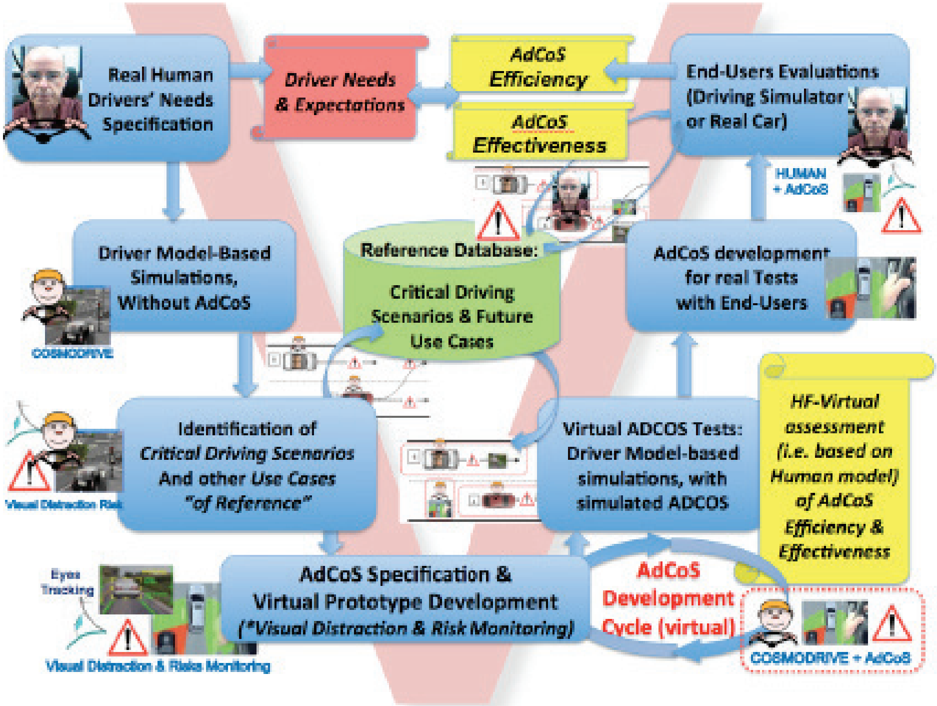

Figure 11. Use of the V-HCD platform for virtual design and test of AdCoS for Automotive

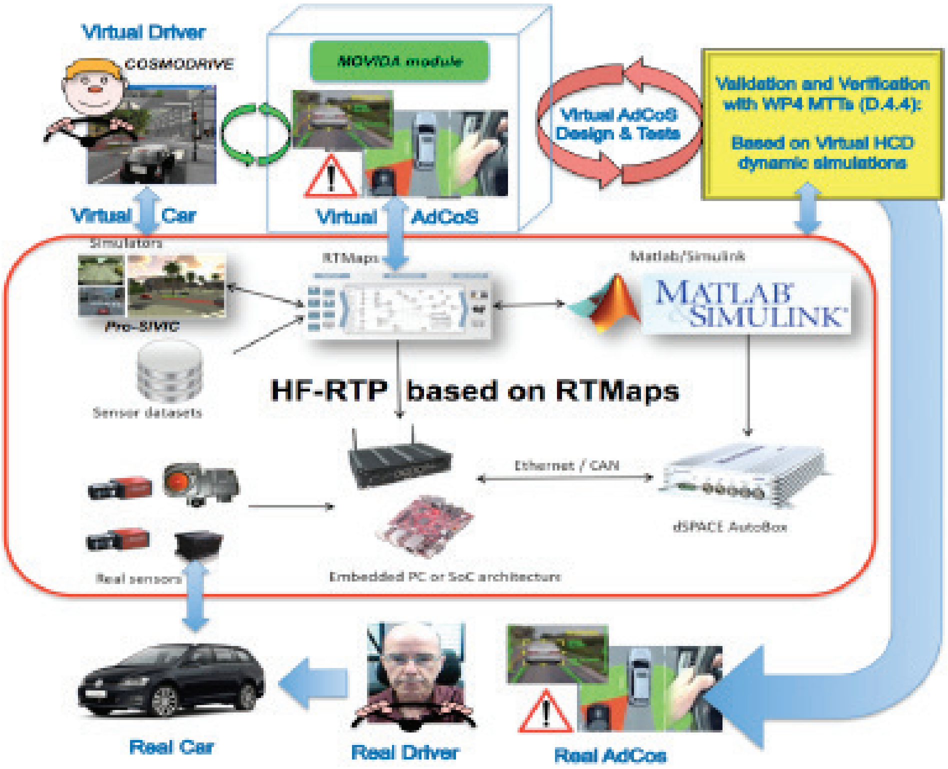

Figure 12. V-HCD platform: from virtual design to real car, supported by RTMaps

HoliDes @ Co-summit 2015 - 10 & 11 March 2015

The future of smart manufacturing and the impact of software innovation in Smart Industry provided the theme of the Co-summit in Berlin, organized by ITEA – the EUREKA Cluster on Software-intensive Systems and Services – and by the ARTEMIS Industry Association on Embedded & Cyber-Physical Systems. The overriding conviction was that software innovation and Cyber-Physical Systems are the enablers of the new smart industry era. With more than 80 project boots being displayed all around the exhibition floor, ARTEMIS and ITEA actually showed to more than 700 visitors and participants the tangible impact of their work.

HoliDes booth was there, showing two of our first year results: ***the Virtual Human Centred Design platform*** in action, for designing and simulating Automotive AdCoS (*read more about it in this number of the HoliDes newsletter !*), and the **Human Efficiency Evaluator**, a tool for the cognitive analysis of AdCoS, applied to an aeronautic use case.

Holides past meetings

Holides Technical Project meeting

TATAKA hosted on 11-13 March, 2015 in Berlin, the Holides Technical project meeting was held in Berlin , Germany. OFFIS lead partner of the project chaired this meeting . The meeting was also attended by representatives of the project consortium.

Next events of interest

- **SENSORCOM 2015**

The Ninth International Conference on Sensor Technologies and Applications SENSORCOMM 2015
23-28 August 2015 in Venice, Italy
See more information at www.iaria.org

- **IOT World Congress**

The event will bring together international thought leaders and technology organizations to showcase the latest innovations and solutions available in the Internet of Things (IoT).
16-18 September 2015, Barcelona Spain
See more information at www.iotsworldcongress.com

- **ITEA 3 PO Days**

On 22 September, the ITEA 3 Call 2 for project proposals will be launched in conjunction with the ITEA Project Outline (PO) Preparation Days in Brussels on 22 and 23 September. This event is a stepping stone for many to start preparing a PO.
22-23 September 2015, Brussels Belgium
See more information at https://itea3.org

- **ESWEEK**

Embedded Systems Week (ESWEEK) is the premier event covering all aspects of embedded systems and software. By bringing together three leading conferences (CASES, CODES+ISSS, and EMSOFT), three symposia (ESTIMedia, IoT, and RSP) and several workshops and tutorials, ESWeek allows attendees to benefit from a wide range of topics covering the state of the art in embedded systems research and development
4-9 October 2015, Amsterdam The Netherlands
See more information at www.esweek.org

- **ICT 2015**

The European Commission, together with the Fundaçao para a Ciência e a Tecnologia Portugal bring you: ICT 2015 – Innovate, Connect, Transform, 20-22 October 2015 in Lisbon, Portugal.
20-22 October 2015 in Lisbon, Portugal
See more information at http://ec.europa.eu/digital-agenda