Introduction to AWARE2ALL: **Safety systems and human-machine interfaces oriented to diverse population towards future scenarios with increasing share of highly automated vehicles**

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Abstract

Facing to the challenge of future highly automated vehicles, where occupants can freely orient themselves to engage in non-driving activities. This new environment prompts questions about how car occupants will actually sit, what activities they will engage in, and how they will informed through the HMI to keep them in the loop if necessary.

AWARE2ALL aims to pave the way towards Highly Automated Vehicles (HAVs) deployment in traffic, by effectively addressing the changes in road safety and changes in the interaction of different road users caused by the emergence of HAV through the development of innovative technologies along with the corresponding assessment tools and methodologies.

AWARE2ALL will develop safety and HMI systems that will be interrelated through achieving a holistic understanding of the scene to ensure safe operation of the HAV to address new safety challenges posed by the introduction of HAVs in mixed road traffic.

Keywords: Automated vehicles and HMI

Introduction

In 2020, someone died on European roads every 25 minutes, with a total of 18,844 people that lost their lives. It represents an unprecedented annual fall of 17% on 2019 result of lower traffic volumes due to the COVID-19 pandemic, but it is expected that traffic accidents will soar again once the pandemic subsides (US has reported in the first half of 2021 an increase of 18.4% in road fatalities over 2020). Road accidents are the lead cause of death for people aged 5–14 and the second leading cause of death for those aged 15–29. More than 46% of those killed in Europe in 2018 were Vulnerable Road Users (VRUs) –pedestrians, cyclists and motorcyclists and it was estimated that human error was involved in about 95% of all road traffic accidents[3].

Highly automated vehicles (HAVs) are Connected and Automated Vehicles (CAVs) presenting SAE-L4[4] features and have the potential to improve road safety by reducing crashes due to driver error and also by representing an alternative to high-risk drivers (e.g., drunk or distracted drivers). However, HAVs can introduce additional safety risks that will result in new safety-critical situations that must be

addressed. Some of these additional safety risks are, among others: component failures, increased risk-taking, unconventional seating position and occupant postures, increased vehicle travel, interaction with VRUs and mixed traffic (HAVs interacting with Human Driven Vehicles – HDVs)[5]. In the last years there have been many attempts to forecast future penetration rates of HAV, but the bandwidth of the rates is very high due to high uncertainty[6]. An optimistic scenario considers a penetration of 15% by 2030 and 40% by 2040, with first applications in commercial use vehicles (shuttles, shared cars, trucks). The obstacles for HAVs introduction in the market mainly come from safety and human factors concerns[7]. Hence, the expected new safety-critical situations must be addressed, especially those involving human road users (HRUs), that includes VRUs and HDVs.

AWARE2ALL Ambition

AWARE2ALL aims to pave the way towards HAV deployment in traffic, by effectively addressing the changes in road safety and changes in the interaction of different road users caused by the emergence of HAV through the development of innovative technologies along with the corresponding assessment tools and methodologies. AWARE2ALL will develop safety and HMI systems that will be interrelated through achieving a holistic understanding of the scene to ensure safe operation of the HAV, addressing the identification of new safety-critical situations and the most likely positions and postures considering the expected HAV applications.

AWARE2ALL will develop safety systems adapted to these new scenarios in mixed traffic, considering two perspectives:

- *Inside the vehicle, oriented to occupant safety:* a continuous occupant state monitoring will assess the interior situation (e.g., activities performed by the occupants) and in case of an emergency situation (e.g., sudden reach of the ODD[8] limit due to an abrupt change of weather) would decide if it is possible to perform a handover/handback to a driver or to perform a fallback manoeuvre and avoid a collision and if it is not possible, then advanced passive safety systems are adapted to the occupant status to reduce the severity of injuries if a collision is unavoidable. At any time, the behaviour of HAV systems needs to be adequately and timely communicated to the occupants by internal HMI (iHMI).
- *Outside the vehicle, oriented to HRUs safety:* a surround perception system will allow the HAV to identify the HRUs behaviour and to anticipate safety critical situations. By allowing the vehicle to effectively communicate with HRUs through external HMI (eHMI), dangerous situations could be avoided.

AWARE2ALL Methodology

Overall Concept

This project is positioned to orchestrate and ensure reliable integral safety of the occupants with special attention to the new variety of possibilities that automated driving functions will bring to vehicle occupants (including leisure activities) and ensuring safe control transitions between SAE levels when necessary. The AWARE2ALL concept is supported by three main pillars:

P1- AWARE2ALL develops an integral safety concept that automatically takes decisions according to the occupants' state, overall situation (interior layout, exterior scene, etc.) to guarantee always that even if a crash is unavoidable, the severity is minimised.

P2- AWARE2ALL informs the occupants adequately about the autonomy and decision state of the system as well as about the driving situation, to ensure that occupant alertness is adequate for the current driving mode. This information is adapted to the occupants' types and roles, enabling them to respond timely to any required actions.

P3- AWARE2ALL informs road users adequately about the systems' state and intentions and adapts to the user type, thus promoting safe interaction.

In a nutshell AWARE2ALL will pave the way towards the development of an Integral Safety approach to match the demanding requirements of new vehicles addressing diverse SAE automation levels, with focus on L4 and with the occupants playing different roles. The next figure shows AWARE2ALL's approach.

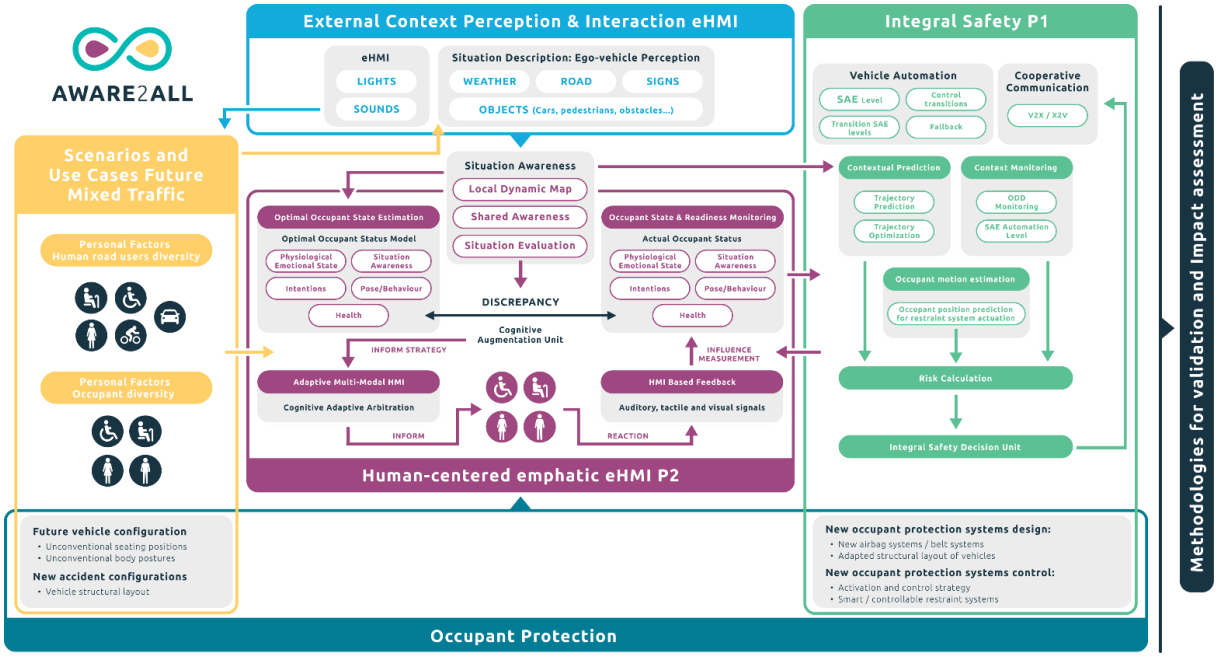

Figure AWARE2ALL overall concept

The Integral Safety pillar (P1) will integrate components from the two other pillars: exterior (P3) and interior (P2) situation awareness building, using collaborative perception and interaction technologies. Special attention will be paid to the development of a smart holistic and empathic assistant that will enhance the interaction between the occupants and the vehicle, always aiming for the optimal occupant state (physical, psychological), taking occupant diversity into account. The safety module will continuously monitor the overall situation and will automatically take decision to act accordingly to guarantee that a minimum risk situation is always reached.

AWARE2ALL will develop new interior and exterior interaction design concepts to optimize the interaction between all scene occupants (interior and exterior). Occupant monitoring and driving readiness assessment will enable reaching an advanced awareness level between the human and the

vehicle in all traffic situations, in order to achieve safety and comfort in the emerging automated transport ecosystem.

This approach includes the definition and monitoring of ODD to ensure the safety of the automated driving under all circumstances defining Minimal Risk Manoeuvre and Fallbacks to ensure the safety of both occupants and other traffic participants. AWARE2ALL will advance the information presentation so that the occupant can always fully understand the circumstances under which the automated driving functions are operational, the vehicle's status and the traffic situation.

AWARE2ALL and Integral Safety

The integral safety system consists of the connected active and passive safety systems. The active safety system uses the traffic environment information to generate a risk field based on that optimizes the planned trajectories for crash avoidance and/or crash severity mitigation. In case that a risk is detected from the environment, the information is shared with HRUs via the eHMI. The passive safety system will get the vehicle dynamics prediction information from the active safety system and generates the occupants' body motion prediction for adapting the restraint system activation accordingly. This interface between active safety and passive safety will also handle the different take-over strategies between automated driving and manual driving. In case that a collision is unavoidable, the HAV would warn the HRUs via the eHMI.

AWARE2ALL and iHMI & OMS

The interior HMI and occupant monitoring pivots around a Human-Centred Cognitive Augmentation (HCCA) concept to build a shared perception of the situation awareness (vehicle/occupants). The HCCA concept is defined around the continuous comparison between the optimal occupants states and the actual occupant states. The optimal occupant state is calculated based on the context including the traffic situation perceived by the ego-vehicle and the actual automation level of the vehicle as well as personal factors which include age, cultural factors, etc. The occupant state is measured and estimated with the new Occupant Monitoring Systems (OMS) proposed by AWARE2ALL including physiological observations (e.g., fatigue, gaze and blink patterns), intentions and behaviour descriptors. The cognitive augmentation unit calculates the discrepancies between the optimal or target values and the observed magnitudes. Following an information strategy, the adaptive multimodal HMI is triggered. The loop is closed measuring the driver reactions via the HMI interaction and the OMS. The OMS also identifies the position of the occupants in the vehicle interior; therefore, this information will feed the active safety system to assess if a handover is required and will also be an input for the passive safety system, that will adapt the restraint system to the detected position of the occupants if needed. The situation in the interior of the vehicle is shared with HRUs via the eHMI in case that has safety implications (e.g., transition from autonomous mode to manual mode).

AWARE2ALL and eHMI

AWARE2ALL aims to ensure safety both inside and outside the vehicle, and two systems will be developed for the eHMI:

Perception system: allows identification of the external situation of the vehicle and of the HRUs with whom the vehicle must interact and will feed the occupant monitoring system, therefore having impact in the iHMI and also in the active safety system. The system will be able to detect and analyse the HRU's attention, through a combination of sensor fusion (or data fusion) and object detection that will be performed simultaneously allowing to generate a representative map of the vehicle's environment. 2D image analysis processing will be involved, but also 3D point-clouds generated with LIDAR (useful as validation reference to improve system reliability). The processing will be executed in an on-board HW system (not embedded) that will be installed into a physical demo.
Communication system: allows interaction with HRUs using multi-modal interfaces. One interface will be exterior lighting. After recognition of the vehicle's surroundings by the perception systems the patterns defined by the communication strategy (warning signs, symbols, etc.) will be transferred. Some technologies with potential to be used in AWARE2ALL are using microLED for taillights, an immersive technology where the picture elements (pixels) are the light source that is programmable and can be controlled individually to create the patterns, and DLP (Digital Light Processing) or MLA (microlens array) for the use in ground projection. Within the project, different uses of lights will be investigated to determine those with higher impact on the behaviour of road users. The other interface to be explored will be sounds and the use of the AVAS (Acoustic Vehicle Alerting System)

AWARE2ALL demonstrators

AWARE2ALL systems will be implemented in a total of four demonstrators, one virtual (Demo 1), two physical (Demo 2 and Demo 4) and one hybrid (Demo 3) that will include a physical prototype that will run in a static driving simulator.

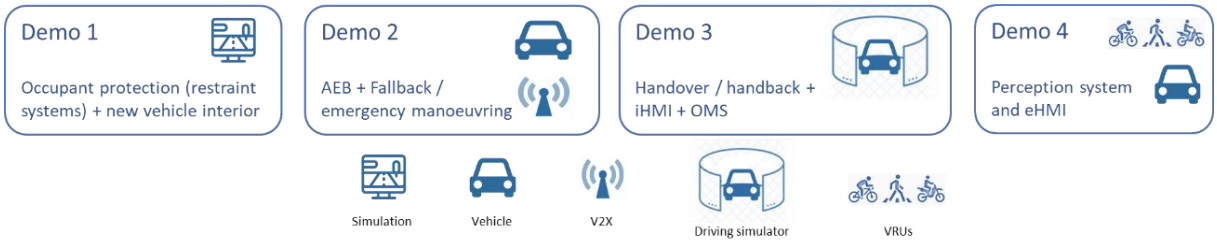

Figure. New safety technologies developed in AWARE2ALL and their prototyping in demonstrators

Demo 1. Passive Safety virtual prototype: This demo will include the 3D simulation model of the new vehicle interior configuration with seats, belt systems and airbag systems for crash simulation in LSDyna or PAMcrash. The configurations are defined for forward facing and rearward facing seating positions and cover also one variant for a seat integrated restraint system with advanced body-in-white and interieur_structure adaptations. The advanced airbag systems will handle the occupant diversity by closed-loop control functions activating variable filling curves and ventilation times[31] using airbag contact sensor technologies[32].

Demo 2. This demo will showcase an automated L4 shuttle, deploying strategies for fallback and emergency situations on system components/sensors failure including fail-operational functionalities, such as AEB, evasive manoeuvring, or safe/comfortable stops. The systems will exploit infrastructure capabilities via V2X interconnection protocols with other agents, including connected vehicles and infrastructure elements.

Demo 3. This demonstrator is based on a Renault platform driving simulator with environment visualization based on openStreet maps and vehicle dynamics simulation including active safety features. AWARE2ALL OMS and iHMI solutions will be integrated. The Active Safety features will be based on a new trajectory optimization architecture creating a risk field based on object motion prediction, crash severity prediction and ego-motion prediction using a reference path from navigation function.

Demo 4. eHMI physical prototype: This demonstrator will be based on a Seat or a Cupra platform, that will support in the systems integration. In this vehicle the external perception system will be implemented using the AWARE2ALL platform sensors.

Conclusions

This paper presents the first steps of AWARE2ALL project towards the development of new methods and tools to ensure safety of HAVs (shared cars and shuttles) in mixed traffic, protecting both diverse occupants (elderly, disabled, women, men) of the vehicle and the HRUs (VRUs, HDVs) that interact with the vehicle. The AWARE2ALLholistic approach covers the automotive value chain (universities, RTOs, TIER1 and OEM) to support the introduction of HAVs by offering an integral solution able to face future safety critical situations.

Aknowledgment

This work was funded by the Horizon Europe programme of the European Union, under grant agreement 101076868 (project AWARE2ALL).

Funded by the European Union. Views and opinions expressed here are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.