Augmented Reality Interfaces for Enabling User-centric Experiences in Intelligent Transportation Systems

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Abstract
This paper presents the vision of a novel platform for supporting human-centric design of future on-board user interfaces. This is conceived to facilitate the interplay and information exchange among onboard digital information systems, autonomous AI agents and human passengers and drivers. An important pre-requisite for this platform is to be flexible enough to support alternative embodiments of future Intelligent Transportation Systems (ITS), ranging from self-driving and remote control of vehicles to current human driving modes. For the case of self-driving cars, two Human-to-AI (H2AI) Augmented Reality (AR) interfaces, have been designed to provide passengers with intuitive visualization of information available in the AI modules controlling the car behavior. To validate the proposed user-centric paradigm, a novel testbed has been developed for assessing whether H2AI solutions can be effective in increasing human trust in self-driving cars. The results of our experimental studies, performed with several subjects, clearly showed that visualizing AI information brings a critical understanding of the autonomous driving processes, which in turn leads to a substantial increase of trust in the system. A solution tailored for supporting remote driving for connected busses has also been developed and it is currently being deployed and tested with industrial partners. The idea is to use AR to provide richer information displays to enhance the video stream fed to the remote drivers.

Introduction

Fueled by the recent successes in semi and fully autonomous driving, the automotive and transportation industry is undergoing the most rapid evolution of its history. Cars are rapidly transitioning from mere transportation means into the next generation media and service platforms. With *machine intelligence* gradually taking over the controls, drivers are progressively becoming passengers while cars are being transformed into mobile data centers for accessing, consuming and creating multi-media. To become fully accepted, self-driving cars need to enable an advanced interplay and information exchange among onboard information systems, autonomous agents and humans. In fact, recent surveys suggest that large amounts of people are not currently willing to use autonomous vehicles, or may feel concerned in them [17] [16], [8], while, the level of trust in the autonomous system is an important factor for reliance decisions [9] [3] [12]. An inappropriate level of trust may lead to disuse (underutilization) or misuse (over-reliance) effects [3][9][12]. A way to create appropriate trust through an interface is by revealing the operations of the automation and showing intermediate results and information processed by the system in a comprehensible way for the users [9].

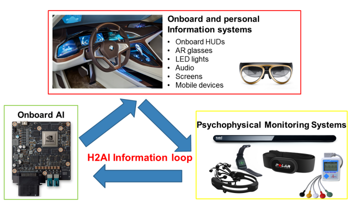

Figure 1: Envisioned components of onboard sysb-systems.

FUTURE HUMAN-CENTRIC ONBOARD SYSTEMS

Most of the currently ongoing research and development efforts within autonomous vehicles focus on the development of hardware and software solutions that are capable of coping with a wide range of factors *external* to the car, e.g. other vehicles or pedestrians, weather etc. For autonomous systems to be widely accepted, we strongly believe that the current approach needs to be complemented by the development of onboard sub-systems fully dedicated to adapting and optimizing the car's driving behavior and decision-making to elements that are *internal* to the car, i.e. passengers/drivers state of mind and well-being. The vision of such a sub-system, fully dedicated to the humans onboard, is illustrated in figure 1, where three logical components are shown. These are interconnected and continuously exchanging signals in what we refer to as "Human-to-AI" (H2AI) loop. In our vision, the H2AI loop is initiated by information sent from a "Psychophysical Monitoring System" to the "onboard AI" modules. This information, capturing the passengers' intentions, state of mind and well-being, is used by the onboard AI to decide on whether some specific information needs to be communicated to the passengers and which of the available personal and onboard interfaces to use. Sensors could for example include contact based EEG, hearth rate and respiration monitoring units, and/or contact-less units like eye-trackers and cameras. In principle, both dedicated onboard interfaces, like Heads-up displays (HUD), car screens and speakers, or personal interfaces, like mobiles, wearable AR glasses, VR etc., could be used. Once the decision is taken, this is communicated to the selected "Information system(s)" which, in turn, is(are) activated with the specified content type, thus reaching the passengers. To close the loop, after the information is perceived by the passengers, the impact on their state of mind is monitored again via the onboard psychophysical sensing units to assess whether it has achieved the desired effect.

AR Interfaces

To start the exploration of the proposed human-centric approach, we decided to focus on visual modalities, since they provide a very immediate way of communicating time-critical information to the users. A crucial step in the process is to correctly "explain" potential obstacles in the environment, likely to condition the decision process of onboard AI: this is the equivalent of the *why* type of information described by Koo et al. in [7].

Two different AR interfaces have been designed for this purpose. One uses eye-trackers and provides visual information super-imposed to real objects in the drivers' field of view. The other one, much simpler, features a LED strip in the dashbord, providing mono-dimensional visual feedback under the potential obstacles in proximity of the car. Our designs extends to the context of self-driving cars and usage of eye-tracking, the initial designs presented in [5] and [15], and presents a novel LED-based solution that complements the approach used in [10].

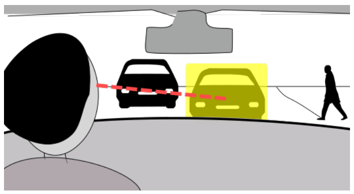

Figure 2: Drawing of the AR interface, showing the gaze point of the user, and a highlighted object.

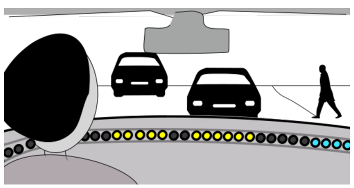

Figure 3: Drawing of the LED interface showing objects highlighted by the LEDs below them in the dashboard.

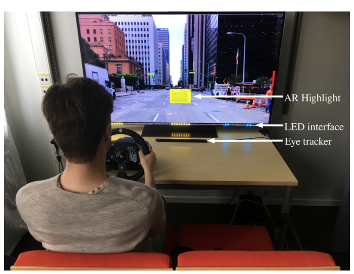

Figure 4: Image of the experimental testbed, including a Tobii eye-tracker, a LED strip controlled by Arduino Leonardo and a wide screen 4K TV.

Fully Augmented Interface

This interface uses eye-tracking to monitor drivers' attention and therefore to gather input concerning specific objects of interest in the driving scene in front of them. This information is used by the system both to filter the large amount of information available at AI modules in a given time instant and to trigger a visual response to the users presenting information about the objects detected at the gaze point. The initial way in which these augmentation are used is to showcase whether a potential obstacle has been detected by the systems and accounted for in its current driving computations. Different color coded highlighting are used for pedestrians and vehicles and they are visualized by superimposing a bounding box over the objects identified by user's eye-gaze. This AR interface can be implemented both using onboard HUDs or users' wearable devices.

LED-based Augmentation

In the second interface, all potential obstacles are presented to the user using LED lights. To avoid overwhelming the users with too much visual information at once, a "tunable" radius threshold has been implemented to display only the potential obstacles detected in proximity of the vehicle. In practice, this interface can be implemented via a LED strip positioned at the bottom of the windscreen or within the dashboard. Individual lights are activated with the same color code of the previous interface, i.e. blue lights for pedestrians, yellow for vehicles. The position and number of LED lights activated per object depend on the object proximity and width while accounting for the correct user's perspective.

Experimental testbed

Self-driving

One of the major challenges for studies involving self-driving cars and future ITS in general is the identification of testing environments capable of providing an adequately realistic environment. For example, running experiments in autonomous vehicles on real roads is out of the scope of many exploratory studies thus, often tests are run in simulators. Two different embodiments have been developed for our initial experimental testbed. One uses high definition dashboard videos content, representing the case of a fully autonomous car driving in various scenarios. A video, showcasing some examples for this embodiment is available at [11]. The other one, instead, uses content from the video game GTA V [4], running at 4K resolution. This game provides hyper-realistic graphics and traffic environments, for which it got recently attention within the self-driving car research community [6]. Initial work using this game has focused on using it as data generation source for the learning algorithms of onboard AI. In this paper instead it has been used to assess the user-experience associated with different HMIs. Substantial modifications to existing game mods ([14], [2]) for self-driving and for controlling weather and traffic environment have been performed to gain access to objects in the scene.

Active driving

An additional dimension that makes video games like GTA very interesting is the possibility of extending the current set up to include also active deriving scenarios. In these set-

Figure 5: GTA testbed: clear setting with AR interface.

Figure 6: GTA testbed: Extreme fog with LED interface.

tings, we envision the role of AR to be of pure super-vision. The H2AI framework is still applicable and especially for what concerns the use of eye-trackers. In this case, instead of being used for visualizing the information available at the AI modules, eye-trackers could be crucial to correctly supervise human drivers. For example the system could use monitor user attention (gaze and object detection) in real time and highlight obstacles like other vehicles and pedestrians that have been potentially missed by the drivers.

Remote control

Similar to the active driving case, we envision the possibility of defining novel interfaces for supporting remote control for connected vehicles, e.g. busses. Pre-requisite is the availability of cameras on board, connected via a 5G low-latency network to a remote location, where the drivers are located. An in depth description of such use case, including setup, background and objectives is available at [1]. Based on the content of the video feed, drivers can steer the busses and control their speed. The idea for this case is to use the supervision provided by H2AI to highlight specific object in the traffic environment and provide a richer experience than with the video only. In order to provide the system with machine understanding of the traffic scene in real time, a modified version of the YOLO [13] deep learning framework has been developed. Current performances support AR augmentation for real time HD video at 60fps.

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