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# Augmented reality for pedestrian detection: first elements about a study conducted on a real car

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**Abstract**

Head-up displays (HUD) permit registered augmented reality in cars. It is a powerful tool to enhance safety on road and help the driver to be more aware of his driving environment. In this study frame, we have used an AR HUD system embedded in a car and tested reactions of people driving this car in a scenario of pedestrian detection with a HMI design adapted to this purpose.

**Author Keywords**

Automotive head-up display; augmented reality; human machine interface; pedestrian detection; user testing; simulation; real car.

**Introduction**

Augmented Reality (AR) is defined by Azuma ([1]) as any interface that has the following three characteristics: it combines the real objects and the virtual information; it is interactive in real time; and registered in 3D. The latter characteristic means that the virtual information is perfectly superimposed on the real object for the user's eyes.

AR is a promising feature for automotive human-machine interfaces (HMI) as the ocular path to get

information is reduced to zero. Foreseeable technical solutions for AR in cars are head-up displays (HUD).

In order to test the added values and the assets of registered AR, we used both a driving simulator and an AR HUD equipped on a car. On one hand, simulation enhances repeatability and safety, and allows exploring new use cases very fast. On the other hand, a real setup is essential in order to avoid the issues due to the biases of simulation, and understand more deeply how the human interacts with the fusion of real and virtual contents. Main differences between real and simulated HUDs are described in [2]: projection distance, accommodation and vergence efforts, HUD and scene brightness...

Many studies on driving simulators have been done about pedestrian detection interfaced with AR and proved the benefit of AR compared to the classical HMI provided by an instrument cluster (sound + graphical icon), cf. [3]-[6].

In our project, we first conducted a user testing on a driving simulator, which allowed us to precisely define the use cases and to adapt the HMI design. Afterwards we did an experiment on a real car to observe the behavior of the drivers on a closed circuit with a pedestrian detection system. The use case was to drive the car with and without augmented reality and test the behavior of breaking with "sudden intrusion" of a pedestrian (euro NCAP dummies) on the road. Several aspects of the experiment were from interest:

- Test an AR HUD in real situations, with users,
- Verify the relevance of the whole detection chain (detection, latency of the system, visual grammar used...),
- Compare AR with classical HUD.

In the following document, we will present the configuration tested on the circuit, the system used in the car to create a virtual image and to provide registered augmented reality content and the characteristics of the use case. Comparisons to the study preliminary conducted on the simulator will be done. First results will be presented. We will conclude about items to be further studied on real cars.

### **Detailed study case: pedestrian detection on road with AR HUD system**

#### *Presentation of the circuit and the AR HUD system*

The road was provided by UTAC-Ceram (*Union Technique de l'Automobile, du motocycle et du cycle*) and consisted of a flat asphalt road. The pedestrians were Euro NCAP dummies, some of them being mobile and some of them being standing still on or on the side of the road.

The AR HUD system was equipped on a BMW X5 and its specifications were the following: windshield HUD, field of view of 15°x4°, look down design to cover the road from approx. 20m to 80m, a virtual image between 7 to 15m and perceived brightness higher than 10k cd/m<sup>2</sup> (the image was clearly seen by a bright summer day). The ADAS (Advanced Driver-Assistance System) for this setup was primarily done by cameras and lidar, processed by computers embedded on board.



Figure 1: Picture of a real scene with superposed virtual image generated by the AR windshield HUD system



Figure 2: IRT SystemX driving simulator setup

The following picture (Figure 1) presents one of the dummies seen from the car, with one of the overlay generated by the AR system. The HMI consists of 2 yellow brackets (that indicate the distance from car to dummy, or more precisely the time from the car to the dummy), a speedometer ("10km/h" on the picture) and a road sign ("50km/h" on the picture).

#### *Preliminaries to the use case*

Most of the use cases are firstly tested in a driving simulator which was developed at IRT SystemX (Institute for Technological Research (IRT) that was created in order to support French Innovation) and consists of the key elements of a car environment: seat, driving wheel, safety belt, gear lever knob... The scene is provided by SCANeR and projected by 3 video projectors on a concave screen and the HUD is done by a standard monitor screen reflected on a flat transparent glass panel, defined as a binocular mirrored HUD by Gish [7]. The Figure 2 below shows a typical condition of working of the simulator in a city driving use case (rendering of cars and pedestrians).

#### *Use case: pedestrian detection on road with AR HUD system*

A total of 28 participants (2 females and 26 males) took part to the study. The age of participants ranges from 24 to 59 years old with an average age of 42 (SD = 10). Participants were recruited among Renault, UTAC-Ceram or Valeo employees. They had to have a valid driving license, to drive at least 10,000 km per year and to be not suffering from color blindness or stereo blindness.

Concerning the procedure, the experiment took place in a closed test track consisting of a two asphalt lanes

road. The complete duration of participation lasted approximately 30 minutes. After signing a consent form for their participation, the participants were familiarized with the test car and the AR windshield HUD. Then, participants drove twice in the same route, one time with augmented reality HMI and one time with reference HMI. The order of presentation of the two HMIs was counterbalanced among participants. Along the route, three static pedestrian dummies were placed on both sides of the road. The experiment finishes with a mobile pedestrian dummy that was hidden behind a van and that crossed the road when the test car was approaching. The participants were instructed to drive at 50 km/h and 10 km/h when approaching the static dummies. After the driving session, participants were debriefed and filled post-test questionnaires.

The pictures below show the graphical design used in the HMI with AR. A first version was developed thanks to simulation and the ones below were the ones used during the event on the circuit. The color and shape correspond to the distance from the car to the object, measured through Time To Collision (TTC). This graphical design can also be seen on the figure from the real scene (yellow bracket), cf Figure 1.


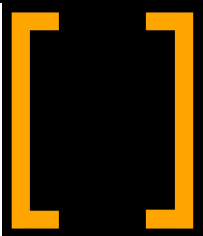
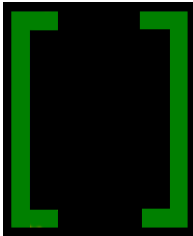
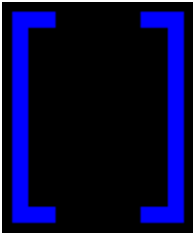
1.		2.	
	Red warning sign		Amber brackets
	TTC < 1.3 s		TTC < 3.0 s
3.		4.	
	Green brackets		Blue brackets
	TTC < 4.0 s		TTC > 4.0s

Table 1: 4 AR-HMI visual cues. Each shape and color is associated with a Time To Collision (TTC) indicator.

Two graphical interfaces were tested: a standard IHM, like in any HUD on the market, which indicated pedestrian detection as symbol at a fixed position on the virtual image, and AR IHM which highlighted pedestrian detection with different combination of shape and color. Our hypothesis was that AR IHM will help to better anticipate presence of pedestrian on the road.

### Results

The first results are currently analyzed. During the test with users, it appeared that the simulation and the real setup would provide different results, due to obvious reasons (e.g. sit in a room vs. sit in a moving vehicle) and due to more difficult phenomena to solve or simulate like the difference of convergence between real environment and virtual image, differences of luminance between virtual image and real scene or like overall latency (from detection to display).

During the debriefing interview after the simulator study, several participants suggested to substitute the red brackets that highlighted the pedestrian with a red warning sign instead in order to understand faster that a danger was there (one of the key difference between reference IHM and AR IHM). During the debriefing interview after the study in the test vehicle, most of participants appreciated the warning sign. It offered a clear understanding of the situation without creating confusion or requiring analysis on what the highlight wanted to suggest.

### Conclusion

Augmented reality systems are designed to enhance understanding of situation for the driver and to avoid creating confusion and distraction. This aspect is reinforced with hazardous situation management that requires quick and safe reactions from the driver. Our very first results from our experiment are showing that strongly intuitive symbology (red panel, green bracket...) is still the preferred way to communicate efficiently with the driver. Our first results also show that the AR system in a car in real situation received a good acceptance from our panel of participants even if some technical aspects need to be adjusted or solved.

From an ergonomic point of view, the graphical design appears to be a key factor, which will enable all the assets of such highly technical system. From a technical point of view, we still need to find the right values to offer a smooth continuity between reality and virtual image in regards with given use cases. Indeed, an AR system for use cases on a highway may not be designed like an AR system for use cases in cities. It could require different characteristics or specifications (e.g. latency time, projection distance, field of view, luminance...)

As our experimentations continue, we also discover new aspects of such a system. The use case presented here implied short driving sessions and we wanted to observe reactions of drivers on sudden and unpredicted events (pedestrian crossing the road) with the help or not of an AR system. But our day to day uses of our augmented reality system on extended period of time has learnt to us that the cognitive charge is important and has to be taken into account in the design. Large difference of luminance between real and virtual contents, non adapted projection distance, overall large latency and complex grammar are one of the parameters we've identified that will trigger dizziness or fatigue faster than in a regular driving situation. That's why our next experiments will be designed for open road, like in cities, for period of time larger than 2 hours.

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