Automotive Displays from Direct View to AR Head-Up

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Advanced displays enable new multimodal interactions for automotive use like (semi-) autonomous driving ranging from direct view to AR head-up displays. This paper presents selected challenges and solution for future automotive applications.

I. Introduction

The evolution of high resolution electronic displays in cars started when TFT LCDs achieved automotive grade [1]. Drivers were navigation and multimedia for center stack displays and e.g. sign recognition and visualization for instrument cluster. Fig. 1 shows a modern premium dashboard (left) and an advanced center stack display with multi touch operation to control various car functions. Future cars with (semi-) autonomous driving enable more use of in-vehicle displays which will change the interior from a drivers workplace (Fig. 2 left) to a car of leisure, fun and work (Fig. 2 right). HMIs will change from more functional to emotional.

Fig. 1. Modern dashboard (left) and center stack display with touch functionality (right); source: MERCEDES, TESLA.

Fig. 2. Vision of future interior with displays and interior lighting (right) and autonomous driving cars (left); source: BMW, MERCEDES, PANASONIC.

II. Automotive Display Challenges

The readability of displays is a must as pointed out in Fig. 3: Lighting conditions from night and day including dazzling through sunlight require high luminance and dimming range (left). Advanced HMIs and infotainment need excellent grey scale and color reproduction.

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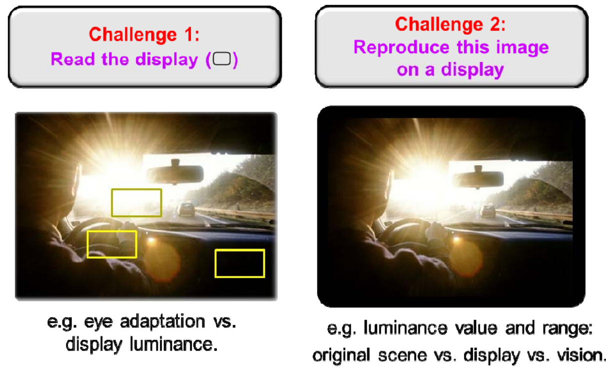

Fig. 3. Automotive challenges: Bright light and reflections (left) and high quality visualization of HMIs and multimedia (right); source: MERCEDES.

III. Head-Up Displays Towards AR

Military aircrafts are equipped with head-up displays (HUD) since decades. Their advantages apply as well to cars - so many models are available today with HUDs. However todays HUD have a relative small field of view (FOV) in the range of 8° x 4° (Fig. 4 left) and a projection distance of about 2 m. This is enough for visualizing e.g. speed and navigation arrows. However, for augmented reality (AR) information (Fig. 4 right) the FOV must be significantly larger (> 20° x 10°; [2]) and should have multi-depth (3D; see e.g. [3] and [4]) projection distances. This is very challenging in terms of picture generating units, optics, power consumption and HUD volume.

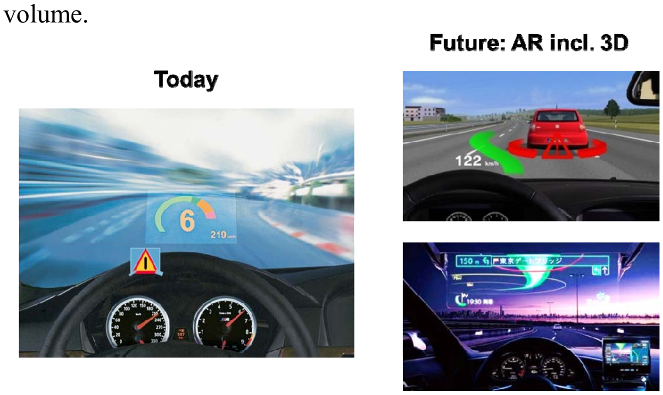

Fig. 4. From today's HUD with small FOV (left) towards AR and 3D with large FOV (whole windscreen); source: BMW, PIONEER.

Fig. 5 shows a HUD by BMW for motorcyclists. Displaying information directly into the driver's line of vision avoids lowering the gaze. In consequence, there are no attention gaps by taking the eyes off the road to look down to the instrument cluster. The advantage of HUDs for motorcyclist is obvious and even larger as for cars.

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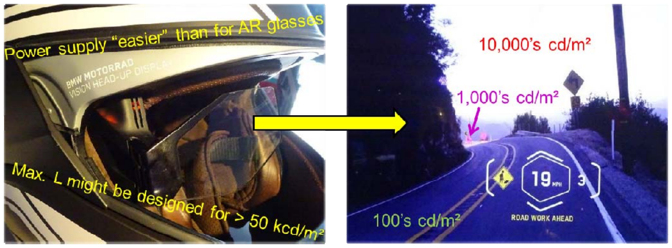

Fig. 5. Future motorcycle helmet with HUD functionality; source: BMW.

A major challenge for HUDs is the readability as the image (foreground) is projected on the road or surrounding (AR) as background. The readability for text is expressed by the contrast ratio (C_R):

$$C_R \approx \frac{L_{Foregound}}{L_{Background}} + 1 \qquad (1)$$

Fig. 5 right shows insets of typical background luminance $L_{Background}$ values ranging from 100's (road) to 10,000's cd/m² (bright sky). This requires a huge dimming ratio down a few cd/m² for night drive. In consequence, the luminance of the HUD ($L_{Foreground}$) should be at least five times the background luminance to achieve a C_R of at least 5:1which is a reasonable compromise for most HUD content. This results in about 100,000 cd/m² for HUDs displaying AR information on bright background (Fig. 4 bottom right). With a typical reflectance of the windscreen, this sums up to a million cd/m². High luminance requirements for outdoor use is one of the reasons why consumer electronics AR goggles failed in the past for outdoor use. A low contrast ratio results as well in a limited grey scale reproduction of lower grey levels and bleaching of colors [5].

Besides HUDs, goggles can be used for displaying AR information in a car, see Fig. 6. This might be easier to achieve technically compared to HUDs covering the whole windscreen but might be not widely accepted by drivers. When connecting AR goggles to car cameras and capturing the drivers head position and gaze, camera images can be used as AR information where normally no view is possible. Fig. 7 shows examples of a skater (left) and parking (right).

Fig. 6. AR goggles (left) for driver information (right); source: BMW.

AR HUDs enable advanced functionality as visualized in Fig. 8: The image of the front camera of the truck is streamed to the car to follow and superimposed as AR image onto the rear of the truck. It is obvious that this "see-through truck" requires a lot of image processing however, this raises the safety significantly even for automated driving.

Fig. 7. Car exterior become "transparent" by AR glasses; source: BMW.

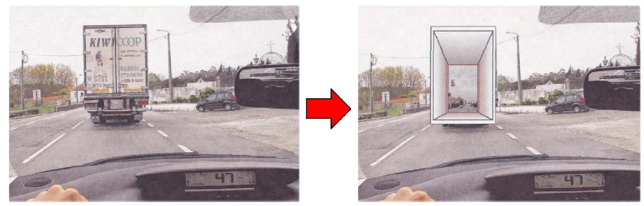

Fig. 8. AR HUD used for see-through a truck; source: University of Porto.

Basically the use of augmented reality should be limited to a reasonable amount that can be handled by the driver. A brief evaluation with students showed that an overflow of AR information (Fig. 9) is annoying and hides relevant information.

Fig. 9. Too much AR might be distracting; source: BMW.

IV. Summary

The number, size, resolution and optical performance of automotive displays will rise in future because of (semi-) autonomous driving. Augmented reality HUDs will provide advanced information in terms of safety and entertainment.

References

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