Visual Displays for Automated Driving: a Survey

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Abstract

This paper presents the results of a literature survey on visual displays used in automated driving. We describe six visual display designs: (1) a display with three main components, (2) a bird's-eye view display, (3) an informative speedometer, (4) a head-up display, (5) eye-catching lights for informing, and (6) eye-catching lights for guiding. Finally, a discussion is provided regarding visual display features that could be included in a human-machine interface for automated driving.

Author Keywords

Human-Machine Interface (HMI); Automated driving.

ACM Classification Keywords

H.5.2. User Interfaces: GUI, Screen design, Input devices and strategies, Interaction styles, User-centered design.

Introduction

The last decades have seen an increase of automated driving systems, which aim at improving comfort and safety [1, 6, 17]. As the level of automation increases, the driver's role shifts from that of a manual controller towards a supervisor. High levels of automation will allow the driver to engage in non-driving tasks such as working or resting.

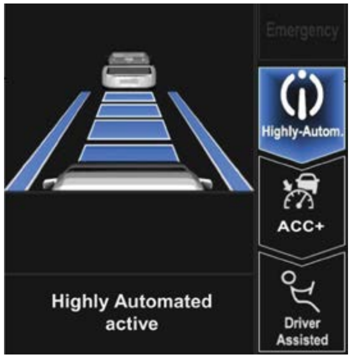

Fig. 1: A possible combination of three display components. These components were proposed in the HAVEit project as essential. From [8].

Fig. 2: Example of the Safety Shield implementation. From [3].

However, automation can have various adverse effects [7]. Dangerous situations can occur when the driver has to take back the control of the car within a short amount of time. Furthermore, misuse or disuse may occur when the driver over-trusts or under-trusts the automation, respectively [14].

A visual display could be useful for supporting the situation and mode awareness of the driver [21, 13]. Furthermore, a visual display may be helpful in ensuring that the degree of driver trust matches the capabilities of the automation [9, 17].

Many research projects and car manufacturers have approached the issue of display design and various solutions have been proposed. The aim of the present literature survey is to provide an overview of existing visual displays for automated driving, from both the academic enterprise and commercialized solutions.

Methods

Our literature search included visual displays for levels of automation from low to high (SAE levels 1 to 4 [18]). In other words, our survey focused on partially (SAE level 2), highly (SAE level 3) and fully (SAE level 4) automated driving, as well as on driver assistance systems (SAE level 1), such as adaptive cruise control (ACC) and lane keeping systems. The searches were conducted using Google search and Google Scholar. Additional eligible studies were retrieved from the reference list of [6].

Results

Our searches retrieved 23 relevant documents. Herein, we highlight a selection of six visual displays. These displays have been selected because they appear to be in a mature stage of development and/or because they aim at supporting situation/mode awareness.

A display with three main components

Three visual components, to be displayed on the instrument cluster or on a separate display, were defined in the EU-project HAVEit [8, 17] (Fig. 1):

1. A *1D automation scale*, indicating the current and the available levels of automation. The scale can be placed horizontally or vertically and should have the same spatial mapping as the control device [17].
2. An *automation monitor* including three elements: *horizontal bars*, indicating the status of the ACC (longitudinal automation), *vertical bars*, indicating the status of the Lane Keeping System (lateral automation), and a *vehicle icon*, annotating a detected target vehicle.
3. A *message field*, for explicit suggestions (e.g., “Stay in lane – Vehicle in left blind spot” [8]).

This generic design was applied in the demonstrator vehicles of the HAVEit project [8], and some elements are present in on-the-market interfaces.

Bird’s-eye view display

Some displays provide drivers with a bird’s-eye view. For example, the Safety Shield developed in the InteractIVe project [3] informs the driver about the position of a potential threat by highlighting parts of the shield (Fig. 2). Two levels of urgency (low in yellow and high in red) were used.

Informative speedometer

In the HAVEit project [8], it was suggested that all information about speed should be integrated in the speedometer. This includes the current speed, the set

Fig. 3: Example of an informative speedometer on the market. 1) Set speed 2) Speed of the detected target vehicle 3) Current speed of driver's vehicle. From [24]

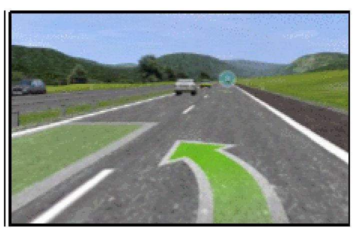

Fig. 4: Simulator implementation of augmented reality. From [23]

speed for the ACC, and the speed of the car in front. The speed limit can be included as well (or in the automation monitor [8]). The concept of the informative speedometer is currently applied in consumer cars, such as the Volvo XC90 2016 (Fig. 3).

Head-up display

The driver's view can be by enriched with objects presented via a head-up display (HUD). An example is shown in Fig. 4, indicating a lane change manoeuver [23]. HUDs are typically used to communicate information like speed, automation status, or a takeover request [2, 24].

Eye-catching lights for informing

Lights can be used for informing about a potential danger (e.g., the collision warning of Volvo, Fig. 5) or about the automation status (e.g., the display tested for BMW's Traffic Jam Assist [20], Fig. 6). The criticality of the conveyed message can be encoded using colours or patterns like blinking or fading [12].

Eye-catching lights for guiding

Lights can be used to attract the attention towards the direction of a threat. An interesting concept tested by [16] is that of a strip of LEDs that runs 360 degrees inside the cabin. The LEDs switched on correspond to the angular range represented by the threat. A similar concept is the ambient light display 'Sparkle' [12].

Discussion

The selected results of this survey indicate that several promising visual displays have been proposed for automated driving.

Examples of displays that aim at guiding the driver are the augmented reality HUD proposed by [23], the LED strip by [16], and the ambient light display 'Sparkle' [12]. The spatial resolution of the Safety Shield from [3] (Fig. 2) could be increased, for example, by fusing it with the LED strip concept (similar to the RADAR display tested by [19]).

Eye-catching lights aim to attract the driver's attention. However, the information content of a binary light may not be sufficient in complex traffic scenarios. Another limitation of binary lights/warnings is that they could lead to annoyance and automation disuse [14].

The requirement to enhance situation awareness and automation-mode awareness is addressed by the informative speedometer and the automation scale and monitor, already available on the market. An interesting idea proposed by [5, 10] is to communicate the degree of automation uncertainty. Such concept could prevent automation misuse and the false belief of automation infallibility [5].

In highly automated driving (SAE level 3), the driver may engage in tasks other than driving, such as using a tablet. To reduce the 'driver-out-of-the-loop' problem, feedback could be presented on the tablet itself. For example, the LED strip could be presented on the frame of the tablet (cf. the ambient light display 'Sparkle' [12]). Similar concepts have been published by [22], where a video image of the driving environment was presented nearby the display for the non-driving task, and by [11], where the take-over message was shown on a mobile phone.

The results in this paper focused on the visual display of the human-machine interface (HMI). We note that the auditory and tactile modalities also have

Fig. 5: Collision warning of Volvo XC90 2016. From [24].

Fig. 6: BMW's tested interface for Traffic Jam Assist. From [20].

important potential in HMIs for automated driving [15, 4].

In conclusion, we surveyed six visual displays for automated driving. The work will be extended as part of the projects DAVI/IAVTRM (http://davi.connekt.nl) and HFAuto (http://hf-auto.eu).

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