Reducing In-Vehicle Interaction Complexity: Gaze-Based Mapping of a Rotary Knob to Multiple Interfaces

David Dobbelstein, Marcel Walch, Andreas Köll, Ömer Şahin, Tamino Hartmann, Enrico Rukzio
Ulm University, Ulm, Germany
{firstname.name}@uni-ulm.de

ABSTRACT
We present a gaze-based interaction approach that maps a single rotary control knob to multiple interfaces in the car using the user's gaze to determine the respective interaction context. By this, the complexity of physical interfaces (e.g. number of buttons) can be reduced and abstracted to a single remaining physical control interface located at the steering wheel to allow for interaction that doesn't require drivers to take their hands off the steering wheel. We implemented a prototype that uses multiple eye-trackers in a driving simulator to explore the concept of gaze mapping.

Author Keywords
Gaze-based interaction; Eye-tracking; Automotive;
Hands-free interaction

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation (e.g. HCI): User Interfaces - Input devices and strategies.

INTRODUCTION
The advances in in-car driver assistance and information systems have led to an increase of controllable interfaces mounted in the cockpit. Most of these interfaces comprise seperate physical inputs via buttons, switches, rotatory knobs or sliders.

We want to reduce the amount of physical interfaces by using the user's gaze to determine the context and map a single control interface to different control functions.

By abstracting away several physical inputs, assembly complexity can be reduced leading to a potential decrease in assembly costs. The driver's single remaining physical input interface is located at the steering wheel, allowing for *hands-free* interaction, i.e. interaction that doesn't require drivers to take hands off the steering wheel. We propose this gaze-based interaction mainly for tertiary tasks [5] and corresponding interface functions, such as adjusting side mirrors, controlling the ventilation system or changing music.

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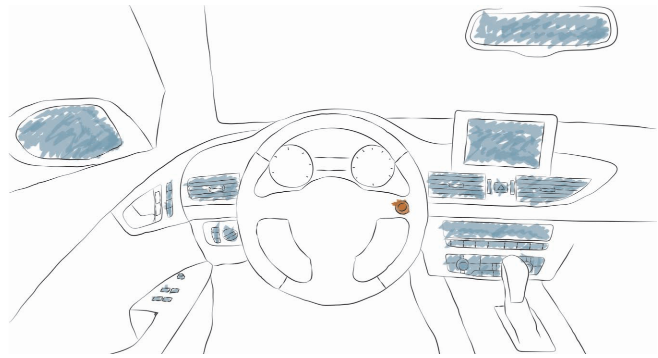

Figure 1. Multiple interfaces in the cockpit (blue) that can be controlled by a single rotary knob (red). A glance of the user onto the respective interface determines the interaction context.

RELATED WORK
Eye-tracking in automotive contexts has mostly been used to passively monitor driver metrics such as driver fatigue (e.g. [2]), cognitive load (e.g. [7]) and to analyze the driver's attention [9]. Indicating the user's awareness, these can help the system to initialize safety features such as warnings when the driver is being inattentive to road events [1].

In combination with system-based context detection of the vehicle's surroundings, gaze can be used to allow the driver to query information by voice commands, where the context of the command is determined by the gaze direction [3].

Explicit gaze-based interaction for the driver has already been proposed by Kern et al. [4]. In their work, gaze was introduced as a substitute for touch interaction to control an infotainment system. Instead of touching an interface element, the user could look at it and then press a button on the steering wheel for selection. To ease the attention switching process between looking at the street and briefly interacting with the system, the last item is kept highlighted so that the driver can select it without looking back onto the screen. Poitschke et al. introduced a similar system where gaze-bazed interaction is used for multiple screens including a head-up display and a centered touchscreen [8].

Our concept incorporates similar explicit gaze-based interaction, but extends these works by letting the driver not only highlight and select interface elements on displays, but also physical interfaces within the car, such as buttons to adjust the side-mirrors.

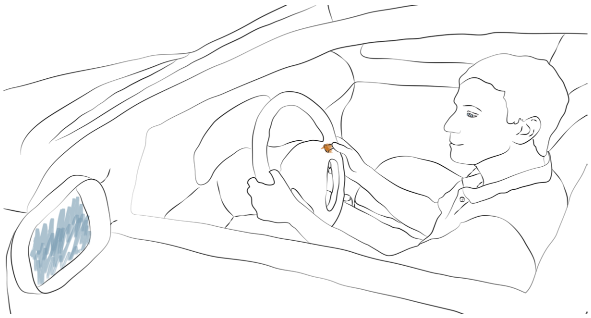

Figure 2. The user is glancing to the side mirror to adjust it using the control knob on the steering wheel.

CONCEPT

Since gaze direction is highly correlated with the user's mental attention, interests, plans, and intentions [8], users tend to glance at a physical interface before interacting with it. The glance is then followed and accompanied by hand movement to reach for the interface.

We introduce a gaze-based mapping where the user does not have to reach for the physical interface, but instead can utilize a rotary control knob on the steering wheel that alters its function based on which interface the user was glancing at last. The user can thus select visible objects in their surrounding via gaze direction but does not have to reach for them. All interaction that is based on pressing a button, rotating a knob or using a slider can be substituted by the single control knob that is located at the steering wheel.

Commercial eye-trackers have become inexpensive and could be integrated into the cockpit in a non-intrusive way. A single eye-tracking camera has only a limited field-of-view and cannot encompass the driver's gaze direction for the whole cockpit. For this reason, we propose to build multiple camera modules into the cockpit to cover a wider space.

To minimize visual distraction, gaze is only used as an initial indicator for the interaction context, while the interaction itself is based on the rotary control knob. Feedback can be given auditory or visually in a head-up display.

IMPLEMENTATION

Two Tobii Rex eye-trackers were incorporated into a driving simulator setup. As controllable interfaces, an adjustable side mirror, an infotainment display running a radio application, and a phone mount handling incoming calls were integrated (see Fig. 3) to be controlled by the rotary control knob on the steering wheel via gaze mapping. The gaze direction of instruments within the cockpit can be calibrated by an implemented java software framework running on top of the low-level Tobii Gaze SDK.

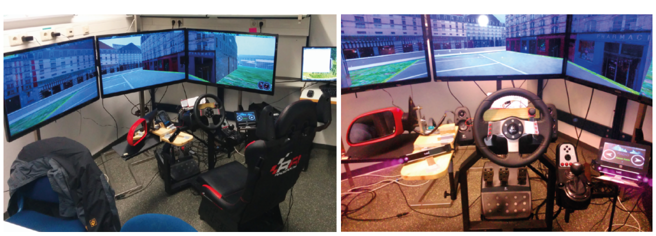

Figure 3. The driving simulator setup. Two Tobii Rex eye-tracker are mounted on the left and right of the steering wheel to cover the instrument panel.

With the given implementation, the driver can adjust the side mirror by looking at it and pushing the knob into the corresponding direction (two-dimensional joystick), accept or initiate a phone call by glancing at the mobile phone (contacts are arranged in a one-dimensional list) and change or turn on or off the radio in a similar manner.

LIMITATIONS AND FUTURE WORK

Technical Limitation

Having to only glance at an interface for selection is essential for our concept to be not too visually distracting from the driving task. Unfortunately with the current integration of multiple eye-trackers to extend the cameras' field-of-view, each tracker falls back into a standby mode after losing track of the driver's eyes. It takes a short while for the eye-tracker to recover upon rediscovering the eyes, so that short glances can so far not reliably be detected (more specifically, only when the respective eye-tracker was already in an active mode).

Affordance

Individual physical interfaces inherit affordances by their design. By abstracting multiple interfaces into a single remaining interface, their affordance is reduced and information about the current state needs to be conveyed in another way. E.g. a button that is pressed or a rotary knob that is turned to a discrete position can visually and haptically indicate the current state of the interface, which would be given up when abstracting it away. Using indicator lights or icons on a head-up display could provide visual feedback, while the rotary control knob could change its haptic properties based on the context [6], e.g. switching from continuous to a discrete stepping feel or blocking the rotary function.

Future Work

An evaluation is needed to explore effects on driver distraction for gaze-based interface mapping. Further, we want to explore whether the driver's mental model of mapping interface to function corresponds to their gaze direction. We expect the driver's cognitive load to be high during learning due to not being used to indicate interaction context by gaze.

Incorporating multiple eye-trackers into the cockpit enables both, the analysis of driver metrics and the potential for explicit gaze-based interaction. By taking vergence and accomodation distance of the eyes into account, the system could also differentiate the users gaze within the cockpit (near distance) from visual attention on the road (far distance) [10]. This could be especially useful for head-up displays where gaze direction is not necessarily a sufficient discriminator between road and interface.

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