Novel Multimodal Mid-Air Gesture Displays for Drivers

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ABSTRACT

Multimodal displays can reduce driver distraction by distributing *In-Car Infotainment System* (ICIS) information to other sensory modalities such as tactile and auditory channels. Such systems have potential for improving the performance of drivers, and the user experience while at the same time reducing visual workloads, permitting quick reaction times and reducing perceived mental workload. With these variables in mind, this work seeks to investigate the design and use of such displays to convey confirmation feedback effectively and reliably to show a gesture has been recognised. The goal is to assess usability, performance, and driver workload. This will form the basis for designing mid-air gesture interfaces that will utilise multimodal displays to inform drivers.

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; User Interfaces — Haptic I/O, Interaction styles, and Evaluation/methodology

Author Keywords

Multimodal interaction; haptic feedback; steering wheel; mid-air gestures

INTRODUCTION

I am at the end of my first year of a 3 year PhD programme in the University of Glasgow, School of Computing Science. I have completed my first year evaluation and I expect to finish my doctoral work mid 2018.

Since very little is known about the combination of 1) multimodal feedback, 2) mid-air gestures and 3) in cars, my research will focus on the effectiveness, reliability and safety of multimodal displays for mid-air gestures in driving scenarios. Specifically, I aim to investigating the influence of the used modalities, type of information, complexity of multimodal messages, driver distraction, and usability of such displays. My end goal is to design novel multimodal in-car displays based on an application to map the distance between steering wheel and dashboard meaningfully. Thus far I have evaluated the effectiveness of haptic patterns presented to the palm of drivers on the steering wheel, by completing a set of experiments in a driving simulator.

CONTEXT AND MOTIVATION

Mid-air gestures are a new interaction technique for car-manufacturers. Mid-air gesture recognition is reliable and robust enough to be considered in facilitating in-car interaction (e.g. Leap Motion). However, these gestures decouple the user's hand from the interface [1], and make the user feel disconnected form the device. An interface that can provide continuous feedback to the user might couple the device to the user's hand [1]. A multimodal display can provide effective feedback, which is important to help users overcome uncertainty during gesture interaction.

However, the main challenge of multimodal displays in cars is to provide information to the driver without it being distracting from the primary task of driving, and thus not increasing mental workload. Therefore, it is essential to create guidelines on designing in-car mid-air gesture displays that will use these modalities to help drivers, without overloading them with information and increasing risk.

STATEMENT OF THESIS

My research looks at how novel multimodal output types can be used to give effective feedback during gesture interaction, to minimise visual feedback and to help drivers decrease eyes-off-the-roads time. While others [3, 6] have used multimodal feedback in cars and showed benefits of multimodal feedback in a driving context (i.e. no increase in mental workload [3], no increase in eyes-off-the-road time, preferred by most over visual only [3, 6], etc.), little is known about the effectiveness of multimodal feedback for mid-air gestures in cars.

Research is needed to explore feedback designs in greater detail to understand what information drivers actually need and can process to help them gesture and support their awareness of how the interface is responding to their actions.

RESEARCH GOALS AND METHODS

The research will be based a set of experiments using a driving simulator and a real car on public roads, investigating the effectiveness of the proposed novel multimodal interaction techniques. Two of these experiments have been conducted and six more are planned. The results will be used to inform the design of multimodal mid-air gesture displays. The experiments are listed below:

- Studies 1 - 2 investigated how perceivable haptic feedback patterns are using an actuated surface on a steering wheel.

Six solenoids were embedded along the surface of the wheel, creating three bumps under each palm. The solenoids can be used to create a range of different tactile patterns with perception rates of up to 81.2%. The real world applicability of the haptic patterns will be tested in an application where the distance between the steering wheel and centre console will be mapped meaningfully. Whilst the driver's hand is moving to the dashboard, hierarchical ICIS menu selections can be made in air, where distance is mapped to how fine grained the menu options are. Furthermore, Study 3 will be conducted in a real world driving scenario.

- Studies 4 - 5 will consider perception of peripheral ambient light feedback [5] for mid-air gestures [2] in terms of rhythm, frequency, duration, and colour coding. Study 4 will also investigate different feedback channels (i.e. vibrotactile, auditory) for a comparative basis. All modalities will be tested in the same application as used in Study 3 for a comparative basis. Study 5 will be based on Study 4 and will be tested in a real driving scenario.
- Study 6 - 8 will investigate ultrasound haptic feedback [1] for mid-air gestures in terms of perception in cars and usability for mid-air gestures. Study 7 will determine the usability of ultrasonic feedback compared to the aforementioned feedback techniques based on the application used in Studies 3 and 5. Finally, Study 8 will determine how usable ultrasound feedback for mid-air gestures is in a real world scenario.

With this work I will provide insights into the usability, strengths and limits of multimodal feedback for mid-air gestures in cars. Therefore, I will present three novel mid-air gesture feedback techniques for cars — haptic steering wheel [7], ultrasound feedback [1], and peripheral ambient light [4] – which will be tested in laboratory and real world driving scenarios.

RESEARCH STATUS

The technology illustrated in Studies 1 [7] and 2 allow the users to process 57 different tactile stimuli via three solenoids embedded into the steering wheel under each palm. The results of the analysis are a clear indication that haptic patterns are perceived with high accuracy (81.2%). However, the more solenoids are involved in a haptic pattern, the worse the identification accuracy (1 stimulus: 92.2%, 2 stimuli: 85.4%, 3 stimuli: 78%, 4 stimuli: 69.5%). Haptic stimuli presented to the thumb region have highest perception accuracy. Generally, the results have shown, that participants have not missed a single tactile message, however presenting patterns to bilaterally decreased identification rate by 10%. There is no significant difference in lane deviation nor steering angle during the three intervals *before*, *during*, and *after* haptic pattern presentation. These findings made in Studies 1 and 2 suggest that haptic feedback on the steering wheel is perceived when presented, does not increase lane deviation, nor perceived mental workload significantly. Additionally, the haptic pattern identification accuracy is high with 81.2%. This leads to the hypothesis that mid-air gesture feedback can be displayed on the steering wheel to the hand of the driver. However, the effectiveness of the combination of mid-air gestures and haptic feedback on the steering wheel has to be tested yet (Study 3). Studies 1 and 2 were a first detailed look at haptic feedback patterns on the steering wheel.

In the remaining 24 months of my PhD I will look at peripheral ambient feedback and ultrasound feedback for in-air gestures in cars. Currently, I am designing a real world in-car study in which the haptic steering wheel will provide mid-air gesture feedback to the driver.

SUMMARY

My thesis research looks at how multimodal feedback helps drivers gesture in mid-air in a driving scenario. So far I have looked at how haptic feedback patterns on the steering wheel may be designed. In the remaining 24 months of my PhD, I plan to focus on peripheral ambient light and ultrahaptic feedback, to see how these can be used to support interaction.

The results from my work will inform designers about the effectiveness and reliability of multimodal mid-air gesture feedback in a driving scenario, such that they can decide on the most appropriate display. Since mid-air gestures in cars is a new research field, there is (to my knowledge) no research investigating multimodal gesture feedback in cars. My results will provide guidelines on delivering multimodal driver mid-air gesture displays in a driving scenario.

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