Augmenting Future In-Vehicle Interactions With Remote Tactile Feedback

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ABSTRACT
For the interaction with in-vehicle interfaces such as infotainment systems, the concept of 'one button per function' has worn out. In order to cope with the increasing functionality of in-vehicle information systems, researchers and practitioners are eager to integrate natural user interfaces and multimodal feedback into the car. In the paper, we discuss our approach of Remote Tactile Feedback and present scenarios for direct touch interactions and tactile feedback before and after an interaction.

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Natural User Interfaces, Remote Tactile Feedback

ACM Classification Keywords
H5.2: User Interfaces. – *Theory and methods.*

Keywords
Experimentation, Human Factors

INTRODUCTION
Researchers and manufacturer start to utilize modalities such as gesture and speech input and auditory and haptic output to improve the safety and expressiveness of automotive user-interfaces. We propose to exploit the unique potentials of Remote Tactile Feedback to further advance multimodal in-car interactions. The spatial separation of direct touch input and resulting haptic and tactile feedback has shown to be beneficial in quantitative and qualitative metrics for touch based interfaces; the in-vehicle application of this approach is the compelling next step.

IN-VEHICLE INTERACTIONS
Minimizing the driver's visual and cognitive load is the main objective for designers and engineers of in-car systems. The defined position of the driver and constraints such as permitted distraction times facilitate the development of novel modalities such as gesture and speech input [2]. For feedback from collision warning or avoidance systems, audio and haptic feedback is already widely used.

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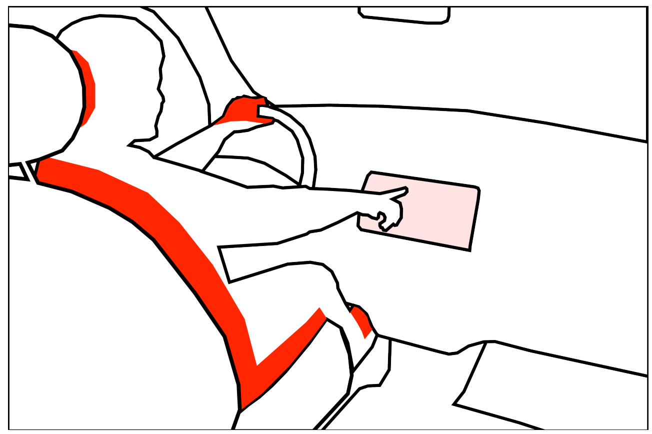

Figure 1: Remote Tactile Feedback can improve and extend touch-based in-vehicle interactions. Colored areas indicate locations on the user's body for the remote application of tactile stimuli.

Nowadays, also many controllers for in-vehicle information systems such as BMW's iDrive[1] are equipped with haptic or tactile feedback. Additionally, due to advantages in usability and flexibility, more and more direct-touch based interfaces such as touchpads or touchscreens find their way into the car. However, the interaction with touchscreens highly depends on visual attention [1], which results in significantly less eye-on-the-road time when drivers interact with touch-based in vehicle systems.

TACTILE FEEDBACK IN THE CAR
Researchers show the highly beneficial effects of active tactile feedback for touch interfaces on error rate, interaction speed and visual load [3]. In a prior work, we present HapTouch, a force-sensitive in-vehicle touchscreen device with tactile feedback that allows the user to explore and manipulate interactive elements using the sense of touch [6]. The results of our user-study indicate positive effects of tactile feedback during touch interactions whilst driving on the errors made during input tasks. This especially holds true for very small virtual elements. However, the variety and expressiveness of generated tactile feedback is limited due to the mechanical complexity and size of actuators. The remote application of tactile stimuli could help here.

[1] www.bmw.com

REMOTE TACTILE FEEDBACK

The spatial separation of direct touch input and resulting tactile output is the basic concept of Remote Tactile Feedback (see figure 1). Moving the tactile stimuli away from the touching fingertip or hand is achieved by integrating actuators in the user's direct environment. Similar to direct tactile stimuli, the remote application of feedback on touch surfaces has positive effects on interaction speed and error rates [4]. Furthermore, this approach has the potential to expand and simplify the use of multimodal stimuli when interacting by touch. For example, in prior work, we describe how to utilize Remote Tactile Feedback to combine rich and versatile tactual characteristics to create novel tactile modalities on direct touch surfaces [5].

SCENARIOS

For Remote Tactile Feedback, electromechanical or electrotactile actuators have to be in contact with the user's body. In the car, large areas of the user's skin can be used to apply various tactile cues: The driver is remaining in a seated position with constant direct contact to the steering wheel, the seat, the armrest or the pedals. We present two possible scenarios of how to utilize the unique characteristics of Remote Tactile Feedback for touch-based in-vehicle interactions:

Direct Touch Interactions

First of all, remote tactile cues can be used to convey standard feedback when interacting with a touchscreen. Resulting tactile stimuli mostly fall into one of 4 categories: During a number input task, the user can manually explore the *form* and function of the on-screen button before it is actually activated. During the manual activation, the altering *state* of the element is communicated haptically. Subsequently, a tactile *acknowledgement* to confirm the interaction could be conveyed using remote tactile stimuli. In addition, *abstract information* such as 'Press Start on Touchscreen' could be communicated even when the user's hand has left the screen. Thus, Remote Tactile Feedback could reduce visual load and enhance safety when interacting via touch.

Tactile Feedback Before and After the Interaction

This scenario is specific for Remote Tactile Feedback: with tactile actuators (e.g. in the steering wheel) in permanent contact with the user's skin, tactile cues on a touch interaction can be given, before, whilst and after the finger actually touches the screen.

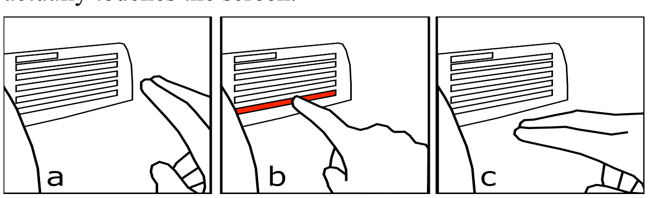

Figure 2: Remote Tactile Feedback can support phases before (a), during (b) and after (c) a direct-touch interaction.

Here is an example (see figure 2): During a list selection task, Remote Tactile Feedback describing the gestural proximity of the finger towards the scroll bar can be given before the finger touches the screen. This results in a form of gestural input: the user approaches the screen with the intention to scroll down a list. Remote tactile stimuli (e.g. from the seat) could inform the user that he is approaching the intended lower part of the virtual list. If the user's finger in front of the screen changes direction, e.g. approaches the list item in the center, the tactile stimulus changes and thus informs the user. This tactile correction could happen in a very short amount of time (e.g. less than 0.5 seconds). The visual load for pointing to the intended screen area is reduced. When the user touches and swipes on the screen the scrolling is performed. After the finger has left the screen, an acknowledgement or the number of passing items is conveyed haptically.

CONCLUSION AND FUTURE WORK

When designing in-vehicle interfaces, minimizing the driver's visual distraction is the primary objective. For touch-based in-vehicle information systems, direct tactile feedback has shown to be highly beneficial in minimizing visual load, reducing error rates and increasing driving performance. The novel approach of separating direct touch input and resulting tactile feedback has the potential to further simplify and expand the use of multimodal stimuli. Due to the driver's defined position and permanent contact with seat, steering wheel and pedal, the car is an appropriate scenario for Remote Tactile Feedback. We briefly described two scenarios of application. The next step is to integrate tactile actuator technology in a car environment. Remote Tactile Feedback could help to improve driving safety and expand and naturalize multimodal interactions in the vehicle.

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