Exploring the Back of the Steering Wheel: Text Input with Hands on the Wheel and Eyes on the Road

Martin Murer, David Wilfinger, Alexander Meschtscherjakov,
Sebastian Osswald and Manfred Tscheligi
Christian Doppler Laboratory "Contextual Interfaces" ICT&S Center, University of Salzburg
Austria
{firstname.lastname}@sbg.ac.at

ABSTRACT

Safe interaction with interactive systems in the car requires both hands to be placed on the steering wheel and eyes to be kept on the road. To allow safe text input in the vehicle, we propose the back of the steering wheel as space for interactive text input elements. In the effort to explore this space, we present two design alternatives for text input elements; one has two sliding sensors and the other has three buttons on each side of the wheel. In combination with a head up display and an adapted keyboard layout, these elements allow text input while driving with the eyes on the road an the hands on the wheel. In a first study with end users, we show the potential of the proposed text input approach for future vehicles.

Categories and Subject Descriptors

H5.2. [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces

Keywords

Back of the device interaction, steering wheel, text input

1. INTRODUCTION

Applications that require text input are increasingly used in todays vehicles, both on in-car systems as well as on nomadic devices, such as mobile phones. This has to be seen critically, since text input while driving has a high distractive potential, especially when the input modality is not optimized for the vehicle (e.g. on a mobile phone). In order to allow safer typing while driving, different text input mechanisms have been introduced in the car. Speech recognition, touchscreen keyboards, and text input via a rotary knob (e.g., BMW iDrive) are popular in current cars. Gesture input has also made its way into vehicles, allowing the user to draw the shape of the letters on a touchpad (e.g., Audi MMI). One major drawback of all these systems (with the exception of speech input) is that they all require the user to take at least one hand off the steering wheel. Additionally, most of the established text input approaches require the users to observe a visual display, which is usually placed in the central console, to monitor the letter selection. This takes the sight and attention away from the road. In a study comparing current in-car systems we measured an average visual distraction time of 64 seconds when typing in a navigation destination while driving (currently under publication). In order to reduce these safety risks, investigating even less distracting text input modalities for drivers is an ongoing requirement for automotive user interface development. Efforts in this direction are encouraged by the fact that text input in the car is likely to increase in the future due to services like email or Twitter, which are foretold to be used in the vehicle.

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2. DESIGN GOAL

Our research is driven by one of the major interaction paradigms in the car; safe driving requires both hands to be placed on the steering wheel and the eyes to be observing on the road [5]. To achieve a high level of safety, driver interaction with in-car systems should follow this paradigm. This is even more true for interactions like text input that take a longer period of time and more steps than turning a single button e.g. to change the sound volume.

The most widely known approach to support hands on the wheel and eyes on the road during text input is the combined usage of voice input and sound feedback. Nevertheless speech based systems have not yet reached a level of quality that makes them usable for all text input use cases. Speech input in the vehicle still suffers from quality and acceptance. We, therefore believe that in the near future speech input will not completely replace other forms of text input, simply due to a lacking flexibility. One can argue that highly distractive activities like typing text has to be completely banned from cars while driving. Although typing text (on mobile phones) is forbidden by law in many countries, reality shows that drivers text while driving. For example, 35% of the drivers in the US state that they read or type messages or emails on their phones while steering a vehicle [1]. Thus, prohibiting this type of functionality on in-vehicle systems is not the solution.

Acknowledging that manual text input in the vehicle will be conducted in the future, efforts have to be taken to make this input as safe as possible. In order to keep hands on the wheel while manually controlling an interactive system at the same time, the input modality has to be placed on the steering wheel or within close proximity. Modern steering wheels already hold a high number of interactive elements on their front side. In terms of information visualization systems, these include volume controls or directional pads to navigate through the infotainment system. These elements have to be manipulated with the thumb in order to keep the hands safely on the wheel. Using the other fingers requires the user to let loose of the steering wheel. This makes a placement of text input elements on the front of the steering wheel less beneficial, since texting with only one finger is less comfortable and effective than typing with more fingers. Additionally, the high number of elements on the front of the steering wheel can lead to a visual overload, requiring the user to search for buttons.

We defined the following design goals for a novel interaction approach for safe text input in the vehicle:

- Users should be able to keep their eyes on the road. This means that if visual output is used, this output should be positioned in a way that the road is still in the field of vision of the driver.

- Both hands should stay on the steering wheel in a position to maintain control.

- Novel input elements should not add to the clutter of elements in the cockpit.

In the designs following these goals we accept a reduction of input speed. It is not a goal of the system to allow text input as fast as possible, but to make it as safe as possible by avoiding distraction from the road and reducing hands off the wheel time. Longer task durations are accepted if the safety of conducting the task is increased.

2.1 Back of the Steering Wheel Concept

In order to achieve the above mentioned design goals we suggest to place text input elements on the steering wheel. In an effort to reduce the cluttering of interactive elements, we identified the back of the wheel as promising space for the integration of input elements within the driver's reach. This space allows the integration of text input hardware supporting an eyes-free interaction with both hands on the wheel. Elements in this space can be pressed (in fact pulled) with up to four available fingers while keeping the wheel secured.

For this purpose, we introduce the Back of the Steering Wheel (BSW) text input system. We understand this approach as a combination of interactive elements on the back of the steering wheel and a visual output created by a head up display (HUD). Although both already have found their way into modern cars, we believe that when combined, they enrich each other leading to a text input system that is highly suited for the requirements of safe in-car interaction.

Following our design goals, we suggest to mount interactive elements on the back of a steering wheel in the position of the shifting paddles. These input elements can be pulled resulting in the input of a sign. Typing text using elements on the back of the steering wheel is supported by a display which could show available options and key configurations. In order to keep eyes on the road, we envision a HUD interface. In combination with the buttons on the back of the steering wheel, this allows safe driving by letting the user keep both hands on the wheel and the eyes on the road while typing text. Figure 1 illustrates the BSW concept.

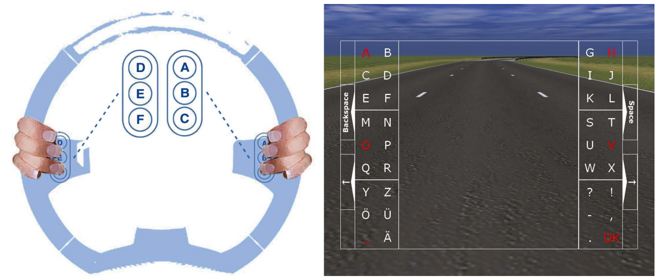

Figure 1: BSW concept (left). HUD projection overlaying the driving simulator (right). The central area is used to display the written text.

In the next section, the BSW approach is discussed with related literature. Thereafter, we present two prototypical implementations of this system.

3. RELATED RESEARCH

Back of the device interaction has gained attention in recent HCI research. A main advantage of this approach is the possibility to increase the size of an input area in relation to the device dimensions [12], allowing the reduction of the size of the device. Another advantage of using the back of devices is the avoidance of fingers obscuring the screen, as shown by [3]. Others have used the back of a device to expand the interaction possibilities giving the users the possibility to interact with a device from both sides [9].

An immanent issue with back of the device interaction is that, while it reduces the occlusion of a display by fingers, the fingers are now occluded by the device itself. Concepts like pseudo-transparency address this issue by showing the user's fingers on the display, letting the user "see through" the device [11]. While these approaches show promising results, we feel that back of the device interaction is most beneficial when inputs can be made without the need to look at the input device. This, for example, can be achieved by a separation of input and output modalities, as used in our BSW approach.

One application scenario is text input, which is well suited for interaction without looking at the modality. Especially with increasing experience, text can be typed with eyes free from the keyboards. In this context, the back of a device has already shown to be a promising space for text input elements (RearType, [8]).

All of these related efforts show the potential of using the back of the steering wheel for eyes free text input. Although this space has been used by car manufacturers, the most popular usage of this design space are shift paddles. Other functions have also already been integrated, such as a button to trigger voice input (Ford Focus). In addition, research has identified the potential to place interactive elements for controlling in car systems on the back of the steering wheel in the vehicle [7].

The potential of interactive elements on the steering wheel for letter input that allows hands on the wheel and eyes on the road was already investigated [5]. Different to the BSW approach, they installed a touchpad on the front of the steering wheel which was manipulated with the thumb. They investigated different interaction designs for a list selection of street names, but not for free text input.

In terms of visual output modality, HUDs have shown their potential in recent system developments since they do not block the user's view on the road while reducing gazes on elements away from the road. Drivers using HUDs are more cautious and aware of the road environment [6] compared to head down displays. Being designed in a plain and unobtrusive manner HUDs, currently pose the visual display modality which is least distracting from the road.

4. IMPLEMENTATION

Following the BSW conceptual model, we mounted interactive elements on the back of a steering wheel in the position of the shifting paddles (see Figures 2 and 3). We developed two design alternatives; one has touch sensors on both sides of the wheel and the second one has three buttons on each side of the steering wheel. Three buttons were chosen, since three different zones can be easily distinguished and touched with fore, middle, and ring fingers.

For typing text with the BSW system, we applied a keyboard using six zones or keys for typing text similar to the Tiki'Notes keyboard available for iOS [10]. The concept is based on the idea that input keys can be reduced if two steps to type in a letter are acceptable. Using this approach, six groups of letters can be chosen containing six letters each (Group 1: A-F, Group 2: G-L,...). These groups are arranged in a 2x3 rectangle (see Figure 1) and are directly mapped to an array of 2x3 keys, three on each side of the steering wheel. A key press opens the corresponding group of letters, which are again each assigned to one key (e.g., Group 1: A, B, C, D, E, F). Pressing a certain key now triggers the input of the corresponding letter. After this input is completed, the group is exited and a new letter can be typed. In this step, the approach allows the inclusion of text input support mechanisms such as predictive text or autocorrection.

Typing text on the back of the steering wheel is supported by a display showing past input and key configurations. In order to allow the user to keep the eyes on the road, we designed a Head Up Display (HUD) interface (see Figure 1). In combination with the buttons on the back of the steering wheel, this allows safe driving by letting the user keep both hands on the wheel and the eyes on the road while typing text.

To explore the usefulness of the BSW approach, two interactive prototypes were built. We used a Fanatec Porsche GT3 steering wheel [4], which is equipped with shift paddles. We detached the paddles and used the mounting points for attaching the input elements to the wheel. The elements were attached to an Arduino sensor board and to a PC. In order to simulate a HUD, we mounted a video projector in front of the car mockup and projected the HUD with a black background on top of the driving simulator software. Since we wanted to investigate the potential of the BSW approach in an exploratory manner, we built a small JAVA tool that allowed us to quickly change certain settings of the system behavior and the HUD, such as position and font size.

4.1 Design Alternative 1

In a first version of the BSW system, we mounted two touch sensitive sensors on each side of the steering wheel. Each sensor was covered with acrylic glass to allow an easy movement of the fingers over the surface. The basic idea was to include a hardware element which would support both sliding (e.g., for deleting the last letter) and pressing. For that purpose, we divided the active area of the slider into three zones, with each zone serving as one button to achieve the six button text input. We achieved this functionality by reading the sensor data when it was pressed strong enough to trigger a shifting paddle click event. Additionally, the slider allowed the quick switching of keyboard sets, e.g. from letters to numbers by sliding up and down. To support the users' orientation on the sliding element, the area which was currently touched by the finger was inverted on the HUD. Users could, therefore, slide over the element until the area that they wanted to press was highlighted. Then they could press the slider to confirm the highlight.

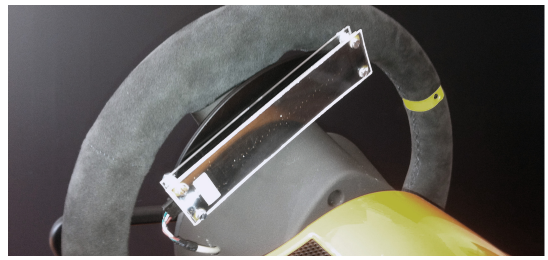

Figure 2: Steering wheel from the back with one slider element (right hand).

4.2 Design Alternative 2

When finishing the construction of the first prototype, we invited researchers of our group to try out the BSW system. To run an informal evaluation and to try out the system, we asked them to type in words with and without driving. We decided to build a design alternative due to negative aspects discovered with the prototype. The system did not allow the user to rest the other fingers on the sensor when pressing the element to make an input. The touch sensors could not measure which finger was actually placed on the intended keys. Thus, lifting the fingers required the users to target the location of the three sensitive areas again and again, a difficult task on the plain surface. We additionally discovered targeting issues; it was not easily possible to discover which element the finger would be placed on. While the position could be corrected when finding the wrong area to be highlighted, this correction caused annoyance and was distracting. Additionally, there was a lack of physical feedback to which area was actually touched, confirming the approach of [8] who used physical keys on the back of their keyer. Replacing the touch elements of the first prototype, we mounted three hardware buttons on each side of the steering wheel (see Figure 3). These buttons allowed the user to leave all fingers on the buttons while pressing one element, additionally it was easier to target a single button since they provided a better physical feedback. For deleting the last letter or going forward in the text, two buttons at once could be pressed.

5. USER STUDY

To gain first feedback on the BSW text input approach, we conducted an evaluation together with end users on Design Alternative 2. For that purpose, we set up a driving simulator at a University event where the public was invited to look at science projects. The setup was open, every visitor could

Figure 3: Steering wheel from the back with three buttons on each side.

become a participant by simply siting down in the simulator and try out the text input modality while freely driving in the simulator. We handed a system usability scale (SUS) questionnaire to each visitor who used the BSW system. We added demographic questions and two additional items (5-point Likert-scale) investigating the success in reaching our design goals (*I was able to keep my eyes on the road while typing text* and *I was able to leave both hands on the steering wheel while typing text*).

In total, 17 people (13 male and 4 female) participated in our study with an average age of 34 years (SD=12.7 years). Three of the participants did not own a driving license. Regarding the SUS questionnaire, a score of 69.4 was reached. As the score can range between 0 and 100 and the usability increases the higher the score gets, scores above 60 can be considered as good, in the sense that people accept a system. Referring to the rating scales described in [2], the SUS score of our system can be described in three ways: the acceptability is marginally high, a school grade of a D was reached and the user rating of the system can be described as good. Regarding the two additional items (1:not - 5:very), a very high confirmation about leaving the hands on the steering wheel could be assessed (mean= 4.3, SD=1.02) as well as an average agreement to the statement about the system allowing the eyes to stay on the road (mean= 3.1, SD=1.21).

6. CONCLUSION AND FUTURE WORK

In this paper, we presented our approach on how to achieve text input in the vehicle with hands on the wheel and eyes on the road. We introduced the back of the steering wheel as promising space for the integration of input modalities for eyes free interaction when combined with a HUD. A first user study showed good success of the approach for supporting users in keeping their hands on the wheel while typing but also unveiled improvement potential in the system's support for keeping eyes on the road. In future efforts, we will address the mental workload of the BSW text input to investigate to what extend the minds of the users were on the road while typing. Additionally, we will experiment with other means of displays, such as a combination of a HUD with auditory feedback to support the "eyes on the road" paradigm to increase safety while typing in the vehicle.

The work described in this paper is a first step in a row of activities that we will conduct on exploring the BSW space. We are already working on implementing other interactive elements such as touchpads, which will allow gesture input for texting, keeping both hands on the wheel.

7. ACKNOWLEDGMENTS

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