Augmented Interaction and Visualization in the Automotive Domain

Roland Spies[1], Markus Ablaßmeier[1], Heiner Bubb[1], and Werner Hamberger[2]

[1] Institute of Ergonomics, Technical University of Munich,
Boltzmannstraße 15, 85747 Garching
{spies,bubb}@lfe.mw.tum.de, ablassmeier@tum.de
[2] AUDI AG, Development HMI, 85045 Ingolstadt
werner.hamberger@audi.de

Abstract. This paper focuses on innovative interaction and visualization strategies for the automotive domain. To keep the increasing amount of information in vehicles easily accessible and also to minimize the mental workload for the driver, sophisticated presentation and interaction techniques are essential. In this contribution a new approach for interaction the so-called augmented interaction is presented. The new idea is an intelligent combination of innovative visualization and interaction technologies to reduce the driver's mental transfer effort that is necessary between displayed information, control movement and reality. Using contact-analog head-up displays relevant information can be presented exactly where it is needed. For control, an absolute natural and direct way of interaction is delivered by touch technologies. However, to leave the eyes on the road, the driver needs haptic feedback to handle a touchpad blindly. Therefore, the touchpad presented in this contribution, is equipped with a haptic adjustable surface. Combining both technologies delivers an absolutely innovative way for in-vehicle interaction. It enables the driver to interact in a very direct way by sensing the corresponding environment on the touchpad.

Keywords: head-up display, touch, haptic feedback, interaction, automotive, augmented reality.

1 Introduction

To keep the increasing amount of information in modern vehicles easily accessible and controllable for the driver and also to minimize his mental workload, sophisticated presentation and interaction techniques are of major importance. In the car domain, error-prone situations often occur regarding the human-machine interaction with different in-car applications, as the driver often has a certain mental workload [1] by combining displayed information, interacting with different input devices and transferring it to the reality.

J.A. Jacko (Ed.): Human-Computer Interaction, Part III, HCII 2009, LNCS 5612, pp. 211–220, 2009.

Automobile manufacturers have already introduced a couple of innovative visualization and interaction techniques. The head-up display for example provides information according to the situation in reality like e.g. navigation information or the current vehicle speed. This visualization method enables the driver to keep his glance on the road and reduces accommodation problems. In the recent past a lot of scientific work has been done on presenting the information in a contact-analog way in the HUD [2,3,4,5,6].

A further challenge of car manufactures today is the increasing amount of comfort functions in modern vehicles e.g. navigation, media and communication systems and soon internet services. To keep all these systems controllable while driving, car producers have integrated these functions in menu-based central infotainment systems which are mostly controlled by one multifunctional input device. Currently, many different solutions of such control devices are available on the market. These solutions can be divided into two different groups: first, an integrating approach represented by touchscreens and second an approach separating display and control element, e.g. turning knobs or joysticks in the center-console. These systems are often extended by voice control and a lot of recent research publications deal with multimodal in-vehicle infotainment interaction [7,8,9]. Further research activities handle with innovative ideas for control elements [10,11], e.g. flexible touch-sensitive surfaces for in-vehicle interaction [12,13]. This contribution delivers a highly new approach for intuitive and workload-reduced in-vehicle interaction by combining innovative technologies for visualization and control.

In the following chapter, the theoretical background concerning controlling and displaying menu systems in dual task situations is discussed and the required technical background is given. Afterwards, the new approach of augmented interaction is explained and a couple of demonstrative examples for future realization are given.

2 Background

The following chapter reflects the relevant theoretical background to analyze the parallel tasks of driving and menu operating. Therefore, the driver as well as the vehicle are considered as parts of the human-machine control loop. This consideration should uncover the need for action.

2.1 Ergonomic Reflection of the Driving Task

The driver-vehicle interaction can be described in a conventional control loop as it is shown in Fig. 1 [14]. The left side of the picture shows the task as the input of the loop. The system components are the driver and the vehicle equipped with an infotainment system. The output of the whole system is permanently verified by the driver and adjusted if necessary. In case of menu control while driving it is about a dual task situation which can cause interferences between the two parallel tasks. Inattention, distraction, and irritation occur beside mental treating internal problems as a consequence of the high workload resulting from a superposition of the tasks, which will become manifest in an increased error potential and in erroneous operations of the systems [15]. According to Bubb the driving task can be classified in primary, secondary and tertiary task [16]. The primary task only consists of real required driving operations. These are segmented into navigation, steering, and stabilization. Choosing the route from departure to destination corresponds to the navigation task. Steering includes, for example, lane changes due to the current traffic situation. User interaction with the car to navigate and steer is called stabilization. These tasks are essential for a safe control of the car, and therefore have highest priority while driving. Secondary tasks are operations that are not essential to keep the vehicle on the track. Examples are the turn signal, honking, and turning the headlights up and down. Tasks not concerning the actual driving itself are categorized as tertiary tasks, e.g. convenience tasks like adjusting the temperature of the air condition or communication and entertainment features.

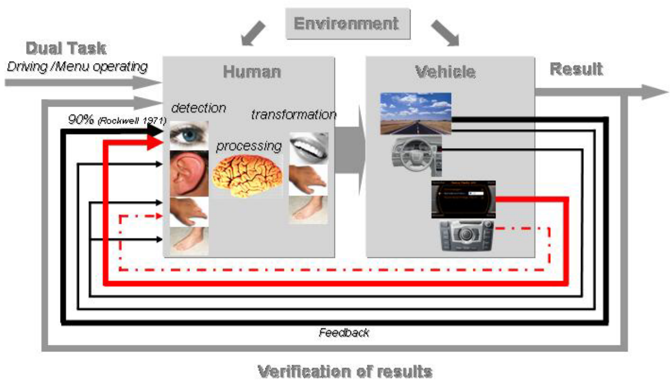

Fig. 1. Control loop of driver vehicle interaction

While working on a desktop PC, the user can predominantly execute her or his operations in a concentrated way, as there is no dual task competition. However in the car domain, often error-prone situations occur regarding human-machine interaction with different in-car applications, as the driver often has a certain mental workload. This basic stress level is due to the execution of so-called primary and secondary tasks, and may be increased by environmental impacts, like the conversation with a co-driver. If the driver interacts, e.g. with a communication and infotainment system in such a stress phase (tertiary task), he probably will be distracted from driving.

A reason for this is founded in the human information detection. The fact that the primary as well as the tertiary task share mainly the visual channel [17] (Fig. 1) leads to gaze movements away from the road and consequently traffic blindness occurs. Here it is necessary to either provide additional channels (e.g. haptic) to transfer information or to merge it with the reality to avoid gaze movements away from the driving scene.

Another reason for the interferences between driving and tertiary tasks is the mental overload effected by compatibility problems between displayed information, control movements and reality [18]. The following part explains a theory of the human information processing and presents ergonomic rules to avoid such incompatibilities.

2.2 Human Information Processing

During system design it is important to identify workload bottlenecks and overload. As the human operator is a central part of a human-machine system, the correction of these workload problems is necessary for the safe and efficient operation.

The Multiple Resource Theory of Wickens [19] allows predicting when tasks will interfere with each other or can be performed in parallel. If the difficulty of one task increases a loss of performance of another task will be the result.

Wickens describes several processing resources. All tasks can be divided into the following components (see Fig. 2): there are the encoding, central processing and responding stages. The visual and auditory components are input modalities. The central processing component describes the level of information processing required. The responding component consists of manual or vocal actions.

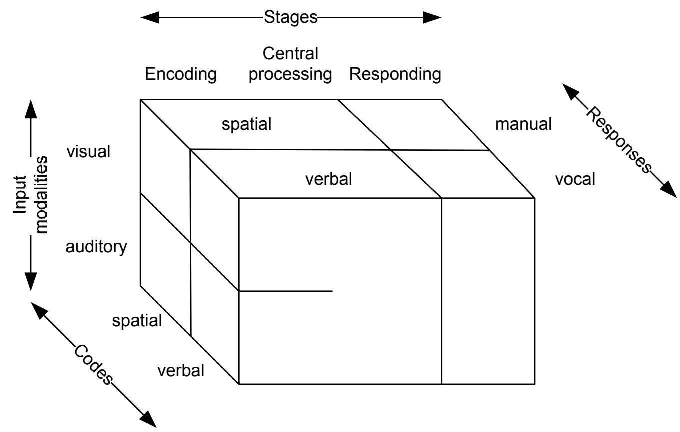

Fig. 2. Wickens' Multiple Resource Theory (MRT) Model [20]

Wickens postulates that using multiple information channels increases the mental capacity and reduces interference effects [19]. To avoid additional mental effort a compatible design between information visualization, control element and reality is important [21]. To adjust the user interface according to the task, the task itself has to be analyzed. The ergonomic analyses according to Bubb provide a method to identify the content of the task according to space (dimensionality) and time [22]. Menu control is a two-dimensional task, what means that in principle, movements on the surface are possible in two directions (e.g. selecting items on a display). To guarantee a compatible interaction, ergonomic solutions require a two-dimensional input device for such a task. Turning knobs in some current automotive solutions are one-dimensional, what means that e.g. moving maps on a display is very inconvenient and requires a mental transfer effort from the user. Concerning the information presentation, ergonomic solutions also require compatibility between information content, the user's mental model and reality.

Summing up the mentioned theoretic facts above, it is possible to derive visualizing as well as control concepts.

2.3 Conclusion

To come up to the claim of a two-dimensional input device which can be controlled blindly, provide additional information via another channel and can be mounted in the center console for ergonomic reachability, the following concept proposes a touchpad with a haptic adjustable surface. The idea is that every kind of structure which is displayed at a screen can be felt on the touchpad surface for orientation. Elevated elements on the touchpad (e.g. buttons) can be sensed and pressed. This input device enables a direct intuitive interaction with a menu-based system.

For a direct, non-distracting information presentation this concept suggests a contact-analog head up display. This technology enables to project information in reality. The technical realization of both concepts is described bellow.

3 Technical Solutions

The following chapter describes the technologies and current application fields of the preliminary considerations and consequences mentioned above.

3.1 The Contact-Analog Head Up Display

As described, a very innovative display technology for cars is the head-up display (HUD). The HUD projects information directly into the driver's visual field. HUDs were pioneered for fighter jets in the early 70s and later for low-flying military helicopter pilots, for whom information overload was a significant issue, and for whom alter their gaze to look at the aircraft's instruments could prove to be a fatal distraction. In future, HUDs are likely to become more common in vehicles. Further recent developments are done to give the driver contact-analog information. A couple of recent research work shows the potential of giving the driver contact-analog information. The spectrum consists of giving speed and distance information [23], night vision information [3] as well as contact-analog navigation information [24].

There exist several technical approaches for contact-analog HUDs. An early solution is delivered by Bubb [4], where a spatial impression is obtained by bending the display in a certain way according to the first optical illustration law, which produces a virtual display lying on the ground. Further developments given by

Schneid and Bergmeier bring this principle closer to automotive capability [2,3,6]. A completely different approach is delivered e.g. by DENSO [5]. Their suggested realization is based on the effect of stereoscopy via two monocular head-up displays covering an image distance of 2m. The drawback of such a solution is that either the head has to be in a fixed position or a highly accurate eye-tracking-system has to be used, what makes this solution extremely cost-intensive. Moreover, if there is a delay in the system caused by the data transferring computing system, sickness will be the consequence. Fig. 3 shows an example of contact-analog driver information.

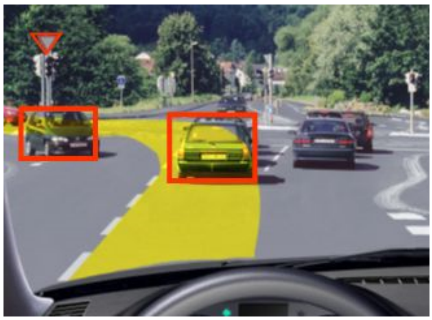

Fig. 3. Example for contact-analog visualization

3.2 The Haptic Touchpad

Touchpads are currently used exclusively in the notebook domain to move a cursor over a display and select items. To make it useable for automotive applications the idea is to give an additional haptic structure on the surface for orientation. Some similar approaches with just a few mechanical, moveable elements or simulated vibration feedback are already published [11,12,13].

Another possibility to realize such an adjustable haptic touchpad surface is to use the so called braille technology. Fig. 4 shows a few examples of haptic displays realized in the braille sector for blind people, using piezo-activated pins.

Fig. 4. Examples for Braille displays [25,26]

4 Augmented Interaction – A New Approach for In-Vehicle Interaction

This chapter explains a new approach for in-vehicle interaction and presents demonstrative use-cases for the combination of the presented display and control techniques.

4.1 Definition of Augmented Interaction

A new way of interaction in the automotive domain can be reached combing both introduced innovative technologies from chapter 3. The structured surface of the touchpad (see section 3.2) enables direct mapping of the displayed information with virtual objects represented by the contact-analog HUD (see section 3.1). The driver interacts with the touchpad by sensing the corresponding environment, activates and manipulates functions directly by pressing and moving on the sensed elevated objects. As a consequence, the mental workload can be reduced through the simple and direct cognitive mapping (see chapter 2). Real and virtual objects are fused together. This kind of interaction will be called augmented interaction.

4.2 Illustrative Use-Cases for Augmented Interaction

In the following, two examples for direct augmented interaction are given to illustrate the potential benefit of the suggested concept.

4.2.1 POIs along the Route

An application of navigation systems is that the driver wants to get further information about a points-of-interest (POI) in his direct surrounding area while driving. With state-of-the-art interfaces, the driver realizes an interesting building outside his vehicle then searches the corresponding POI on the digital map on his central display inside the car and finally selects and activates the information with the central control element depending on the infotainment system. The concept of augmented interaction in this contribution enables the driver to feel his surrounded environment including relevant points-of-interest on the haptic touchpad surface. The driver places his finger on the interested objects and afterwards he gets the real object highlighted contact-analog by the HUD. To avoid an information overflow just the currently touched objects are highlighted. After the relevant object is selected the driver can directly activate further information by pressing the sensed elevated element on the touchpad (Fig. 5).

4.2.2 Adaptive Cruise Control

The second example described in this context stands for interaction with an adaptive-cruise-control (ACC). The potential of contact-analog information concerning distance and speed control is already shown in several recent research contributions (e.g. [24]).

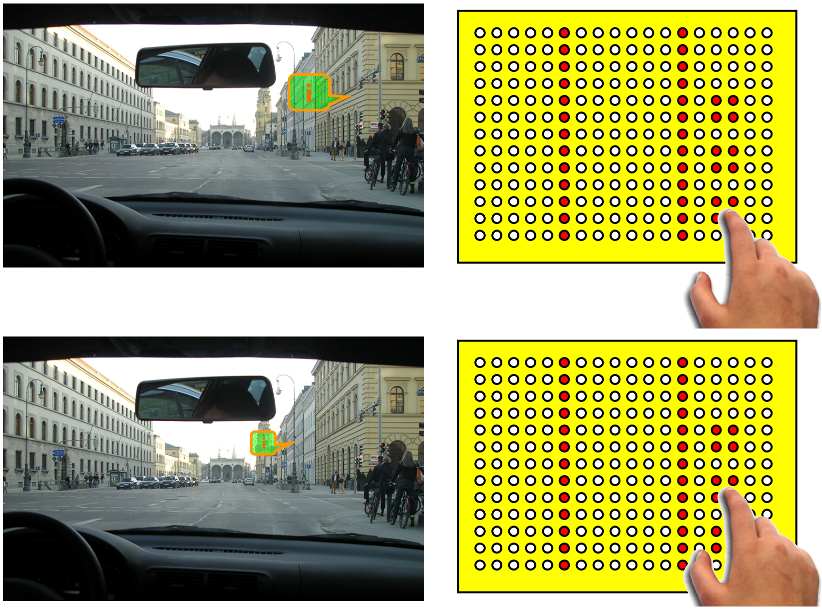

Fig. 5. Examples for highlighting POIs along the route

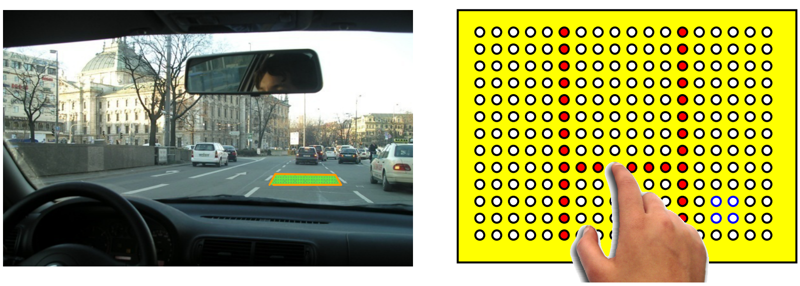

Fig. 6. Examples for adjusting the distance bar

Combined with ACC the contact analog HUD can give a direct system feedback merged with the reality. The drawback of current systems is to adjust speed and distance. Currently, there are a lot of different HMI-variants available on the market. Some control elements are mounted at a drop arm; some are integrated in the steering wheel. All these solutions require a certain mental transfer effort for control and are hard to handle while driving. The augmented interaction solution here projects the environment in front of the vehicle in bird view on the touchpad surface, so that the driver can feel the distance bar with his finger and directly adjust the distance to the front vehicle by moving this bar. A direct visual feedback is given by the contact-analog HUD by a green break bar (Fig. 6). As a consequence the vehicle adjusts the distance to the front vehicle according to the new position of the break bar. If the user wants to chose an illegal distance the system can give information via the HUD by giving the bar a red color for example.

5 Summary and Conclusion

In this contribution a challenging new way of in-vehicle interaction is presented. The so-called augmented interaction is expected to reduce the mental effort for the driver while interacting. This is reached by the intelligent combination of innovative display methods together with new control technologies. For the driver-adjusted display of information a contact-analog HUD is used to present the information directly where it is needed. For an adequate control of this information a haptic adjustable touchpad is used that maps the reality to the surface. As a result the driver can now interact directly by touching the corresponding haptic surface.

To realize the presented approach of augmented interaction for vehicles a lot of further aspects have to be considered. Contact-analog HUDs are still not automotive capable respecting packaging size, sensor technologies and field-of-view. Also the haptic configurable touchpad is a very complex element and still very space and cost-intensive. Additionally, a lot of effort has to be invested to map the reality to the haptic surface and to realize the presented use-cases. Therefore, elaborate computer processing is affordable.

After the prototype is finished studies are necessary to evaluate this approach according to driving scenarios and prove the presented theoretical benefits of the combination of these new technologies.

References

1. Praxenthaler, M.: Experimentelle Untersuchung zur Ablenkungswirkung von Sekundäraufgaben während zeitkritischer Fahrsituationen, Dissertation, Universität Regensburg (2003)
2. Bergmeier, U.: Methode zur kontaktanalogen Visualisierung von Fahrerassistenzinformationen unter automotive-tauglichen Gesichtspunkten. In: Produkt- und Produktions- Ergonomie – Aufgabe für Entwickler und Planer. Kongress der Gesellschaft für Arbeitswissenschaft, vol. 54, pp. 125–128. GfA Press, München (2008)
3. Bergmeier, U., Bubb, H.: Augmented Reality in vehicle – technical realization of a contact analogue head-up display under automotive capable aspects; usefulness exemplified through night vision systems. FISITA World Automotive Congress (F2008-02-043), Munich (2008)
4. Bubb, H.: Untersuchung über die Anzeige des Bremsweges im Kraftfahrzeug, BMVg – FBWT 76-7, pp. 198–202 (1979)
5. Koji, N., Hiroshi, A., Nobuaki, K.: Denso Corporation, Windshield display for active safety, FISITA World Automotive Congress (F2006D105), Yokohama (2006)
6. Schneid, M.: Entwicklung und Erprobung eines kontaktanalogen Head-up-Displays im Fahrzeug, Dissertation, TU München (2009)

7. Geiger, M.: Berührungslose Bedienung von Infotainment-Systemen im Fahrzeug, Dissertation, TU München (2003)
8. Mischke, M., Hamberger, W.: Multimodalität im Dualtask - eine Lösung für die Probleme der Sprachbedienung. In: Prospektive Gestaltung von Mensch-Technik-Interaktion, vol. 7. Berliner Werkstatt Mensch-Maschine-Systeme, Berlin (2007)
9. Hummel, S.: Akzeptanzentwicklung bei multimedialen Bedienkonzepten, Dissertation, TU München (2008)
10. Sendler, J.: Entwicklung und Gestaltung variabler Bedienelemente für ein Bedien- und Anzeigesystem im Fahrzeug, Dissertation, TU Dresden (2008)
11. Vilimek, R.: Gestaltungsaspekte multimodaler Interaktion im Fahrzeug Ein Beitrag aus ingenieurspsychologischer Perspektive, Dissertation, Universität Regensburg (2007)
12. Doerrer, C.: Entwurf eines elektromechanischen Systems für flexible konfigurierbare Eingabefelder mit haptischer Rückmeldung, Dissertation, TU Darmstadt (2003)
13. Hayward, V.: Change of Height: An Approach to the Haptic Display of Shape and Texture Without Surface Normal. In: Experimental Robotics III. Springer Tracts in Advanced Robotics, pp. 570–579. Springer, New York (2003)
14. Bubb, H., Seiffert, R.: Struktur des MMS. In: Bubb, H. (ed.) Menschliche Zuverlässigkeit, pp. 18–20. ecomed – Fachverlag, Landsberg (1992)
15. McGlaun, G., Lang, M., Rigoll, G., Althoff, F.: Kontextsensitives Fehlermanagement bei multimodaler Interaktion mit Infotainment- und Kommunikationseinrichtungen im Fahrzeug. In: Nutzergerechte Gestaltung technischer Systeme, Tagungsband VDI-Fachtagung USEWARE, VDI-Bericht 1837, pp. 57–65. VDI-Verlag Düsseldorf, Darmstadt (2004)
16. Bubb, H.: Fahrerassistenz primär ein Beitrag zum Komfort oder für die Sicherheit? VDI Nr. 1768, pp. 25–44. VDI-Verlag (2003)
17. Rockwell, T.H.: Eye Movement analyses of visual information acquisition in driving: an overview. Paper presented at the North Carolina State University, Raleigh (1971)
18. Bullinger, H.J.: Ergonomie Produkt und Arbeitsplatzgestaltung. B.G. Teubner Verlag, Stuttgart (1994)
19. Wickens, C.D.: Engineering Psychology and Human Performance. Columbus, Merrill (1984)
20. Wickens, C.D.: Attention and Situation Awareness, Ph.d. thesis, Univ. Illinois (1996)
21. DIN EN ISO 10075-2, Ergonomische Grundlagen bezüglich psychischer Arbeitsbelastung, Teil 2: Gestaltungsgrundsätze (2000)
22. Bubb, H., Schmidtke, H.: Systemstruktur. In: Schmidtke, H. (ed.) Ergonomie, vol. 3. Auflage, Hanser Verlag, München (1993)
23. Assmann, E.: Untersuchung über den Einfluss einer Bremsweganzeige auf das Fahrverhalten, Dissertation, TU München (1985)
24. Tönnis, M., Lange, C., Klinker, G., Bubb, H.: Transfer von Flugschlauchanzeigen in das HUD von Kraftfahrzeugen. In: Proceedings 22. Internationale VDI/VW Gemeinschaftstagung Integrierte Sicherheit und Fahrerassistenzsysteme, Wolfsburg (2006)
25. See by Touch, `http://see-by-touch.sourceforge.net/index.html`
26. TIM - Der Blindenmonitor, `http://www.blindenmonitor.de`