Work 41 (2012) 4192-4199
DOI: 10.3233/WOR-2012-0121-4192
IOS Press

Comparison of two human-machine-interfaces for cooperative maneuver-based driving

Benjamin Franz[a*], Michaela Kauer[a], Anton Blanke[a], Michael Schreiber[a], Ralph Bruder[a], and Sebastian Geyer[b]
Technische Universität Darmstadt
[a] *Institute of Ergonomics, Petersentrasse 30, D-64287 Darmstadt, Germany*
[b] *Institute of Automotive Engineering, Petersentrasse 30, D-64287 Darmstadt, Germany*

Abstract. In the project "*Conduct-by-Wire*" which is founded by the German Research Foundation (DFG) cooperative maneuver based driving is examined. In this paper two different input devices (gesture recognition and tactile touch display) are compared in a simulator study with 29 participants. It shows that the major advantage of the gesture recognition is that there is no need for the driver to take his gaze off the road. In contrast, the number of gazes at the tactile touch display is significantly higher. The major advantage of the tactile touch display is that no input errors occurred during the test drives. Conversely, the gesture recognition was significantly worse. Nevertheless, further work is needed to decide which input device is the best.

Keywords: *Conduct-by-Wire*, maneuver-based vehicle guidance, advanced driver assistance system, interface design, gesture recognition

1. Introduction

In the last decades, the number of driver assistance systems in passenger cars is growing [7]. According to the three-level hierarchy of the driving task [4] (model is explained in figure 1) current driver assistance systems relieve the driver on stabilization (e.g. ABS, ESP), guidance (e.g. ACC) and navigation level (e.g. navigation system). On one hand, current driver assistance systems reduce driver loads by providing support in certain situations or assuming subtasks such as longitudinal guidance [11, 2]. On the other hand, driver assistance systems also create new strains since the driver has to operate and monitor each system [11].

Furthermore, with reference to [19], the control complexity increases with every increase in the degree of the assistance. To ensure the safe use of assistance systems, the driver has to combine the modes of each system (e.g. ACC is on / off) with an overall mode of the vehicle (e.g. ACC does not recognize a preceding vehicle but the lane departure warning recognizes the lane boundaries). Therefore functional knowledge is needed which is not necessarily present in every driver [19].

A possible solution to eliminate the negative effects of an increasing number of driver assistance systems could be to change the current driving paradigm (cf. [18]). With new vehicle guidance concepts such as *Conduct-by-Wire* (*CbW*, [17]) or H-Mode [5] the driver interacts with one driver assistance system which combines functions of several systems and integrates new ones.

A new driving paradigm like *Conduct-by-Wire* (see section 2.1) leads to the need of new driver-vehicle interaction concepts. In this paper two different input devices for *Conduct-by-Wire,* a tactile touch display (see section 2.2) and a gesture recognition device (see section 2.3) are described. Both input devices are supplemented by a static head-up-display

* Corresponding author: Benjamin Franz. E-mail: b.franz@iad.tu-darmstadt.de. Fax: +49 6151 16 7040. Tel: +49 6151 16 7040

1051-9815/12/$27.50 © 2012 – IOS Press and the authors. All rights reserved

described in section 2.4. In section 3 both input devices are examined and compared with a conventional steering wheel and pedals in a simulator study. The purpose of the study is to determine which input device is more suitable for maneuver-based vehicle guidance.

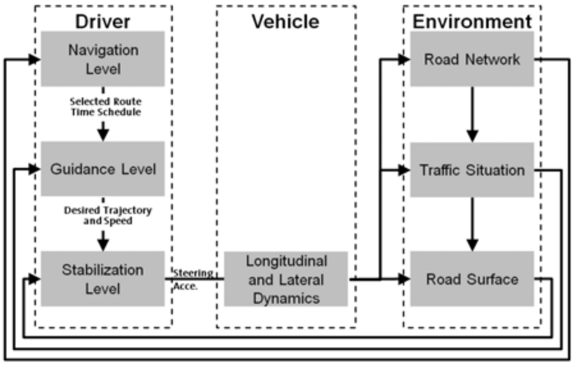

Figure 1: Three level hierarchy of the driving task [10]. Navigation level: The route based on the road network is selected. Vehicle Guidance: The adequate trajectory is determined. Stabilization level: The chosen trajectory is converted into steering, braking, and accelerating inputs.

2. Theoretical Background

2.1. Conduct-by-Wire

The idea of the project "*Conduct-by-Wire",* which is founded by the German Research Foundation (DFG), is to transfer the vehicle control from stabilization to guidance level [19] (cf. figure 1 and 2). Instead of providing continuous control inputs the driver controls the vehicle with the help of discrete maneuver commands (e.g. "lane change right" or "follow lane").

After a maneuver is handed over to the vehicle it verifies if the chosen maneuver can be executed. For example in case of a "lane change right"-maneuver the *Conduct-by-Wire* system checks if there is a lane next to the driver on the right side of the own vehicle and whether it is permitted to change lanes. Afterwards the system verifies that there are no other vehicles on the target lane and performs the lane change or otherwise informs the driver. In addition to the maneuvers the driver can also pass a driving parameter (e.g. "desired vehicle speed") to the *Conduct-by-Wire* system. A complete overview of all maneuvers and parameters needed in a typical motorway scenario (cf. [15]) and used in this study is given in table 1.

As a result *Conduct-by-Wire* is a consistent and simplified vehicle guidance concept which provides most of the functionality of advanced driver assistance systems and is extended with additional functions. Nevertheless, according to [19] the driver remains responsible for guiding the vehicle.

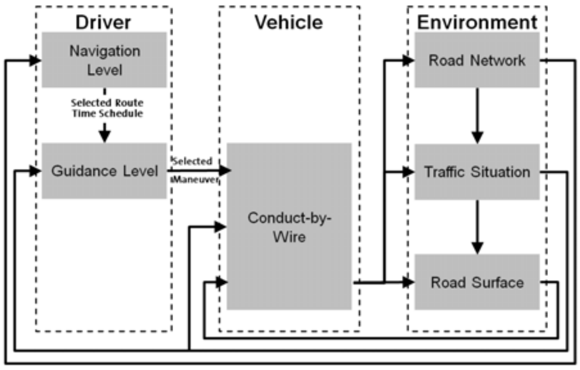

Figure 2: Three level hierarchy of the driving task with *Conduct-by-Wire* [18]

Table 1

Complete overview of all maneuvers and parameters needed in a typical motorway scenario (cf. [15]).

Maneuver	Description
Follow lane	The vehicle follows the current lane with the desired vehicle speed. In the case of an upcoming reduction in speed limit a higher vehicle speed is reduced automatically. If the ego-vehicle is approaching a preceding vehicle the speed is automatically reduced until the desired time gap is reached.
Lane change left / right	If the traffic situation allows a lane change to the left / right within 10 seconds it is performed by the vehicle. Afterwards the *Conduct-by-Wire* system switches to the maneuver "follow lane" automatically. If the desired lane change is not possible the *Conduct-by-Wire* system informs the driver and rejects the maneuver command.

Parameter	Description
Desired vehicle speed	The desired vehicle speed can be chosen by the driver.
Eccentricity to the center of the current lane	The lateral position of the vehicle in the lane can be chosen by the driver.
Time gap to the preceding vehicle	Desired time gap to a preceding vehicle. Four different time gaps can be chosen by the driver: 1s, 1.5s, 2s or 2.5s

2.2. Tactile Touch Display

The first input device is an Immersion TS1000 touch display which is mounted in the center of the steering wheel. The display is fixed to the vehicle and therefore does not move if the steering wheel is turned. Since the display is equipped with actuators the driver gets tactile feedback if a button is pressed.

The displayed content (see figure 3) can be divided into three different parts: the maneuver (dark grey background), and two parameter areas (light grey background) (cf. [10]).

Figure 3: Displayed content of the tactile touch display. In this example two maneuvers are available ("*lane change right / left*") and the maneuver "*follow lane*" is executed.

The maneuver area shows currently available and unavailable maneuvers with the help of a three-by-three icon-array as well as the active maneuver. The icon of the active maneuver is highlighted with a blue frame whereas icons of currently unavailable maneuvers are grayed out. In the example (see figure 3) only two maneuvers are available ("*lane change right / left*") and the maneuver "*follow lane*" is executed.

The first parameter area can be found on the left side of the screen. Next to a button to enable / disable the *Conduct-by-Wire* system both parameters ("*eccentricity*" and "*time gap*") can be set by the driver.
At the bottom of the screen the second parameter area, the speedometer area, can be found. On a horizontal scale two speeds are marked with a blue bar and a red triangle. The bar represents the current vehicle speed whereas the red triangle displays the desired vehicle speed.

2.3. Gesture Recognition

The second input device is a multi-touch pad based on frustrated total internal reflection (FTIR) [8] which is integrated in a modified right arm rest of the driving simulator [6] (cf. figure 4). The detection and tracking of the input points ("blobs") is done by the open source software *Community Core Vision* [3]. Self-developed software provides gesture recognition functions based on a pattern recognition algorithm described by (cf. [20]).

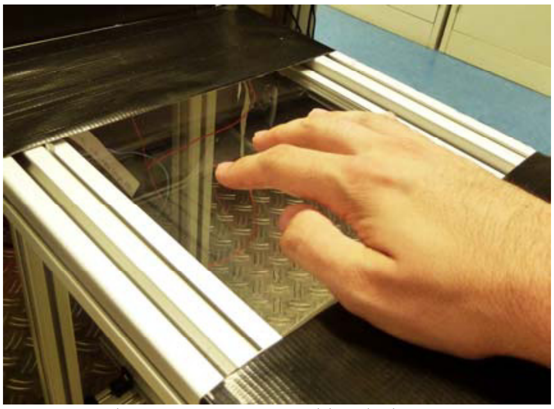

Figure 4: Gesture recognition device [6].

Similarly to the input commands of the Conduct-by-Wire system, the gestures can be divided into two groups: maneuvers and parameters. Maneuver gestures are performed with one finger whereas parameter inputs are executed with two or three fingers [6].

After the gesture is completed and recognized the maneuver is carried out by the vehicle. In contrast, parameters can be modified continuously.

A complete overview of all possible gestures can be found in table 2.

Table 2

Complete overview of all possible maneuver and parameter gestures [6].

Maneuver	**Gesture description**	
Follow lane		Sliding with one finger up.
Lane change left		Sliding with one finger from bottom-right to top-left.
Lane change right		Sliding with one finger from bottom-left to top-right.
Parameter	**Gesture description**	
Desired vehicle speed		Sliding up (increase speed) or down (reduce speed) with three fingers.
Eccentricity to the center of the current lane		Sliding horizontaly with two fingers.
Time gap to the vehicle ahead		Sliding up (enlarge time gap) or down (reduce time gap) with two fingers.

Since the interface doesn't provide haptic effects, all feedback has to be given visually or acoustically (cf. [6]). Due to the complexity of the interaction with the *Conduct-by-Wire* system, a visual feedback was preferred. Therefore a static head-up-display (2.4) was designed, which is required for use of the gesture recognition. For ease of comparison, the head-up-display was also used together with the tactile touch display and with the steering wheel and pedals.

2.4. Static Head-up-Display for Conduct-by-Wire

The displayed content on the static head-up-display for *Conduct-by-Wire* can be divided into two areas [6]. The first area shows the active and available maneuvers (see figure 5). The icon of the maneuver "follow lane" is displayed in the middle of the area. The maneuver-icons "lane change right / left" are shown on the right / left. The currently active maneuver is highlighted with a blue frame and is displayed less transparently than available maneuvers. If a maneuver is not available at the moment the corresponding icon is not shown.

Figure 5: Static head-up-display with the *Conduct-by-Wire* system turned on [6].

In the second area, parameter and speed information can be found (see figure 5). Three different speeds are displayed on the Head-up-Display alphanumerically. The vehicle speed is shown on the left hand. In the middle the current speed limit can be found while the desired speed is displayed on the right hand. The color representation changes from green to red if the vehicle speed is higher than the speed limit.

The time gap to the preceding vehicle is represented by a maximum of four green horizontal bars displayed above the speed limit information. The more bars shown, the longer the current time gap is.

On the left and right side of the speedometer-area the eccentricity to the center of the current lane is displayed with a maximum of four green vertical bars. The more bars shown on the left the larger the distance to the left lane boundary is and vice versa.

If the *Conduct-by-Wire* system is turned off the displayed content is reduced (see figure 6). Only the vehicle speed and the speed limit are presented to the driver. Even here, the color changes from green to red if the vehicle speed is higher than the speed limit.

Figure 6: Static head-up-display with the *Conduct-by-Wire* system turned off

3. Simulator Study

3.1. Preliminary Considerations and Hypotheses

3.1.1. Driver's Gaze Behavior

If both input devices for *Conduct-by-Wire are compared,* differences in the driver's gaze behavior can be assumed. All information needed to conduct the vehicle can be gathered from the environment or from the head-up-display. Therefore there is no need to take the driver's gaze off the road with the gesture recognition system. The same applies to the conventional driving with a steering wheel and pedals which is also supported by the (reduced) head-up-display (see figure 6).

Conversely, although driving with the tactile touch pad is also supported by the head-up-display, the driver must look at the device to use it.

Concerning the driver's gaze behavior, the following hypotheses are formulated:

G1: The percentage of gazes at the road is significantly lower when driving with the tactile touch display than when driving with the steering wheel and pedals.

G2: The percentage of gazes at the road is significantly lower when driving with the tactile touch display than with the gesture recognition.

G3: There is no significant difference between driving with the gesture recognition and driving with steering wheel and pedals in terms of the percentage of gazes at the road.

G4: The number of gazes at the input device is significantly reduced while driving with the steering wheel and pedals compared to driving with the tactile touch display.

G5: The number of gazes at the input device is significantly reduced while driving with the gesture recognition compared to driving with the tactile touch display.

G6: There is no significant difference in the number of gazes at the input device while driving with the steering wheel and pedals compared to driving with the gesture recognition.

3.1.2. Input errors

Since the user's input is interpreted by a gesture recognition system, errors can occur. Including the input errors, four states can be discerned: true positive (a gesture was recognized correctly), false positive (a different gesture was recognized), false negative (a gesture was executed but not recognized), and true negative (no gesture was executed and recognized).

In a safety-critical task, like operating a vehicle, all failures must be avoided at all times. Especially false positives should never occur. Therefore a high recognition rate (true positives) has to be achieved. In the literature, recognition rates for gesture recognition systems vary:

With a system constructed by [14] based on hidden Markov models and a Nintendo Wii game controller, an average recognition rate of 89.7% with five trained gestures could be achieved. [13] developed a sign language recognition system based on hidden Markov models which identifies 80.4% of the 51 trained postures. An average recognition rate of 93.14% was achieved by a system presented by [12] which recognizes 10 hand gestures from continuous motion. In an automotive context, [1] designed a hand and head gesture recognition system for controlling an infotainment system. Two different gesture sets were trained to the system with average recognition rates of 86% (17 gestures) and 93% (5 gestures).

In summary, it can be inferred that with the introduced systems true positive rates between 80.4% and 93.14% could be achieved. Transferred to the *Conduct-by-Wire* system, with which on average 1.59 maneuvers and parameters per kilometer are commissioned by the driver [15], a failure would happen every 3.2 (false positive) or 9.2 kilometers (false negative).

While for a mass-production vehicle both values may seem to be too low, we assume that in our prototype study similar recognition rates can be achieved.

In contrast, when using the tactile touch display an input error can only occur if a wrong button is pressed or unintentionally touched.

Concerning the input errors the following hypotheses are formulated:

E1: The number of input errors is significantly higher while driving with the gesture recognition compared to driving with a tactile touch display.

E2: The true positives rate of the gesture recognition is in the range of 80 to 93%.

E3: The false positive rate is zero.

3.1.3. Pragmatic Quality

The pragmatic quality (PQ) measures the controllability of a product and answers the question of how well the user's goals are reachable with the product [9]. Transferred to an input device for *Conduct-by-Wire,* the user's goal is to safely operate the vehicle. Since a conflict between occurring input errors and the driver's goal can be assumed, it can be expected that high input failure rates cause a low pragmatic quality.

As described in chapter 3.1.2, a higher number of input failures are expected while driving with the gesture recognition, than while driving with the tactile touch display or the steering wheel and pedals. Therefore a higher pragmatic quality is assumed as well. If one compares the pragmatic quality of the tactile touch display directly to the steering wheel and pedals, a low failure rate and therefore no significant difference is expected.

Concerning the pragmatic quality of the input devices the following hypotheses are formulated:

PQ1: Compared with gesture recognition the pragmatic quality of the tactile touch display is significantly higher.

PQ2: Compared with gesture recognition the pragmatic quality of the steering wheel and pedals is significantly higher.

PQ3: There is no significant difference if the pragmatic quality of the steering wheel and pedals and that of the tactile touch display are compared.

3.1.4. Hedonic Quality

The hedonic quality (HQ) describes how innovative and valuable a product appears to the user [9]. It consists of two sub-qualities, namely identity and stimulation. The hedonic quality identity describes the possibilities of the user to communicate a particular identity with the product whereas the hedonic quality stimulation indicates how the product stimulates the user's need to develop and move forward [9].

In contrast to the steering wheel and pedals the gesture recognition and the tactile touch display are new input devices. Therefore it is presumed that their hedonic quality is significantly higher. Since gesture recognition is less common than the tactile touch display or touch displays in general (e.g. smartphones etc.) it is assumed that its hedonic quality is even higher.

The following hypotheses can be formulated:

HQ1: Compared to the steering wheel and pedals the hedonic quality of the tactile touch display is significantly higher.

HQ2: Compared to the tactile touch display the hedonic quality of the gesture recognition is significantly higher.

3.2. Design of the Simulator Study

The simulator study took place at the static driving simulator of the Institute of Ergonomics Darmstadt. An overall of six test drives had to be completed by each participant. For each input device (steering wheel, tactile touch display, and gesture recognition) a 4km familiarization and an 18km test drive were carried out. The test track was modeled after an existing autobahn section from Darmstadt to Wuerzburg, Germany. The order of the input devices was permuted.

To measure the hedonic and pragmatic quality of the input devices after each drive, questionnaires (e.g. *AttrakDiff II* [9]) were answered by the participants. After all test drives the input devices were compared in an overall questionnaire.

Additionally, simulator and gaze data were collected for each drive. Also the input devices were filmed with several cameras to record input errors and behavior. Additionally, to get information about input errors and the desired input the method "thinking aloud" (cf. e.g. [16]) was used in which participants comment on their thoughts and any incurred problems.

3.3. Collective of Test Subjects

A total number of 29 test subjects participated in the simulator study. 16 participants were male and 13 female. The average age was 26.97 (SD: 5.65) years whereas the youngest participant was 18 and the oldest 43 years old. 27 participants were right-handed.

All participants had a valid driver's license for an average of 8.5 (SD 4.95) years.

3.4. Test Results

3.4.1. Objective Results: Driver's Gaze Behavior

The highest percentage of gazes at the road is achieved while driving with the steering wheel and pedals (AM: 88.6%; SD: 4.1%; cf. figure 7). With the gesture recognition, the percentage of gazes at the road is highly significant lower (AM: 84.4%; SD: 6.1%; p: 0.002). The lowest percentage of gazes at the road was determined with the tactile touch display (AM: 79.8%. SD: 8.5%). Compared to the gesture recognition and the steering wheel and pedals a highly / very highly significant reduction (p: 0.002 / p: 0.0002) can be shown.

Therefore hypothesis G1 and G2 cannot be rejected whereas hypothesis G3 must be rejected.

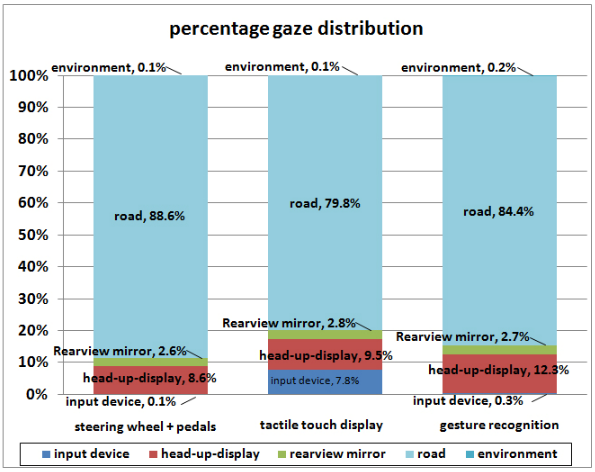

Figure 7: Percentage gaze distribution.

The highest number of gazes at the input device measured was with the tactile touch display (AM: 38.2; SD: 10.9; cf. figure 8). Compared to the tactile touch display, the gesture recognition (AM: 2.6; SD: 3.9) and the steering wheel and pedals (AM: 0.44; SD: 0.93) had a very highly significant ($p < 0.001$) reduced number of gazes at the input device. Comparing the steering wheel and pedals with the gesture recognition a significant (p: 0.013) difference can be shown.

Therefore hypothesis G4 and G5 could be confirmed whereas hypothesis G6 has to be rejected.

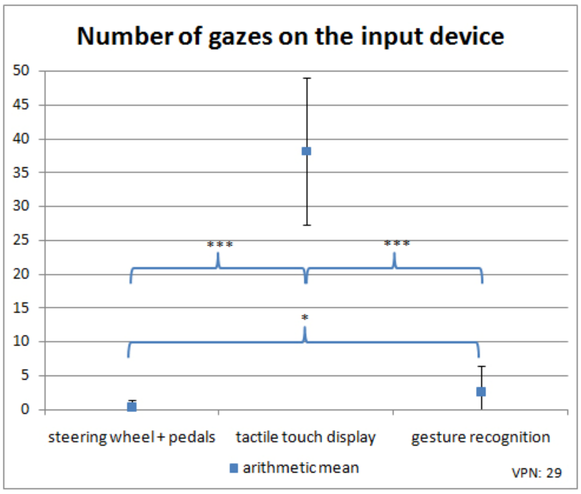

Figure 8: Number of gazes at the input device. The figure shows the arithmetic means with the corresponding standard derivation. */**/***: significant / highly significant / very highly significant correlation

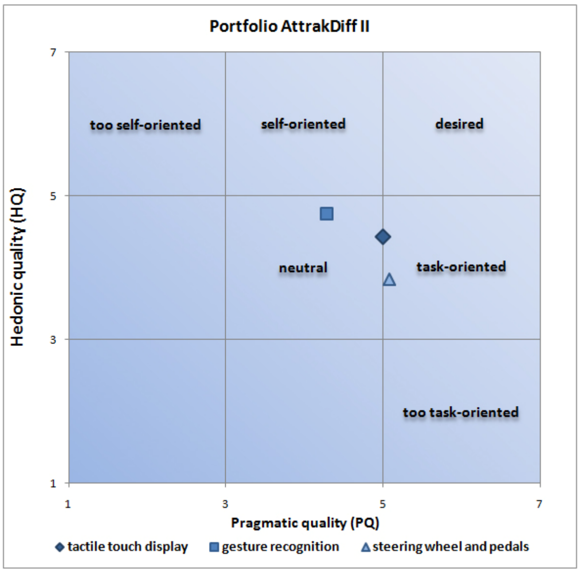

Figure 9: AttrakDiff II portfolio diagram. PQ: measure of the controllability; HQ: measure how innovative and valuable the product appears to the participant

3.4.2. Objective Results: Input Failures

With the gesture recognition, nearly every participant experienced a number of false negative input errors (AM: 6.6; SD: 5.2) whereas with the tactile touch display no errors occurred. Most input errors occurred during a maneuver input. An overall recognition rate of 80% could be achieved.

Additionally one participant experienced a false positive when he commissioned a lane change to the right and a lane change to the left was executed.

In summary, hypothesis E1 and E2 are confirmed whereas hypothesis E3 has to be rejected.

3.4.3. Subjective Results: AttrakDiff II

The participants rated the pragmatic quality of the steering wheel and pedals the highest (PQ: 5.1; SD: 0.8; cf. figure 9). Compared to the tactile touch display (PQ: 5; SD: 0.7) the difference is not significant. The gesture recognition received the lowest rating (PQ: 4.3; SD: 1.2). The difference between the tactile touch display and to the steering wheel is highly (p: 0.003) / very highly significant (p: < 0.001).

Therefore hypothesis PQ1, PQ2 and PQ3 could be confirmed.

The participants rated the gesture recognition as the most hedonic input device (HQ: 4.8; SD: 0.6). The tactile touch display (HQ: 4.4; SD: 0.7) and the steering wheel (HQ: 3.8; SD: 0.7) received highly (p: 0.0099) / very highly (p: < 0.001) significantly lower ratings.

Therefore hypothesis HQ1 and HQ3 could be confirmed.

4. Discussion and Conclusion

In this study two different input devices for *Conduct-by-Wire* have been examined. Compared to the conventional steering wheel and pedals both input devices have advantages and disadvantages.

The major disadvantage of the gesture recognition is its input failures. Even one false positive occurred during the test drives and therefore the recognition rate has to be improved in future work.

On the other hand, with the gesture recognition the percentage of gazes at the road could be enhanced by 4.6% compared to the tactile touch display. If the gazes at the head-up-display are also counted as gazes at the road the improvement is around 7.4%.

If the gesture recognition is compared to the steering wheel a significant difference can also be found. This effect can be explained with the observation that some test subjects looked at the gesture recognition after an input error occurred. Also some participants checked if their hand is positioned correctly on the surface. It is presumed that these effects diminish when the driver is used to the device.

In contrast, the major advantage of the tactile touch display is its higher pragmatic quality compared to the gesture recognition which is close to the rating of the steering wheels and pedals. Also no input errors occurred while using the device. Therefore the first choice should be the tactile touch display because of safety reasons. Though, when the participants were asked directly which input device for *Conduct-by-Wire* they would prefer, 16 people rated the gesture recognition as the best. This shows that both concepts should be persecuted and improved in future work.

Additionally, another input device concept which combines the advantages of the gesture recognition and the tactile touch pad will be tested in an upcoming study.

References

[1] Althoff, Frank; Lindl, Rudi and Walchshäusl, Leonhard. Robust Multimodal Hand- and Gesture Recognition for Controlling Automotive Infotainment Systems. In VDI-conference: Der Fahrer im 21. Jahrhundert, Braunschweig, Germany, 2005.

[2] Biehl, B.. Vorgaben an die Verkehrsplanung – Anforderungen an den Menschen (aus psychologischer Sicht). In: Lang, E.; Arnold, K. (Eds.): Der Mensch im Straßenverkehr. Stuttgart, Germany, 1993.

[3] Community Core Vision. http://ccv.nuigroup.com/

[4] Donges, E.. Aspekte der aktiven Sicherheit bei der Führung von Personenkraftwagen. In: Automobil-Industrie, Vogel AutoMedien GmbH & Co. KG. 2/82, pp. 183-190, Wuerzburg, Germany, 1982.

[5] Flemisch; Adams; Conway; Goodrich; Palmer and Schutte. The H-Metaphor as a guideline for vehicle automation and interaction, Nasa Langley Research Center, 2004.

[6] Franz, B.; Kauer, M.; Schreiber, M.; Blanke, A.; Distler, S.; Bruder, R. and Geyer S.. Maneuver-Based Driving Today and in the Future – Development of a New Human-Machine Interface for Conduct-by-Wire. In: 6. VDI-Tagung Der Fahrer im 21. Jahrhundert, Braunschweig, 2011, submitted for publication.

[7] Gelau, C.; Glasser, T. M. and Seeck, A.. Fahrerassistenz und Verkehrssicherheit. In Handbuch Fahrerassistenzsysteme, H. Winner, S. Hakuli, and G. Wolf (Eds.), pp. 24-32, 2009.

[8] Han, Jefferson. Low Cost Multi-Touch Sensing through Frustrated Total Internal Reflection. Symposium on User Interface Software and Technology: Proceedings of the 18th annual ACM symposium on User interface software and technology. pp. 115-118, Seattle, WA, USA, 2005.

[9] Hassenzahl, Marc; Burmester, Michael and Koller, Franz. AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In: *G. Szwillus, J. Ziegler (Eds.): Mensch & Computer 2003: Interaktion in Bewegung. pp 187-196, Stuttgart: B. G. Teubner, 2003.*

[10] Kauer, Michaela; Schreiber, Michael; Bruder, Ralph: How to conduct a car? A design example for maneuver based driver-vehicle Interaction. Proceedings of IEEE Intelligent Vehicle Symposium, pp 1-8, San Diego, California: University. 2010.

[11] Landau, Kurt: Usability criteria for intelligent driver assistance systems. Theoretical Issues in Ergonomics Science. Taylor&Francis, pp. 330-345, 2002.

[12] Lee, Hyeon-Kyu and Kim, Jin H.. An HMM-Based Threshold Model Approach for Gesture Recognition, IEEE Transactions on Pattern Analysis and Machine Intelligence, 1999.

[13] Liang, Rung-Huei and Ouhyoung Ming. A Real-time Continuous Recognition System for Sign Language, IEEE International Conference on Automatic Face and Gesture Recognition, pp. 558-567, Japan, 1998.

[14] Schloemer, Thomas; Poppinga, Benjamin; Henze, Niels and Boll, Susanne. Gesture Recognition with a Wii Controller. Proceedings of the Second International Conference on Tangible and Embedded Interaction (TEI'08), Bonn, Germany, 2008.

[15] Schreiber, Michael. Konzeptionierung und Evaluierung eines Ansatzes zu einer manöverbasierten Fahrzeugführung im Nutzungskontext Autobahnfahrten. Dissertation, Darmstadt University of Technology, 2011.

[16] van Someren, Maarten; Barnard, Yvonne and Sandberg, J.. The think aloud method: A practical guide to modeling cognitive processes. London: Academic, 1994.

[17] Winner, H. and Heuss, O.. X-by-wire Betätigungselemente - Überblick und Ausblick. In: Cockpits für Straßenfahrzeuge der Zukunft: Darmstädter Kolloquium Mensch und Fahrzeug Darmstadt, Darmstadt University of Technology, VDI Press, pp. 79-115, 2005

[18] Winner, H.; Hakuli, S.; Bruder, R.; Konigorski, U. and Schiele, B.. Conduct- by- Wire - ein neues Paradigma für die Weiterentwicklung der Fahrerassistenz. In: C. Stiller (Eds.): 4. Workshop Fahrerassistenzsysteme 2006, Karlsruhe: Freundeskreis Mess- und Regelungstechnik e.V., pp. 112- 124, 2006.

[19] Winner, Hermann and Hakuli, Stephan. Conduct-by-Wire - Following a new paradigm for driving into the future, Proceedings of FISITA World Automotive Congress, 2006.

[20] Wobbrock, J.O.; Wilson, A.D. and Li, Y.. Gestures without libraries, toolkits or training: A $1 recognizer for user interface prototypes. Proceedings of the ACM Symposium on User Interface Software and Technology. Newport, Rhode Island, New York: ACM Press, pp. 159-168, 2007.