10.20378/irb-58606

# Visual Feedback for Maneuver-Based Driving: First Results from a Design Workshop

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*Abstract:*

*Starting with the automatic gear change, the operation of a vehicle becomes more and more abstract. In the future, we could control vehicles with single, simple commands. For such a maneuver-based vehicle control system, we investigate a head-up display design in a workshop. The aims are to identify common and distinct features of various display designs through mock-ups. First results show that different sizes of GUI elements are preferred by different states. The preferred position of GUI elements in the head-up display (HUD) is the central bottom area. We found two major interface design styles: static interfaces (all elements visible) with fixed layout and dynamic interfaces (only relevant elements visible) with fixed or adaptive layout.*

JEL Classification: Y80 (Related Disciplines)

Keywords: Automotive HMI, Design Research, User-Centered Design, Maneuver-based Driving, Head-Up Displays, Visualization

# 1 Introduction

Automation is a key-factor in future mobility. The number of driver assistance systems and information in the vehicle increases. Therefore, new challenges arise. Drivers have to operate simultaneously with assistance systems. They must understand how individual systems work to recognize system boundaries. A possible approach to overcome these challenge, is the introduction of a global operating concept, which combines individual assistance systems. The driver takes a supervising role and controls the vehicle through various driving maneuvers (e.g., lane change, parking), while the vehicle performs all stabilization tasks (Franz 2014). The maneuver-based vehicle guidance is a complement to manual and automated driving. It ranges from simple complementation (e.g., parking assistant) to substitution (e.g., Conduct-By-Wire, see Winner & Hakuli 2006) of manual or automatic driving. In this article, we will investigate how the visual feedback for such a concept can look like.

The requirements for a maneuver-based driving concept depend on the degree of automation. Under SAE level 2 and 3 (SAE 2018) it was shown that it makes sense to display current maneuvers constantly in a HUD. The reduced gaze to the instrument cluster and increased gaze on the road leads to a higher situational awareness (Franz 2014). In contrast to existing work, this article's aim is to examine the problem assuming SAE level 4 (complete automation of driving in critical situations). Since future display concepts in vehicles might have so-called "virtual windshields" (Haeuslschmid, Pfleging & Alt 2016), we use a HUD as foundation for our designs. In SAE level 4, there is no need to increase situational awareness as in SAE level 2 and 3, but we assume a fundamental usefulness through positive effects on acceptance and trust in the system (Hoff & Bashir 2015, Walch et al. 2017). Within fully automated rides, the drivers can intervene and override the system behavior, which leads to higher acceptance. Even if the driver does not want to control the car at moment, the increased system transparency through the display of maneuvers in a HUD leads to more trust in the automation.

The driver's interaction with a global maneuver-based operating system happens in one of two basic categories: input or output. The input-interaction is the way the driver communicates with the system ("operating" from a driver's perspective) and the output-interaction is the way the system communicates with the driver ("feedback" from a driver's perspective). Interaction requires an interface between the two parties involved. Interfaces for input-interaction can use touch (Franz 2014: touchpad, Kauer et al. 2010: tablet) or touch-less (Detjen et al. 2019: speech or mid-air gesture) techniques. Commonly, the output-interaction is through the visual channel and visual techniques (Franz 2014: HUD, Kauer et al. 2010: tablet), because here, information can be communicated persistently. In this article, we focus on the output-interaction and generate first ideas for an interface from a user-centered perspective and we present insights from a participatory design workshop.

## 2 Method

In the following chapter, we explain the sample, setup and procedure of our design workshop. The basic idea there was to generate mock-ups of a HUD in different maneuver situations. Therefore, we showed experts videos of maneuvers and they designed a mock-up for each video scene.

The workshop took place in a laboratory of the Ruhr West University of Applied Sciences. Eight people attended. They were all male and scientific staff or students at the Ruhr West University of Applied Sciences. They had at least some expertise within design and automotive user interfaces, either through work or through completed lectures in the area. Nevertheless, we introduced them into the topic of maneuver-based driving or refreshed their knowledge in the workshop.

The setup consisted of a TV and a workspace with the workshop material (mock-up elements). On the TV screen, we played a video of a drive. The video had a playing time of about six minutes and included all driving maneuvers used in Franz (2014): turn left/right, change lane left/right, start, straight, follow lane, park, hold at stop-line, hold at side-strip and parking.

At the points in the video where a maneuver began (14 times), we stopped the playback and handed out a screenshot of the situation (DIN-A4-paper). Thus, participants got a realistic impression of the maneuvers and we, therefore, a potentially improved design. The screenshot was representing a windshield or HUD. With their given maneuver elements, they designed their own mock-up of the HUD.

For their mock-up, participants had a complete set of maneuver symbols in three sizes and three states for each size.

Possible sizes were:

- Small: 1.5cm x 1.5cm (~0.36% occlusion)
- Medium: 2cm x 2cm (~0.63% occlusion)
- Large: 2.25cm x 2.25cm (~0.80% occlusion)

Occlusion means the relation of size to HUD, in this case a DIN-A4 paper.

Possible states were:

- Available (blue color): Indicates that a maneuver is selectable/executable, also “normal” state
- Unavailable (blue color, brighter): Indicates that a maneuver is not selectable/executable, also “inactive” or ”disabled” state

- Active (blue color, yellow border): Indicates that a maneuver is executed at the moment, “active” state

The combination of state and size leads to nine sets of maneuver elements and 81 elements in total, c.f. Figure 1, Figure 2.

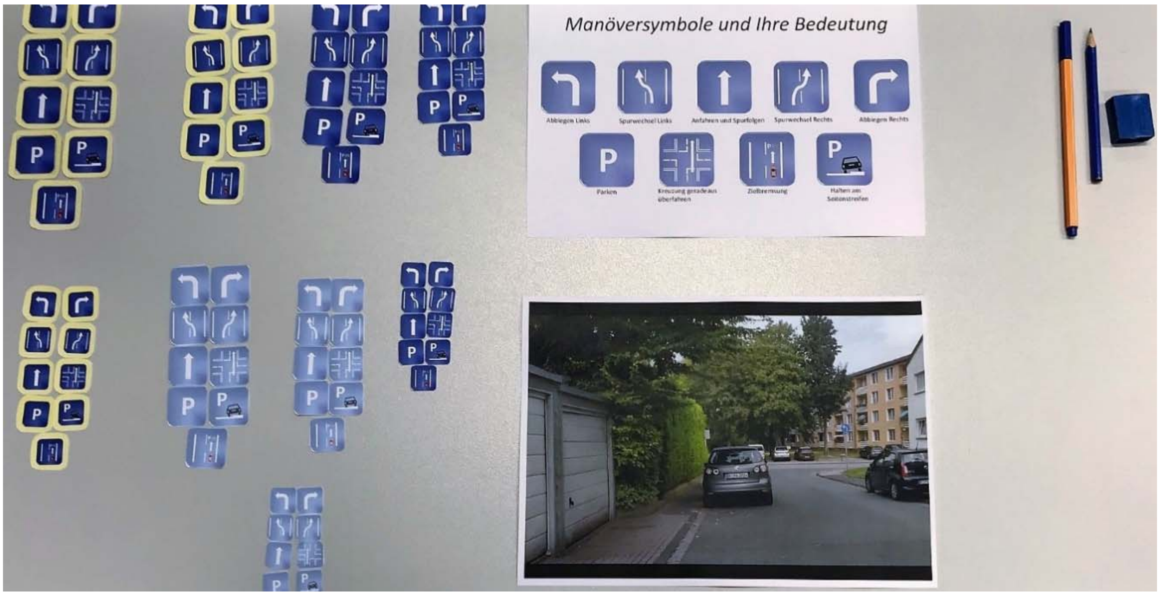


Figure 1: Workspace with Workshop Materials – Maneuver Symbols (Left) and Explanation (Top Right), Maneuver Situation on Paper (Bottom Right)

After the video, participants completed a questionnaire regarding further visualization: how they would improve the maneuver state visualization, how they would integrate driving parameters (speed, distance to next car, position on lane) and if they would add some kind of animation. The answers were free text and/or sketches.

## 3 Results

We group our observations in size of GUI elements, HUD layout, interface style and behavior, and visualization. Overall, 352 maneuver elements in the 14 mock-ups of driving situations were used. To simplify the results, we report our following findings for all situations and participants combined.

### 3.1 GUI Element Size

We measured how often participants used a maneuver element. They were free to use one of three sizes (small, medium, large) for maneuver symbols within their GUI mock-ups. They were also free to choose the displayed state of their symbols (available, unavailable, active) for each size.

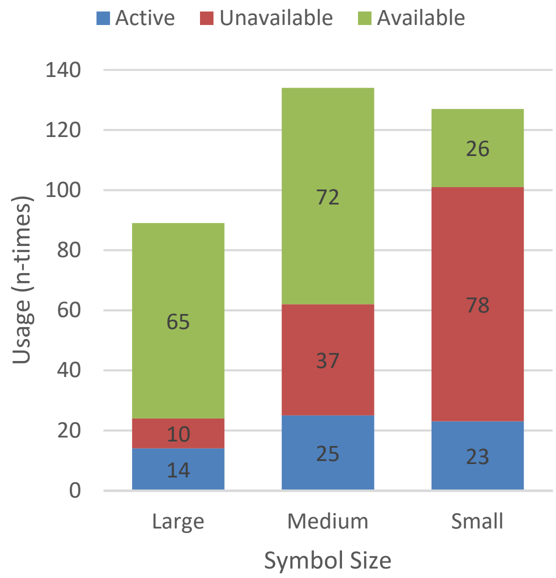


Figure 2: The Usage Frequency of Different Symbol Sizes and Their Relation to States

As shown in Figure 2, participants used the medium sized symbols most frequently ($n$ = 134), followed by the small sized symbols ($n$ = 127), while the large size was least frequent overall ($n$ = 89). We observed that the display state has an influence on the chosen symbol size. To indicate the state "available", participants preferred large or medium sized symbols and for the state "unavailable", they preferred small sized symbols.

### 3.2 HUD Layout

To analyse the spatial distibution of GUI elements, we divide the HUD in 9 qually sized regions: vertical (left, middle, right) x horizontal (top, middle, bottom). Figure 3 shows the distribution of elements for each region. Blue means low usage, red high usage.

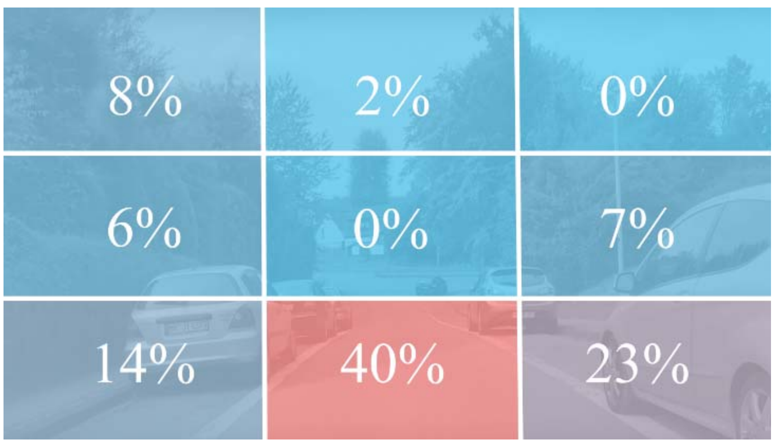


Figure 3: Heat-Map for Used HUD Regions

The main observation is that the three most frequently used regions are in the sections at the bottom. Forty percent of all used symbols are in the middle-bottom region.

### 3.3 Interface Style and Behavior

In terms of interface style and behavior, we found two major categories, in which all GUI-Designs fit in. We call these categories “Static UI” and “Dynamic UI”. They are closely related to the layout. We describe both categories in the following.

*Static UI*

The Static UI has mainly one fixed layout, which contains all interface elements. Each maneuver symbol is constantly visible, regardless if available or not. Their position on the HUD is permanent. So, the highlighted maneuver’s position jumps within the HUD, when a new maneuver is executed.

Figure 4: Examples for the Static UI Category

In Figure 4, we see mock-ups from two participants, which are prototypical for a “Static UI”.

*Dynamic UI*

The Dynamic UI has basically does not contain all interface elements at the same time. It hides unavailable elements, considering they are “unneccessary” (see Discussion). While the position of the active maneuver is fixed in most cases, the position of available maneuver symbols is changed in some versions and in others they are fixed. So, the highlighted maneuver’s position stays at the same position within the HUD, when a new maneuver is executed. Further, we distinguish between a Dynamic UI with fixed layout and a Dynamic UI with a variable layout.

Figure 5: Examples for the Dynamic UI Category

In Figure 5, we see mock-ups from two participants, which are prototypical for a "Dynamic UI".

### 3.4 Visualization

To gain further insight into maneuver HUD design, we collected information about how participants would visualize maneuver states, driving parameters, GUI animations.

*Maneuver States*

We provided a finished design of maneuver GUI elements. Participants uttered some improvements for visualization of the three maneuver states:

- Unavailable/Inactive: "just use outlines", "increase tranparency", "color gray", "hide"
- Available: "keep colors, known from road traffic"
- Active: "not sure if necessary", "highlight with color or border"

*Driving Parameters: Speed, Distance, Lane position*

Participants sketched a possible visualization for the driving parameters speed, distance to next car and lane position. We selected different sketches in Figure 6.

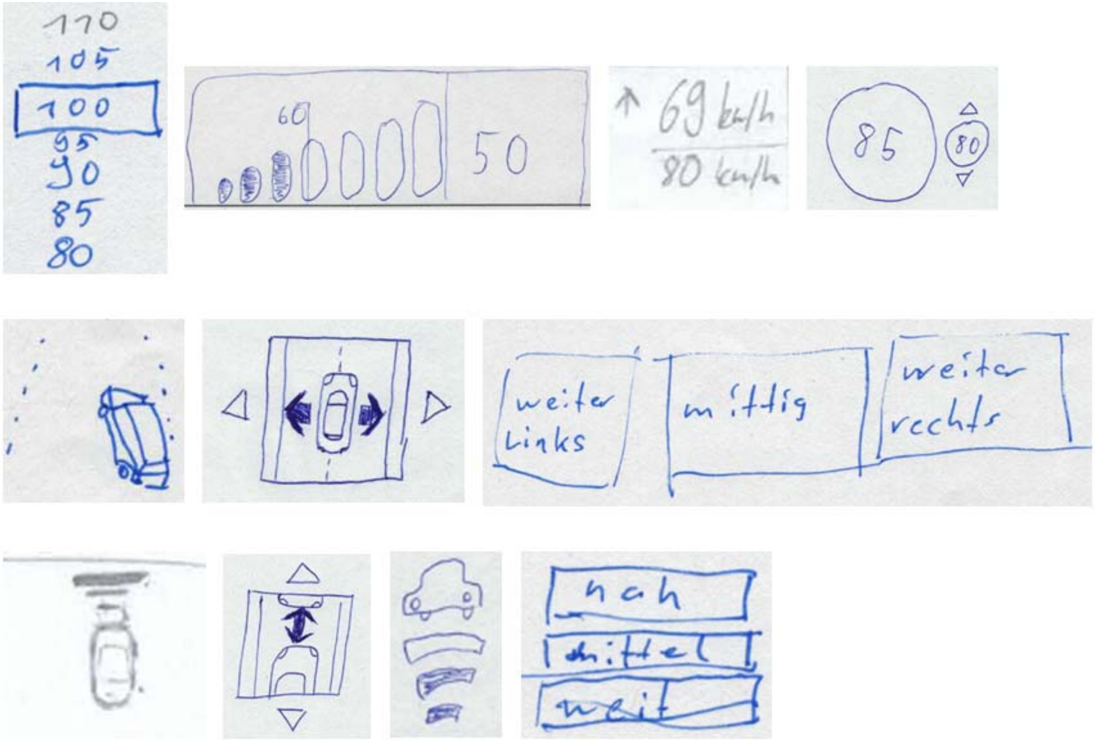


Figure 6: Sketches of the Driving Parameters – Speed (Top Row), Lane Position (Middle Row), Distance to Next Car (Bottom Row)

These sketches show that for distance and lane position a discrete visualization (and consequently input) is preferred, i.e. three categories of distance to the next car ("near", "middle", "far"). For speed, a more continuous visualization (and input), is preferred, i.e. in 1 or 5 km/h-intervals. The speed regulation contains a comparison between actual and desired speed in most cases. An arrow indicates acceleration (upwards) or slow down (downwards).

*Animation*

Reguarding additional animations, participants had contrary opinions. While some said "the less the better" or "no movements", others gave instructions on where to add animations and what to be careful with. We sorted design recommendations and issues of this group by animation target:

- Active Maneuvers: "Active with a pulsing animation"
- Colors/Transparency: "Change of colors for change of states", "Color change only to gray", "Transparency should change from inactive to available", "Tranparency problematic for visibility", "Colors problematic for visibility, i.e. color blindness", "fade in/out"
- Size: "Scale maneuver size to maneuver possibility"
- Layout: "active maneuvers slide to the HUD edge"

*Further suggestions: Maneuver Stack*

Figure 7 shows another mentionable sketch: A visualization of a situation in where multiple maneuvers have been uttered by the driver; a graphical stack, which shows all waiting maneuvers and hightlights the next to be executed (arrow).

Figure 7: Sketch of a Maneuver Stack

## 4 Discussion

In our workshop, we presented predefined maneuver symbols, which proved to be understandable in previous work (Detjen et al. 2018). Another option could have been to ask the participants to draw free hand designs and therefore get more information about how to visualize symbols. We were aware of this, but focused on the layout first, and asked for improvements visualization afterwards. We planned another design study, where the procedure is the other way around.

Another point we want to discuss are the two interface styles and their implications for user interaction. There is a trade-off between minimalistic design and learnability. The less information we present the driver the harder he remembers maneuver elements (the higher the cognitive load and frustration). When the layout is not fixed, he cannot connect a certain position of a GUI element to a certain maneuver (e.g., turn left on left side). On the other hand, this mapping of positions to elements is not necessary for an experienced user, who knows all elements and actions. This is comparable to the gear switch. A novice driver has to look at the symbol on the knob in order to find the right gear, while an experienced driver could shift gears blind.

## 5 Conclusion

Maneuver-based driving is a concept with high potential for future driver-vehicle interaction. In this article, we focused on the vehicle-to-driver interaction. Vehicle-to-driver interaction is important, because it improves user's **acceptance** and **trust** in the system.

We designed **head-up displays** / virtual windshields for maneuver-based driving in a design workshop for 14 maneuvering situations. To increase the imagination of participants, we first showed them a video of the maneuver situation which they designed. They were free to use any number of GUI elements for their mock-up. GUI elements had three **sizes** (small, medium, large) and three **states** (available, unavailable, active). For the "unavailable" state, small elements were preferred and to indicate the state "available", participants preferred large or medium sized symbols.

In a 9-grid **layout** (left/middle/right x top/middle/bottom), users placed the GUI elements frequently in the bottom row of the screen and most frequently on the middle-bottom area.

We presented different visualization sketches for regulating the **driving parameters** speed, distance to next car and lane position. The sketches showed that there is a dependence on the input style. Some preferred a discrete input, some a continuous. Users thought critical about a possible **animation** of a HUD. We recommend to use animations carefully and to turn them off by default.

We observed **two opposite interface design approaches** (static vs adaptive). For a recommendation on which UI-Style or behavior a system should implement, the space of the HUD is the limiting factor. If there is enough space, we would recommend two user interaces, split by two phases: In a first learner-phase, the "Static UI" makes most sense. Through permanent display, the user learns the position of the maneuver elements. When he is familiar with the positions, in the following expert-phase a system should use the "Dynamic UI with fixed layout" and hide the unavailable maneuver elements, because the user does not need this information any longer and the interface is cleaner. This transition between interfaces should be reversible. If there is not enough space to guarantee fixed positions for each maneuver element and maneuvers have to share position in the HUD, the "Dynamic UI with variable layout" should be the style to implement.

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