AutoSimAR: In-Vehicle Cross-Virtuality Transitions between Planar Displays and 3D Augmented Reality Spaces

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Fig. 1. Prototyping an in-vehicle AR interface using VR (left). Handover of content presentation from 2D display to 3D augmented reality head-up/windshield display, visualized by multi-touch gesture towards the windshield display (middle). Content visualization according to the customized AR windshield display (right).

For introducing and subsequently establishing in-vehicle mixed-reality user experiences, novel user-centered methods and techniques for cross-virtuality information presentation and interaction need to be explored. Cross-virtuality mechanisms allow a seamless integration and transition between traditional 2D displays, and 3D augmented reality (AR) windshield displays, in order to provide automotive users (i.e., drivers, passengers) with immersive visual and interaction support, depending on their current non-driving related tasks, such as work and entertainment activities. We further believe that rapid prototyping of automotive human-machine interfaces (HMIs) can be achieved with cross-virtuality technology. For example, standalone virtual reality (VR) head-mounted displays (HMDs) coupled with controllers can be utilized to simulate AR interfaces in order to facilitate an increased level of visual and spatial perception. We aim to explore concepts of innovative visual metaphors, interaction modalities, and finally evaluate them regarding their cognitive, perceptual and ergonomic applicability, and user experience. We believe that cross-virtuality technology in the automotive domain has the potential to fundamentally improve the conception of novel in-vehicle visualization and interaction techniques, as well as to enhance user-centered and non-driving related collaborative activities for automated vehicles.

CCS Concepts: • Human-centered computing → Virtual reality; Collaborative interaction; Information visualization; • Computing methodologies → Mixed / augmented reality.

Additional Key Words and Phrases: cross virtuality interaction, mixed reality, automated driving, human factors
1 INTRODUCTION

In our research project AutoSimAR, we design, prototypically develop, and evaluate novel user-centric methods for the transition of content displayed on flat 2D devices, such as smartphones and tablets, to augmented reality (AR) head-up and windshield displays (HUDs, WSDs), for automated driving scenarios, using cross-virtuality [10]. This involves also explorative analysis of input modalities such as multitouch and gesture input that can be performed with smartphones and tablets. By spanning immersive content across different stages of the reality-virtuality (RV) continuum [9], we believe that the driver’s/passengers’ in-vehicle user experience with work- and entertainment-related data can be improved [8, 16]. AR WSDs provide a large 3D space for displaying content, while the driver can keep an overview of the outside road environment as well as the vision on the track/street [14, 17]. Mitigating motion sickness in automated vehicles (AVs) by utilizing world-fixed AR cues that blend seamlessly into the outside environment could be achieved concurrently [6, 13]. Further, head-up displays were found to enable better task performance than head-down displays [18]. Head-down displays (HDDs), such as dashboard displays, and smartphones/tablets, should therefore not be the primary visual display. However, as these (portable) devices are still available and ubiquitous, we believe that they should be included in future automotive HMIs. In particular, the combination of devices on different stages of the continuum allows the utilization of their respective advantages, such as touch input with haptic feedback of 2D displays [2], with the three-dimensional, immersive, and fundamentally larger design space of AR displays [19]. Additionally, we also focus on collaboration techniques between passengers and interaction of users within the reality-virtuality continuum, with emphasis on highly automated driving (SAE level 3–5).

Based on our exploratory and experimental research, we intend to investigate three areas of interest within cross-virtuality transitional interfaces, i.e., visualizing and interacting with content from 2D smartphone/tablet displays towards 3D AR WSD spaces.

- **Conceptual design of AR interfaces with VR**: In pilot studies, we plan to employ technologies across the RV continuum to sketch and prototypically develop automotive HMIs. To this end, we expect to establish workflows on how transitional interface designers can utilize AR/VR technology for rapid prototyping.

- **Handover and transition of visual content from 2D to 3D AR space**: We have to establish methods to move data visualizations displayed on a 2D (planar) display into 3D space for further usage in AR using a head-up or windshield display. Therefore, a seamless handover, or switch, between devices (i.e., from smartphone to AR HUD).

- **Evaluation of in-vehicle transitional interfaces**: We aim to establish methods and metrics on how to determine the usability and user experience of transitional interfaces. So-called complexity metrics, already employed in desktop and mobile user interfaces (UIs) [3, 11], have the potential to automate the evaluation of cross-virtuality UIs.

These topics of interest will be further discussed in the following.
2 CONCEPTUAL DESIGN OF AR INTERFACES WITH VR

We believe that creating mockups for AR interfaces needs a different approach than those in the mobile or desktop domain. For example, automotive AR interfaces are already being investigated using VR simulators (e.g., [7, 12]). Many of these interfaces are designed in desktop environments and afterwards ported to VR. As alternative, we aim to utilize VR directly to rapidly sketch AR interfaces (see Figure 1, left). Various automotive interior environments may be simulated within VR, leading to an improved designer’s workspace by being immersed in the virtual environment. VR head-mounted displays (HMDs) or CAVEs [4] enable designers and users in the user-centered design process [1] to outline interfaces with various parameters, such as content type, transparency, size, rotation/tilt, and distance, among others [15]. We envision a tool chain that allows the creation of AR interfaces in VR to be subsequently ported to AR HUDs/WSDs. The resulting interfaces will then be used for transitioning 2D visualizations to these 3D AR interfaces, and vice versa. Therefore, we plan to utilize an immersion-first approach across the RV continuum to draft and prototypically develop automotive HMI.

3 HANDOVER AND TRANSITION OF VISUAL CONTENT FROM 2D TO 3D AR SPACE

Once we establish how the target AR HMI should visualize content, we need to determine how to handover visualization control from the planar 2D interface (i.e., smartphone, tablet) to the target AR interface. Ideally, this should work in a seamless manner, in order to emphasize the transformation of visual content and to highlight continuity. Therefore, we need to ensure that the visual representation of the AR content can be aligned in 3D space according to its counterpart on the 2D display before starting the transition. In an exploratory study by Riegler et al. [15], study participants could freely customize an AR WSD using desktop environment. Different content types with varying positions, sizes, and transparency levels resulted in highly personalized interfaces for conditionally and fully automated vehicles [15]. With seamless transitions, users would be able to easily convert head-down displays such as smartphones to head-up displays with immersive content presentations. The actual transition specifies how the animation from the outgoing 2D format to the target 3D AR layout is performed. Subsequently, the transition can also be parameterized (e.g., speed, animation, sound effects). The currently visible content on the 2D screen should ideally be highlighted in the larger AR space, even though more information can/will be visualized, thereby potentially helping the user to follow along, and continuing where they left off.

We are currently developing a prototype to assess handovers and their parameters. For example, by performing a multitouch swipe gesture on a smartphone/tablet towards the windshield, we create the metaphor of shifting content along the RV continuum, visualized by extruding 3D content from 2D space to the pre-defined 3D AR space (see Figure 1, middle). Another topic of interest is the preservation of (mobile) styles and design languages, such as Google’s Material Design styles in the mobile domain, and how they can be transferred to the 3D AR domain.

Once the visualization is handed over to the AR interface, the 2D display device can still be utilized as interaction controller, such as navigating content by swiping, and utilizing pinch-to-zoom gestures to increase/decrease content windows in AR (see Figure 1, right). Thus, we combine the benefits of a large display space with the benefits of a portable controller ubiquitous to the user.

4 EVALUATION OF IN-VEHICLE TRANSITIONAL INTERFACES

Finally, we aim to evaluate the usability and user experience of these transitional interfaces by the means of metrics. As 3D AR interfaces are usually highly spatial (i.e., they integrate into the real environment), we plan to identify
structural user interface complexity metrics [3, 11]. However, as we employ transitional interfaces in vehicles as opposed to stationary office environments, traditional measures might not suffice. For example, motion sickness and, for conditionally automated vehicles (SAE level 3 and 4), safety aspects need to be considered as the driver must be kept in the loop in order to take back control of the vehicle. Therefore, we cannot be simply exploring task performance measures, such as accuracy and interaction speed which are commonly used in AR user studies [5]. A holistic understanding of the user, their cognitive capabilities, and current tasks is needed to evaluate the effectiveness and efficiency of in-vehicle transitional interfaces.

In order to draw conclusions about the effect of in-vehicle transitional interfaces and their parameters, as well as how they are interconnected, we aim to conduct a number of experimental studies to fully quantify their impact on transitions from 2D displays into 3D space. We believe that visual content representations can be performed in such a way that the task performance and user experience can be increased with transitional interfaces, and different devices can be utilized to maximize their contribution to cohesive in-vehicle experiences across the RV continuum.

5 CONCLUSION

To sum up, cross-virtuality has the potential to enhance in-vehicle user experiences by combining conventional 2D screens with immersive 3D AR displays. We expect the visual and spatial perception of information, as well as a collaboration between users and interaction devices such as smartphones and tablets. Across the RV continuum, we aim to establish a seamless handover and switching between devices and stages of the RV continuum in order to facilitate users with novel interaction and collaboration methods.

Open questions that remain to be discussed include the rapid prototyping of transitional interfaces, handover and switching of visualizations across the RV continuum, and evaluating transitional displays in terms of usability and user experience.

In this workshop, we aim to share and discuss our findings and plans on how to design and develop seamless handovers from 2D smartphone/tablet displays to 3D AR HUDs/WSDs, so that in-vehicle users, such as drivers and passengers, can be immersed with AR content visualized in the real environment while ensuring safety, and mitigating motion sickness.

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REFERENCES


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