

A Platform for Rapid Prototyping and Evaluation of Concepts for Interactive In-Vehicle Displays for Automated Vehicles

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Nowadays, automotive user interface research strives towards investigating automated vehicles. To test user concepts, especially pertaining to fully automated vehicles, several methods are evolving, such as VR studies, simulator studies, or Wizard-of-Oz experiments. In all of these methods, researchers need to find an appropriate driving environment which is often created through a driving simulator or a real-life driving video. There is a lack of tools which give researchers the opportunity to rapidly create prototypes for their evaluation. To solve this issues for the case of investigating interactions with windshield displays and dashboards, we design a tool that can be used to support these studies and interfaces in various context. The experimenter can develop a (virtual) user interface through our platform. The interface can be deployed either in a lab setting where the driving context is provided through simulation or recorded driving videos, or it can be easily deployed in a wizard-of-oz car. In this position paper, we present the framework of the tool and foster the discussion for such an idea and its use cases.

CCS Concepts: • **Human-centered computing** → **Interactive systems and tools**.

Additional Key Words and Phrases: autonomous vehicle user interface, prototyping

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1 INTRODUCTION

Automated vehicles of SAE Level 3–5 do not require to continuously monitor or steer the car and only partially require to take over the vehicle [13]. This gives freedom to automotive user interfaces (UI) researchers to extend the interaction within the car, for instance to support non-driving-related activities in the car [2, 9, 10]. Given that many researchers do not have access to prototypes of automated vehicles or want to use novel interfaces such as windshield displays [6, 7], they need to improvise when it comes to testing novel interaction concepts. This often happens through video-based studies or a driving simulator. Recently, a lot of studies in the automotive UI research community were focused on highly automated vehicles [1–4, 8, 12, 14] and most of them used a driving video for the concept development and for the evaluation [1, 3, 4, 8, 14]. To develop and visualize such prototypes, often video editing tools such as Adobe Premier Pro¹ are used to create the video footage and the Unity development platform² enables an interactive prototype. Moreover, to make the prototype congruence with the available study setup, researchers need to start from the scratch, which is often tardy.

Previous work has proposed different platforms which can support the use of driving videos and to develop the UI concepts. For example, Riegler et al. [11] presented a platform called AutoWSD for research on windshield displays.

¹Adobe Premier Pro: <https://www.adobe.com/products/premiere.html>, accessed June 2021

²Unity Game Engine: <https://unity.com/> accessed June 2021

Gerber et al. [5] presented a setup for recording real-life driving video and showcased and released a tool for prototyping and UX research. However, these platforms do not easily support development of novel concepts where the elements of the concepts are displayed in accordance with the video time frame or which are limited to one test environment (e.g. simulator only vs. wizard-of-oz car).

Therefore, we envisioned a tool which can support the development of autonomous vehicles UI concepts where the researchers can use arbitrary (annotated) driving videos and implement their concept and its elements according to the video timeline. In addition, the platform is intended to support experiments in the lab and in wizard-of-oz vehicles. This enables interface designers and developers to speed up the development and evaluation of novel automotive user interfaces around windshield displays.

2 ENVISIONED TOOL

To create an interface concept and experiment, the experimenter needs to complete four phases: System setup, interface develop, context adaptation, and build (see Figure 1). These will support researchers to transform their concept from an idea to a test ready prototype for a study.

In the system setup phase, an experimenter can select the type of the study ranging from low-fidelity lab simulators (single screen) to mid-/high-fidelity simulators (including multi-screen/projection/virtual reality) and wizard-of-oz cars [2]. This will affect how the system will enable interaction and present contents. The system comprises three different components to a) visualize the driving context, b) present the in-vehicle interface, and c) support user interaction with the system. The driving context can for instance be provided as pre-recorded and annotated video(s), as driving simulation, or through a live video feed from a vehicle camera in case of using a wizard-of-oz car (e.g., [2]). For presenting the in-vehicle interface, the study setup determines which components need to be rendered virtually and which devices are physically available and need to be provided. For instance, for in-lab simulator studies based on a monitor, it is sometimes required to display the interior layout of the vehicle, which can be a default layout, or the user can also select/upload their own layout.

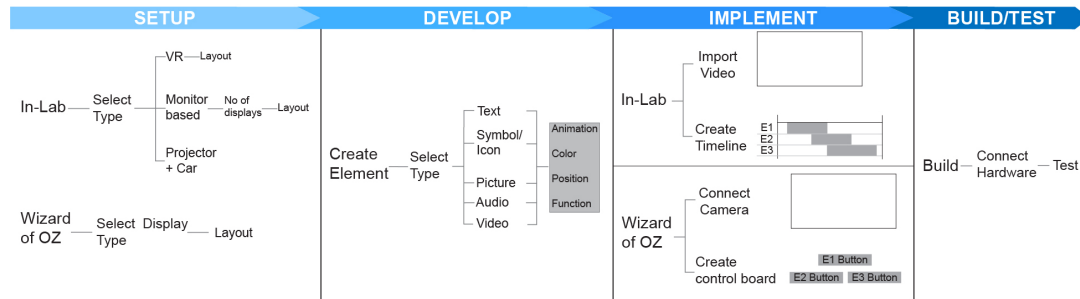


Fig. 1. Framework and workflow of the proposed tool

Next is the development of the interface elements of the envisioned concept. These element could be for instance content elements to support non-driving-related activities (arbitrary GUI elements, videos etc.) and to display vehicle information and status (e.g. text / pictographs to display current speed and intention). Besides content to be shown on the windshield display, other (visual) output modalities such as light bar displays, dashboards, and auditory displays can be integrated as well. For each of the interface elements, the output format (e.g. numeric output for speed, or color

and frequency for turning lights) and the associated content/event (e.g. current speed or warnings) to be presented will be defined. Figure 2 shows the development of different kinds of elements.

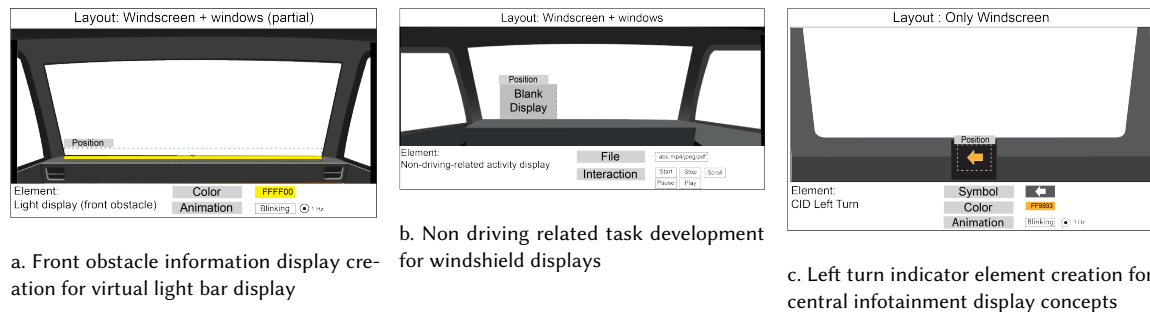


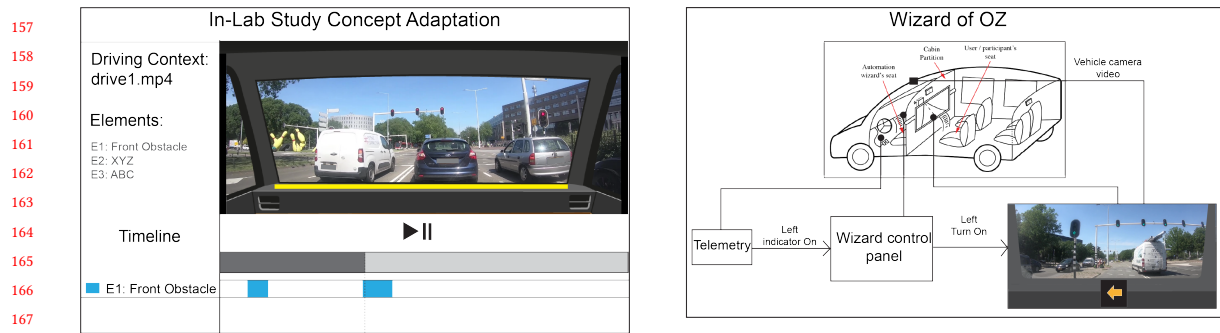
Fig. 2. Interface development phase

In the third stage (context adaptation), the concept will be adjusted according to the test environment. For instance, in case of using a wizard-of-oz car, a specific “wizard control panel” (Figure 3 b) will allow the experimenter to trigger specific events and adjust the presentation and user interface according to the current driving situation (e.g. indicate when turning lights are switched on/off, issue warnings, automatically adjust the current speed). When using pre-recorded driving videos, these videos can be annotated in a video editor that allows dragging and dropping events onto the timeline of the driving video to feed the elements created in the second stage (Figure 3 a). This will create an annotated video file, which for instance contains descriptions about the current speed along the time line, times when indicators are switched on/off, or when and how long specific events are happening (e.g. the information that the car is stopping for a pedestrian). In both cases (video vs. wizard-of-oz car) the idea is that events are described independently from the concrete user interface concept. This allows for an easy exchange of interfaces, for example to test different concepts: For instance, the video meta data would only indicate that a lane change (turning lights) would be indicated while the concrete interface definition then will map this to either a turning symbol on the windshield display or a light bar that is attached around the windshield.

Finally, in the build section, the developed prototype can be exported to a separate application and be connected to the hardware of the study setup.

3 TOOL APPLICATIONS

Apart from the versatility of the tool to support different study setups, our goal is to also allow for creating a wide variety of concepts for automated vehicles that can easily be deployed and tested. This is possible due to the decoupling of driving situation and user interface such that different types of interfaces can easily be generated, which will then react accordingly to the events of the driving context in which they are used. For example, different interface versions can be easily created where events are mapped to different output methods: in on interface obstacle warnings could be linked to a light bar display while another interface shows the same content as part of the windshield display concept. Also, the visualizations can easily be customized, e.g. a pulsating animation can be given to an image, and color can be changed during the drive with a *color_changer* function in Functions. Furthermore, users can create their own script if the requirement is different from the provided functions. This way, the tool will support the development of concepts to support/ provide non-driving-related activities through a display or to design vehicle information display.



a. Lab setup: The video editor allows to annotate a video with interface-relevant events, e.g. when a warning for a front obstacle should be shown. The events shall be independent from concrete interface elements so that different concepts can easily implement different output methods while using the same events.

b. Field study setup: Concept adaptation for wizard of Oz vehicle: The example shows how the vehicle camera feeds the virtual windshield that is shown on the in-car screen. Events such as turning information can either be triggered through telemetry or through input from the experimenter (wizard) through a specific interface.)

Fig. 3. Depending on the study setup, events that trigger information output are generated from pre-recorded and annotated data (lab) or manually or automatically triggered when using a real-world environment.

Secondly, different choices of interior layouts (for example, with or without CID) and an option to upload custom layouts gives freedom to create concepts for different positions (CID, Instrument cluster, or windshield display) or light bar displays (using sprite) placed at the door or dashboard.

4 CONCLUSION

In the position paper, we propose a tool to support rapid prototyping of interactive concepts for autonomous vehicles. We argue that our tool will help researchers to easily develop a wide variety of concepts according to their needs and the available setup. The proposed tool is only at its infancy and there are a lot of possibilities to further enhance its functionalities, such as supporting voice and gaze interaction, and additional use cases, such as developing concepts for semi-automated vehicles. Therefore we want to provoke a discussion on how to enhance its functionalities and its use cases.

REFERENCES

- [1] Matthias Beggiato, Franziska Hartwich, Katja Schleinitz, Josef Krems, Ina Othersen, and Ina Petermann-Stock. 2015. What would drivers like to know during automated driving? Information needs at different levels of automation. <https://doi.org/10.13140/RG.2.1.2462.6007>
- [2] Henrik Detjen, Bastian Pfleging, and Stefan Schneegass. 2020. A Wizard of Oz Field Study to Understand Non-Driving-Related Activities, Trust, and Acceptance of Automated Vehicles. In *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (Virtual Event, DC, USA) (*AutomotiveUI '20*). Association for Computing Machinery, New York, NY, USA, 19–29. <https://doi.org/10.1145/3409120.3410662>
- [3] Cyriel Diels and Simon Thompson. 2018. Information Expectations in Highly and Fully Automated Vehicles. In *Advances in Human Aspects of Transportation*, Neville A Stanton (Ed.). Springer International Publishing, Cham, 742–748. http://dx.doi.org/10.1007/978-3-319-60441-1_71
- [4] Alexander Feilerle, Simon Danner, Sarah Steininger, and Klaus Bengler. 2020. Information Needs and Visual Attention during Urban, Highly Automated Driving—An Investigation of Potential Influencing Factors. *Information* 11, 2 (2020). <https://doi.org/10.3390/info11020062>
- [5] Michael A. Gerber, Ronald Schroeter, and Julia Vehns. 2019. A Video-Based Automated Driving Simulator for Automotive UI Prototyping, UX and Behaviour Research. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (Utrecht, Netherlands) (*AutomotiveUI '19*). Association for Computing Machinery, New York, NY, USA, 14–23. <https://doi.org/10.1145/3342197.3344533>
- [6] Renate Haeuslschmid, Bastian Pfleging, and Florian Alt. 2016. A Design Space to Support the Development of Windshield Applications for the Car. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (2016-01-01) (*CHI '16*). Association for Computing Machinery, San

- 209 Jose, California, USA, 5076–5091. <https://doi.org/10.1145/2858036.2858336>
- 210 [7] Renate Häußlschmid, Max von Bülow, Bastian Pfleging, and Andreas Butz. 2017. Supporting Trust in Autonomous Driving. In *Proceedings of the*
211 *22nd International Conference on Intelligent User Interfaces* (2017-01-01) (*IUI '17*). Association for Computing Machinery, Limassol, Cyprus, 319–329.
212 <https://doi.org/10.1145/3025171.3025198>
- 213 [8] Andreas Löcken, Anna-Katharina Frison, Vanessa Fahn, Dominik Kreppold, Maximilian Götz, and Andreas Riener. 2020. Increasing User Experience
214 and Trust in Automated Vehicles via an Ambient Light Display. In *22nd International Conference on Human-Computer Interaction with Mobile*
215 *Devices and Services* (Oldenburg, Germany) (*MobileHCI '20*). Association for Computing Machinery, New York, NY, USA, Article 38, 10 pages.
216 <https://doi.org/10.1145/3379503.3403567>
- 217 [9] Bastian Pfleging. 2017. *Automotive User Interfaces for the Support of Non-Driving-Related Activities*. Ph.D. Dissertation. University of Stuttgart,
218 Stuttgart, Germany. <https://doi.org/10.18419/opus-9090>
- 219 [10] Bastian Pfleging, Maurice Rang, and Nora Broy. 2016. Investigating User Needs for Non-driving-related Activities During Automated Driving. In
220 *Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia* (Rovaniemi, Finland) (*MUM '16*). ACM, New York, NY, USA,
221 91–99. <https://doi.org/10.1145/3012709.3012735>
- 222 [11] Andreas Riegler, Andreas Riener, and Clemens Holzmann. 2019. Virtual Reality Driving Simulator for User Studies on Automated Driving. In
223 *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings* (Utrecht,
224 Netherlands) (*AutomotiveUI '19*). Association for Computing Machinery, New York, NY, USA, 502–507. <https://doi.org/10.1145/3349263.3349595>
- 225 [12] Andreas Riegler, Philipp Wintersberger, Andreas Riener, and Clemens Holzmann. 2018. Investigating User Preferences for Windshield Displays in
226 Automated Vehicles. In *Proceedings of the 7th ACM International Symposium on Pervasive Displays* (Munich, Germany) (*PerDis '18*). Association for
227 Computing Machinery, New York, NY, USA, Article 8, 7 pages. <https://doi.org/10.1145/3205873.3205885>
- 228 [13] SAE International. 2018. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016.
229 https://www.sae.org/standards/content/j3016_201806/
- 230 [14] Tobias Schneider, Sabiha Ghellal, Steve Love, and Ansgar R.S. Gerlicher. 2021. Increasing the User Experience in Autonomous Driving through
231 Different Feedback Modalities. In *26th International Conference on Intelligent User Interfaces* (College Station, TX, USA) (*IUI '21*). Association for
232 Computing Machinery, New York, NY, USA, 7–10. <https://doi.org/10.1145/3397481.3450687>
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