ARCAR: On-Road Driving in Mixed Reality by Volvo Cars

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ABSTRACT

ARCAR is a proof-of-concept headset-based mixed reality experience, for use by a driver in full control of a moving vehicle. The functional prototype has been implemented using a high end video pass-through mixed reality headset, and tested on roads (closed to external traffic) at conventional driving speeds. Our implementation embodies acceptable solutions to a number of current challenges that have been in the way of in-car XR applications, and enables a wealth of research. ARCAR is intended to serve as a research platform in the near future, enabling investigations on topics which include safety, design, perceived quality, and consumer applications.

Author Keywords

Augmented reality; automotive; driving; mixed reality; on-road; virtual reality; Volvo Cars.

CCS Concepts

•Human-centered computing → Mixed / augmented reality; Virtual reality;

INTRODUCTION

We introduce ARCAR: a proof-of-concept headset-based mixed reality (XR) experience for use by a driver in full control of a moving vehicle. The functional concept has been implemented on a XR headset and used on roads (closed to external traffic) by test drivers, at conventional driving speeds. Owing to the high performance components used in our implementation, common problems like motion sickness are minimized.

Currently ARCAR and its applications are under active development at Volvo Cars in Gothenburg, Sweden. Use cases under consideration include training and simulation scenarios, design tools, and speculative end-user applications. ARCAR is also being utilized as a research tool to investigate topics such as driver distractions, perceived roominess, visibility, reachability, perceived quality [7], and safety.

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Figure 1: ARCAR is a proof-of-concept video pass-through mixed reality experience for a driver in full control of a vehicle.

RELATED WORK

In previous HCI research on driver-oriented XR applications, the implementations are limited to WoZ testing and the focus is often on investigating autonomous driving scenarios. Prototypes described by Goedicke et al. (2018), Yeo et al. (2020) both involve participants who sit next to a WoZ who is actually driving the car, even though they are given the physical affordance of a steering wheel in front of them [2, 8]. Our concept is novel to the literature in that it is meant for use by a driver who is actively in full control of a moving vehicle.

More common in both research [3, 4, 5] and commercial projects [1] are experiments with passenger-oriented XR experiences. Notably, this research has articulated many of the technical and human-centered challenges that prohibit XR applications for passengers (articulated in [4]), and these are also relevant for driver-oriented applications. These include engineering a head tracking system that can be used in a moving car, overcoming motion sickness, social acceptability, and designing appropriate interactions for the constrained physical space. As described below, ARCAR embodies acceptable solutions to a number of these challenges (e.g. head tracking), and enables further research on others (e.g. social acceptability).

Driver-oriented XR is also relevant for design and design research. Related work in this direction includes explorations on XR as a design tool for in-car UX, which compares participant responses to design choices presented in VR and in situ [6]. The VR setup used in these studies is stationary. Our concept enables novel possibilities in this line of research, where design possibilities may be presented in XR while maintaining the embodied experience of driving at speed.

Figure 2: The platform enables just-in-time design of automotive aesthetics and interactive components.

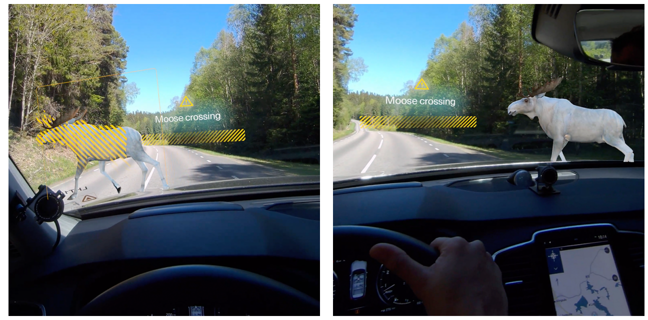

Figure 3: Virtual obstacle injected onto the real road: the obstacle appears not only on the headset, but also on the car's sensors, triggering the car's assistive drive functionality.

DESCRIPTION

The current ARCAR implementation is built using a 2019 model Volvo XC90 and a Varjo XR-1 headset. The headset incorporates dual 12 MP, 90 Hz front-facing cameras for video pass-through with real-time light estimation and reflection mapping, as well as a depth sensor for hand tracking. The hands can be segmented from the video feed and overlaid onto virtual content in a photorealistic fashion.

The headset provides a high end display system with dual video streams in each eye, each combining a 1920 x 1080 low persistence micro-OLEDs screen with a 1440 x 1600 low persistence AMOLED screen, both with flicker-free refresh rates of 60/90 Hz. This equates to a resolution of 60 pixels per degree, with a field of view of 87 degrees. In our experiments we have achieved single-digit photon-to-photon latency between the front-facing RGB cameras and the internal display. which enables safe driving within conventional speed limits, while causing minimal motion sickness. The high end imaging and display pipeline also allows for photorealistic rendering of virtual content, to the extent that the virtual content is indistinguishable from the video feed.

The main software that streams content to the headset from a PC is built in Unity. This software receives signals from a variety of sources which then modulate the MR content, and also interacts with the car systems. The software also for dynamic content to be modified in real time (Fig. 2). This enables the use of ARCAR as a tool for rapid design and design research on automotive aesthetics and user interfaces.

Signals streamed to the XR software from the car include speed, braking, gear, steering wheel position, and UI controls. Signals that are streamed to the car itself include information on virtual content (e.g. virtual obstacles that might be injected on the road). The various assistive functions on the car (some of which are already on the market on consumer models) can then react to the virtual content: for example, collision warnings and assistive braking can be initiated in response to virtual objects.

As McGill et al. (2019) note, IMU-based orientation tracking which XR headsets often rely on is not feasible in a moving car [3]. To enable robust, low-latency, high-precision 6DOF headset tracking, the car is instrumented with an ART ARTTRACK5/C optical motion capture system. The Varjo XR-1 headset also incorporates eye tracking, which enables experimental functionality. For example, the driver's attention and responses with respect to virtual obstacles injected onto the road are recognized by the system, and the car's assistive responses are modulated accordingly (Fig. 3). This also enables research on topics such as driver attention and reactions to various stimuli, and handover interactions for autonomous and assistive drive functionality.

Distinct from previous research on driver-oriented XR headset applications, in ARCAR there is no other driver (e.g. WoZ) in control of the vehicle, other than the one who wears the headset. The only safety features that assist the driver are those which are found already on a commodity Volvo XC90 such as lane-keeping and assistive braking. The only safety feature on the ARCAR prototype that is distinct from the production model is an added emergency stop button on the armrest between the driver and the front passenger, which halts all systems when pressed.

FUTURE WORK AND CONCLUSION

This poster introduces ARCAR – the Volvo Cars Altered Reality Driving Research Platform – as a proof-of-concept to the HCI community. This platform enables a wealth of directions for future research in XR, which include but are not limited to: novel driving experiences, automotive safety and usability, product design workflows, and research methods.

ARCAR enables radically new possibilities, with many unknown unknowns. We envision that the concrete first steps to materialize and investigate the value of ARCAR within HCI research will involve qualitative research to explore three distinct perspectives: (1) consumer-facing applications, (2) participants in human-centered studies where ARCAR is utilized as a research tool, and (3) designers whose workflows might be enriched with novel possibilities.

We expect that the impact of ARCAR will be far-reaching, with implications beyond automotive and HCI.

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REFERENCES

[1] Miles Branman. 2017. Honda's Dream Drive VR experience may be the future of in-car entertainment. https://www.digitaltrends.com/cars/ces-2017-honda-dream-drive/. (2017). Accessed: 2020-07-20.

[2] David Goedicke, Jamy Li, Vanessa Evers, and Wendy Ju. 2018. VR-OOM: Virtual Reality On-ROad Driving SiMulation. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–11. DOI: http://dx.doi.org/10.1145/3173574.3173739

[3] Mark McGill and Stephen Brewster. 2019. Virtual Reality Passenger Experiences. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings (AutomotiveUI '19)*. Association for Computing Machinery, New York, NY, USA, 434–441. DOI: http://dx.doi.org/10.1145/3349263.3351330

[4] Mark McGill, Julie Williamson, Alexander Ng, Frank Pollick, and Stephen Brewster. 2019. Challenges in passenger use of mixed reality headsets in cars and other transportation. *Virtual Reality* (2019), 1–21.

[5] Pablo E. Paredes, Stephanie Balters, Kyle Qian, Elizabeth L. Murnane, Francisco Ordóñez, Wendy Ju, and James A. Landay. 2018. Driving with the Fishes: Towards Calming and Mindful Virtual Reality Experiences for the Car. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 4, Article 184 (Dec. 2018), 21 pages. DOI: http://dx.doi.org/10.1145/3287062

[6] Ingrid Pettersson, MariAnne Karlsson, and Florin Timotei Ghiurau. 2019. Virtually the Same Experience? Learning from User Experience Evaluation of In-Vehicle Systems in VR and in the Field. In *Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19)*. Association for Computing Machinery, New York, NY, USA, 463–473. DOI: http://dx.doi.org/10.1145/3322276.3322288

[7] Casper Wickman and Rikard Söderberg. 2003. Increased Concurrency between Industrial and Engineering Design Using CAT Technology Combined with Virtual Reality. *Concurrent Engineering* 11, 1 (2003), 7–15. DOI: http://dx.doi.org/10.1177/1063293X03011001001

[8] Dohyeon Yeo, Gwangbin Kim, and Seungjun Kim. 2020. Toward Immersive Self-Driving Simulations: Reports from a User Study across Six Platforms. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–12. DOI: http://dx.doi.org/10.1145/3313831.3376787