From Me to We: Combining Driving Simulation and Traffic Simulation for Holistic Usability and Safety Research

Conference Paper · September 2023

DOI: 10.1145/3581961.3609840

CITATION
1

READS
36

3 authors, including:

Andreas Riegler
University of Applied Sciences Upper Austria, Campus Hagenberg
31 PUBLICATIONS **525** CITATIONS

SEE PROFILE

Andreas Riener
Technische Hochschule Ingolstadt
410 PUBLICATIONS **5,896** CITATIONS

SEE PROFILE

From Me to We: Combining Driving Simulation and Traffic Simulation for Holistic Usability and Safety Research

Andreas Riegler
andreas.riegler@fh-hagenberg.at
University of Applied Sciences Upper Austria
Hagenberg im Mühlkreis, Austria

Andreas Riener
andreas.riener@thi.de
Technische Hochschule Ingolstadt
Ingolstadt, Germany

Gerald Ostermayer
gerald.ostermayer@fh-hagenberg.at
University of Applied Sciences Upper Austria
Hagenberg im Mühlkreis, Austria

ABSTRACT

This demo showcases the integration of a virtual reality (VR) driving simulator with a traffic simulator to enhance usability, improve traffic safety, and optimize traffic flow. By combining these two technologies, an immersive and holistic evaluation platform can be created. The VR driving simulator provides a realistic driving environment that enables users to experience various traffic scenarios, including complex and hazardous situations, in a controlled and safe manner ("me"-perspective). The traffic simulator complements the VR driving simulator by simulating realistic traffic patterns, including vehicle interactions, traffic signals, and road conditions based on statistical models of individualistic driving ("we"-perspective). The integration of these simulators allows for the evaluation of driver performance, decision-making, and reactions within a dynamic and realistic traffic environment. This combined approach offers benefits such as enhanced driver training, assessment of driver behavior, optimization of traffic management strategies, and development of intelligent transportation systems. By leveraging VR technology and traffic simulation, this integrated approach holds significant potential for future mixed traffic challenges.

CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**; **Virtual reality**; **Interaction techniques**; *User studies*; *Scenario-based design*; *Interface design prototyping*.

KEYWORDS

driving simulation, automated driving, traffic safety, traffic flow

ACM Reference Format:
Andreas Riegler, Andreas Riener, and Gerald Ostermayer. 2023. From Me to We: Combining Driving Simulation and Traffic Simulation for Holistic Usability and Safety Research. In *15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '23 Adjunct), September 18–22, 2023, Ingolstadt, Germany*. ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3581961.3609840

AutomotiveUI '23 Adjunct, September 18–22, 2023, Ingolstadt, Germany

ACM ISBN 979-8-4007-0112-2/23/09.
https://doi.org/10.1145/3581961.3609840

1 INTRODUCTION

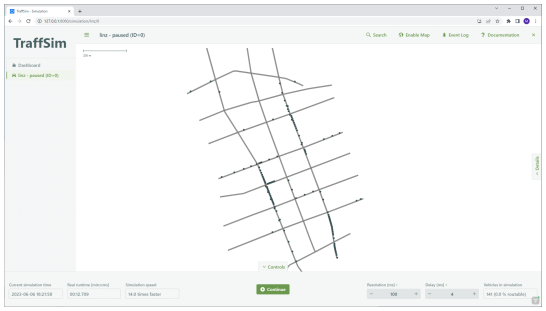
In recent years, the integration of virtual reality (VR) and traffic simulation technologies has garnered significant attention in the field of automotive research [13]. The rapid advancement of technology has revolutionized the automotive industry, paving the way for novel approaches to automotive user interface (UI) research. This demo paper showcases a unique system that combines a VR driving simulator with a traffic simulator, enabling researchers to explore new avenues in automotive user interface design, traffic analysis, and accident prevention. This combination offers a comprehensive and immersive platform for studying driver behavior, evaluating user interfaces, analyzing traffic patterns, and developing proactive measures to enhance road safety and optimize traffic flow [6]. By immersing users in realistic driving scenarios and replicating diverse traffic conditions, this system offers valuable insights into the complex interactions between drivers, vehicles, and road environments [24]. The integration of a VR driving simulator and a traffic simulator addresses the need for realistic and controlled environments to conduct research in the automotive domain [22]. Traditional methods of studying driver behavior and interface design often relied on static or limited scenarios, lacking the dynamic and complex nature of real-world driving conditions [23]. Additionally, previous research conventionally focuses on either the driver perspective using driving simulators, or the traffic perspective [4, 17, 18]. However, by merging VR technology with a traffic simulator, researchers can create highly realistic and interactive driving environments that closely mimic the complexities of everyday road situations [26].

The increasing automation of vehicles could make an important contribution with regard to the EU initiative "Vision Zero", with the goal of avoiding deaths and serious injuries in road traffic [7]. Experts widely agree that automated driving could not only contribute to a significant increase in traffic efficiency in terms of improved traffic flow, but also sustainably increase road safety [5, 25]. However, several studies, such as those by Kyriakidis et al. [8] or Neubauer et al. [12], suggest that increasing traffic automation may also have adverse effects on road safety and traffic flow, which can be attributed to, among other things, reduced situational awareness on the part of drivers, mental overload or underload, and shortened attention spans. Partially automated driving is particularly critical in this context, where in an emergency (e.g., emergency braking of the vehicle in front) the driver is forced to take control of the vehicle within a certain time window. Such takeover scenarios are naturally particularly safety-critical and therefore also play an important role in the development and design of automotive UIs, especially since they should be as easy to use as possible on the

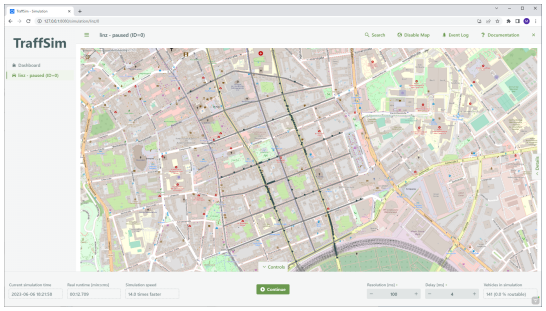
one hand, but on the other hand should only distract and impair the driver as little as possible. For this reason, our proposed system will build a bridge from the development and design of automotive UIs to their effects on safety in road traffic, and thus to an aspect that has received little scientific attention to date, with focus on distraction behaviour. The simulations provide information on the effects of different HMI designs on road safety and traffic flow.

2 SYSTEM OVERVIEW

Our integrated system comprises a VR driving simulator and a traffic simulator. The VR driving simulator [15, 16] provides an immersive setting that aims to replicate the real-world driving experiences, allowing users to interact with a virtual vehicle and navigate through different road conditions. The traffic simulator [1] complements this by simulating realistic traffic patterns, including vehicle interactions, traffic signals, and road infrastructure. By combining both simulators, users can experience and evaluate driving scenarios that closely resemble real-world conditions. This process is iterative, i.e., initial user studies provide results on driver distraction behaviour. Subsequently, this data is forwarded to our traffic simulator, TraffSim [3], and, using statistical models, TraffSim calculates parameters of traffic safety and traffic flow, i.e., potential traffic jams and accidents [10]. These findings are used as input for the HMI design phase, which is adapted accordingly, and the simulations repeated until the optimal HMI designs in the different context situations are found. There is a multitude of benefits that such a combined and holistic approach offers in the field of automotive research.



(a) Microscopic traffic analysis of multiple street crossings.



(b) Map overlay of the microscopic traffic scene

Figure 1: TraffSim traffic simulator displaying a schematic overview of the traffic scene (left), and overlaying the traffic scene with real-world map data (right).

2.1 Automotive User Interface Research

The proposed system provides a powerful tool for automotive user interface research, allowing researchers to study driver interactions with in-vehicle interfaces and assess their impact on driver performance and safety [14, 19]. The immersive VR environment enables the evaluation of different user interface designs, including dashboard, head-up, and windshield displays, voice commands, and gesture recognition, to optimize usability and user experience (UX), and minimize distractions [20, 21]. Hence, the driving simulator supports researchers in adjusting usability/UX and safety aspects, such as improving take-over request (TOR) reaction times while being engaged in non-driving related tasks (NDRTs) in individualistic semi-automated driving scenarios, for example.

2.2 Mixed Traffic Scenarios and Future Mobility Solutions

The system's ability to simulate mixed traffic scenarios is of particular significance. With the growing integration of autonomous vehicles, pedestrians, cyclists, and other vulnerable users on the roads, understanding their interactions and optimizing traffic flow becomes crucial [11]. By incorporating virtual representations of these entities (see Figure 1), the system allows researchers to explore potential mobility solutions and design interventions that enhance safety, efficiency, and overall user experience.

2.3 Traffic Analysis and Accident Prevention

By simulating various traffic scenarios, the system facilitates in-depth analysis of traffic patterns, congestion management, and accident prevention strategies using statistical models [2]. Researchers can observe driver behavior and decision-making in response to complex traffic situations, enabling the identification of potential safety risks and the development of proactive measures [9]. The system also enables the evaluation of emerging technologies, such as autonomous vehicles and connected infrastructure, in mixed traffic scenarios (see Figure 2).

3 CONCLUSION

The integration of a VR driving simulator and a traffic simulator offers numerous advantages and opportunities for automotive user interface research, traffic analysis, and accident prevention. Our system enables researchers to evaluate and optimize user interfaces, develop effective traffic management strategies, and explore innovative solutions for future mobility challenges. By simulating mixed traffic scenarios and leveraging the capabilities of VR technology, this integrated approach contributes to creating safer, more efficient, and sustainable transportation systems. To sum up, the integration of a VR driving simulator and a traffic simulator presents a promising instrument for progressing automotive user interface research, enhancing vehicular safety, and improving traffic flow. This composite strategy to driving and traffic simulation offers an

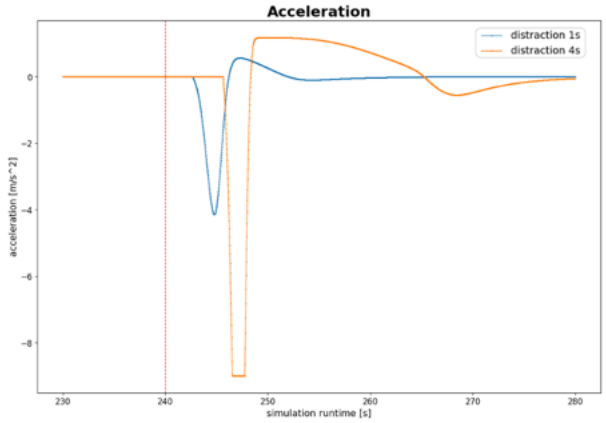


Figure 2: This scenario describes a column of vehicles travelling one behind the other, initially at a constant speed ($v = 25m/s$). The first vehicle in the column ($ID0$) begins to decelerate to $19m/s$ at a simulation runtime of $t0 = 240s$ (red, dashed line) with a deceleration of $1.86m/s^2$. The driver of the vehicle directly behind ($ID1$) is distracted from $t0$ for $1s$ or $4s$, and only reacts to the vehicle braking in front of them with this delay. The graph shows the acceleration behaviour of the vehicle directly behind vehicle $ID1$ ($ID2$). In the case of a distraction duration of vehicle $ID1$ of $1s$, a deceleration of vehicle $ID2$ of slightly more than $4m/s^2$ is sufficient to resolve the situation (blue curve). For the case of a distraction duration of $4s$, vehicle $ID2$ is limited for a certain time by the maximum possible deceleration, resulting in a potential collision.

immersive and realistic framework to assess driver behavior, optimize user interfaces, examine mixed traffic trends, and shape future mobility solutions.

ACKNOWLEDGMENTS

This project is financed by research subsidies granted by the government of Upper Austria, and research subsidies granted for the project AutoSimAR by the Austrian Research Promotion Agency (FFG).

REFERENCES

[1] Christian Backfrieder, Christoph F Mecklenbräuker, and Gerald Ostermayer. 2013. TraffSim–A Traffic Simulator for Investigating Benefits Ensuing from Intelligent Traffic Management. In *2013 European Modelling Symposium*. IEEE, 451–456.

[2] Christian Backfrieder, Gerald Ostermayer, Manuel Lindorfer, and Christoph F Mecklenbräuker. 2016. Cooperative lane-change and longitudinal behaviour model extension for TraffSim. In *Smart Cities: First International Conference, Smart-CT 2016, Málaga, Spain, June 15-17, 2016, Proceedings 1*. Springer, 52–62.

[3] Christian Backfrieder, Gerald Ostermayer, and Christoph F Mecklenbräuker. 2014. TraffSim-A traffic simulator for investigations of congestion minimization through dynamic vehicle rerouting. *ResearchGate* 15, 4 (2014), 38–47.

[4] Qianwen Chao, Huikun Bi, Weizi Li, Tianlu Mao, Zhaoqi Wang, Ming C Lin, and Zhigang Deng. 2020. A survey on visual traffic simulation: Models, evaluations, and applications in autonomous driving. In *Computer Graphics Forum*, Vol. 39. Wiley Online Library, 287–308.

[5] Daniel J Fagnant and Kara Kockelman. 2015. Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice* 77 (2015), 167–181.

[6] Raymond Hoogendoorn, Bart van Arerm, and Serge Hoogendoom. 2014. Automated driving, traffic flow efficiency, and human factors: Literature review. *Transportation Research Record* 2422, 1 (2014), 113–120.

[7] Ellen Kim, Peter Muennig, and Zohn Rosen. 2017. Vision zero: a toolkit for road safety in the modern era. *Injury epidemiology* 4 (2017), 1–9.

[8] Miltos Kyriakidis, Joost CF de Winter, Neville Stanton, Thierry Bellet, Bart van Arem, Karel Brookhuis, Marieke H Martens, Klaus Bengler, Jan Andersson, Natasha Merat, et al. 2019. A human factors perspective on automated driving. *Theoretical issues in ergonomics science* 20, 3 (2019), 223–249.

[9] Manuel Lindorfer, Christian Backfrieder, Christoph Mecklenbräuker, and Gerald Ostermayer. 2017. Driver behavior injection in microscopic traffic simulations. In *Modeling, Design and Simulation of Systems: 17th Asia Simulation Conference, AsiaSim 2017, Melaka, Malaysia, August 27–29, 2017, Proceedings, Part II 17*. Springer, 237–248.

[10] Manuel Lindorfer, Christian Backfrieder, Christoph F Mecklenbräuker, and Gerald Ostermayer. 2017. Modeling isolated traffic control strategies in traffsim. In *2017 UKSim-AMSS 19th International Conference on Computer Modelling & Simulation (UKSim)*. IEEE, 143–148.

[11] Jesús Mena-Oreja, Javier Gozalvez, and Miguel Sepulcre. 2018. Effect of the configuration of platooning maneuvers on the traffic flow under mixed traffic scenarios. In *2018 IEEE Vehicular Networking Conference (VNC)*. IEEE, 1–4.

[12] Catherine Neubauer, Gerald Matthews, Lisa Langheim, and Dyani Saxby. 2012. Fatigue and voluntary utilization of automation in simulated driving. *Human factors* 54, 5 (2012), 734–746.

[13] Vincenzo Punzo and Biagio Ciuffo. 2010. Integration of driving and traffic simulation: Issues and first solutions. *IEEE transactions on intelligent transportation systems* 12, 2 (2010), 354–363.

[14] Andreas Riegler, Christoph Anthes, Clemens Holzmann, Andreas Riener, and Shiva Mohseni. 2021. Autosimar: In-vehicle cross-virtuality transitions between planar displays and 3d augmented reality spaces. In *ISS'21: Interactive Surfaces and Spaces*.

[15] Andreas Riegler, Andreas Riener, and Clemens Holzmann. 2019. AutoWSD: Virtual Reality Automated Driving Simulator for Rapid HCI Prototyping. In *Mensch und Computer 2019* (Hamburg, Germany). ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3340764.3345366

[16] Andreas Riegler, Andreas Riener, and Clemens Holzmann. 2019. Virtual reality driving simulator for user studies on automated driving. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings*. 502–507.

[17] Andreas Riegler, Andreas Riener, and Clemens Holzmann. 2021. A systematic review of augmented reality applications for automated driving: 2009–2020. *PRESENCE: Virtual and Augmented Reality* (2021), 1–80.

[18] Andreas Riegler, Andreas Riener, and Clemens Holzmann. 2021. A systematic review of virtual reality applications for automated driving: 2009–2020. *Frontiers in human dynamics* 3 (2021), 689856.

[19] Andreas Riegler, Andreas Riener, and Clemens Holzmann. 2022. Content presentation on 3D augmented reality windshield displays in the context of automated driving. In *2022 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, 543–552.

[20] Andreas Riegler, Klemens Weigl, Andreas Riener, and Clemens Holzmann. 2020. StickyWSD: Investigating content positioning on a windshield display for automated driving. In *Proceedings of the 19th International Conference on Mobile and Ubiquitous Multimedia*. 143–151.

[21] Andreas Riegler, Philipp Wintersberger, Andreas Riener, and Clemens Holzmann. 2018. Investigating user preferences for windshield displays in automated vehicles. In *Proceedings of the 7th ACM International Symposium on Pervasive Displays*. 1–7.

[22] Seyyed Meisam Taheri, Kojiro Matsushita, Minoru Sasaki, et al. 2017. Development of a driving simulator with analyzing driver's characteristics based on a virtual reality head mounted display. *Journal of Transportation Technologies* 7, 03 (2017), 351.

[23] Seyyed Meisam Taheri, Kojiro Matsushita, Minoru Sasaki, et al. 2017. Virtual reality driving simulation for measuring driver behavior and characteristics. *Journal of transportation technologies* 7, 02 (2017), 123.

[24] Tamás Tettamanti, Mátyás Szalai, Sándor Vass, and Viktor Tihanyi. 2018. Vehicle-in-the-loop test environment for autonomous driving with microscopic traffic simulation. In *2018 IEEE International Conference on Vehicular Electronics and Safety (ICVES)*. IEEE, 1–6.

[25] Richard Viereckl, Dietmar Ahlemann, Alex Koster, and Sebastian Jursch. 2015. Racing ahead with autonomous cars and digital innovation. *Auto Tech Review* 4, 12 (2015), 18–23.

[26] Zheng Xu, Xin Zou, Taeho Oh, and Hai L Vu. 2021. Studying freeway merging conflicts using virtual reality technology. *Journal of safety research* 76 (2021), 16–29.