Special Issue of *Presence: Virtual and Augmented Reality*
Virtual and Augmented Reality for Autonomous Driving and Intelligent Vehicles

Guest Editors' Introduction

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Rationale for this Special Issue

According to statistics published in *IEEE Spectrum* (Prins, Gunkel, Stokking, & Niamut, 2018), the total revenue for virtual reality hardware and software will grow 200-fold from the 2014 basic value by 2020. According to the latest update of the *IDC Worldwide Semiannual Augmented and Virtual Reality Spending Guide*, the automotive domain will be one beneficiary of augmented reality (AR) and virtual reality (VR) technology with spending expected to reach $12.8 billion by 2020. Another 2017 study by the German Association for the Digital Economy (BVDW) and Accenture (Lucas, 2017) outlines the opportunities and challenges of AR and VR in the automotive industry. AR/VR technology will increase road safety, bring intuitive activities to driving, and finally enhance driving experience. AR/VR technology may also help on the transition toward automated driving. AR head-up displays (HUDs) may soon overlay 3D navigation instructions onto road geometry, and moving obstacles such as vulnerable road users (pedestrians, bikers, wheel-chair users) and other vehicles may be highlighted to calm down drivers-passengers and enhance trust in their vehicle's automated operation as the vehicle proves its awareness of its surroundings. VR windshields may allow for dynamic reconfiguration of multi-lane roads based on demand; and will, in the long term, remove road signs, traffic lights, road paintings, amongst others, from the streets (Riener & Ferscha, 2013).

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Time has come that researchers are now asking how AR/VR technology can be efficiently used in both manual and automated driving applications. There are, however, still a number of technological challenges to clarify before AR/VR applications will hit the mainstream market. These include questions addressing the use of head-mounted displays or the use of windshield displays (WSDs; Häuslschmid, Shou, O'Donovan, Burnett, & Butz, 2016; Riegler, Wintersberger, Riener, & Holzmann, 2018). In addition, issues such as context awareness, information relevancy, as well as view and interaction management are research topics of interest. Furthermore, vehicle-to-vehicle or pedestrian-to-vehicle interaction gained lot of interest recently and should also be further investigated in the light of augmented/virtual reality.

The central objective of this special issue was, thus, to provoke an active debate on the potential, constraints, impact, role, and adequacy of using augmented and virtual reality technology in driving applications.

Submissions and Review Process

The papers submitted to this special issue have undergone a rigorous peer-review process where the manuscripts were reviewed by two to four independent reviewers each. In total, 11 papers were submitted to the special issue. Guest editors performed meta-reviews on the papers in each of the three rounds of review, and finally—according to an objective score sheet—the 5 best articles (acceptance rate 45%) were selected for publication. Each of the accepted papers has received at least one review with highest ranking, and the second with at least second-highest ranking.

Summary of Contributions

All papers accepted for this special issue address topics related to driving safety—but look at this important issue from different perspectives. The first paper investigates effects of augmented reality on a driver's visual attention in general, the next paper addresses a very important topic for any simulated environment (including VR): simulation sickness, and the third paper investigates the potential of AR/head-up displays to compensate for age-related deteriorations and, thus, contribute to an improvement in driving safety. The fourth paper looks at possibilities to increase user acceptance and trust by communicating system decisions via AR/VR displays to the driver, and the last paper looks at personalized content presentation on a 3D HUD and the impact on driving safety and experience.

In more details, the contributions are as follows:

Andrew L. Kun, Hidde van der Meulen, and Christian P. Janssen report in the article "Calling while Driving Using Augmented Reality: Blessing or Curse?" (pp. 1–14) on an experiment on the distracting effects of in-car conversations through augmented reality glasses. The authors investigated in a simulated vehicle how distracting video-based conversations with a remote conversant are. Two conditions were examined: The driver either only heard the remote conversant (speech-only condition) or was also able to see the conversant in a virtual window that was presented through augmented reality (video call condition). The authors conclude from this study that further experiments on the effects of augmented reality on the visual attention of the driver are required before the technology can be used on the real road.

In the contribution "A Summary Discussion about Simulation Sickness in Driving Applications with Virtual Reality Head-Mounted Displays" (pp. 15–31), Stanislava Rangelova and Elisabeth André discuss factors related to simulation sickness in virtual reality driving simulations with head-mounted displays. Simulation sickness is a well-known phenomenon that has physiological effects on users, such as disorientation, headache, and nausea. So far, research has mainly focused on driving or flying simulators with standard computer displays; but as any simulated environment could have such an effect, virtual reality should be included in this discussion. Despite the advances of virtual reality technology, discomfort from using head-mounted displays has to be resolved. The contribution of this article is three-fold. First, a review of head-mounted display types in the context of virtual reality driving applications over the recent years is presented; second, characterization and comparison of approaches to mitigate simulation sickness are presented; and third, suggestions for future work on the correlation between simulation sickness and a virtual driving environment are provided in the article.

The article of Sanna M. Pampel, Katherine Lamb, Gary Burnett, Lee Skrypchuk, Chrisminder Hare, and Alex Mouzakitis, "An Investigation of the Effects of Driver Age when Using Novel Navigation Systems in a Head-Up Display" (pp. 32–45), picks-up on the problem of the aging society and the fact that older drivers are faced with age-related deteriorations that can lead to a higher crash risk. In this work, two augmented reality

HUD virtual car navigation solutions were tested (one screen-fixed, one world-fixed), aiming to improve navigation performance and reduce the discrepancy between younger and older drivers by aiding the appropriate allocation of attention and easing interpretation of navigational information. Results from a medium-fidelity simulator study with three different navigational conditions (virtual car HUD, static HUD arrow graphic, and traditional head-down satnav) show that older drivers tend to achieve navigational success rates similar to the younger group, but experienced higher objective mental workload. The conclusion is that both augmented reality HUD systems show potential for older drivers. Results further indicate that further investigation in a real-world driving context is necessary to prove the study outcomes.

The article “Fostering User Acceptance and Trust in Fully Automated Vehicles: Evaluating the Potential of Augmented Reality” (pp. 46–62) by Philipp Wintersberger, Anna-Katharina Frison, Andreas Riener, and Tamara von Sawitzky assumes that “usable” augmented reality aids (in any form, e.g., windshield displays, AR contact lenses, etc.) will be available soon in vehicles to support drivers/passengers. Based on this prerequisite, this work tries to give an answer if augmented reality assistance has the potential to increase user acceptance and trust by communicating system decisions (i.e., transparent system behavior) to the user. Two driving simulator studies with scenario augmentation in fully automated driving were conducted and results suggest that both the augmentation of traffic objects otherwise invisible or the presentation of upcoming driving maneuvers are feasible approaches to increase user acceptance and trust. Quantitative results are further backed by qualitative findings from semi-structured interviews and UX curves. The conclusion of this work is that augmented reality is a technology with tremendous potential for automated driving, in particular with the emergence of more powerful, lightweight, or integrated devices/wearables.

The work of Renate Häuslschmid and her colleagues is motivated by the myriad of fatal accidents caused by the urge of drivers to access content on smartphones while driving. In their article “Personalizing Content Presentation on Large 3D Head-Up Displays” (pp. 80–106), the authors investigate the potential of personalized content on large, 3D head-up displays in vehicles to improve driving safety and experience. As of today it is, however, unclear how personalized content presentation will influence safety as compared to static layouts. To close this gap, the authors identified the types of content drivers access on their smartphones while driving and whether they prefer the same content on a head-up display by means of an online survey; the authors collected drivers’ personalized 3D layouts in a VR situation room and assessed the influence of personalization on driving safety; and finally compared the impact of these personalized layouts on driving safety to a one-fits-all layout concept in a 3D driving simulator study. Study results indicate that drivers have diverging content and layout preferences. They want personalization; however, their personalized layouts do not respect safety sufficiently. The one-fits-all layout led to better response times, but needs to be modified to consider drivers’ individual preferences.

Conclusion

To sum up, technology for AR in driving is not yet technically mature for practical use in vehicles (Gabbard, Fitch, & Kim, 2014). Challenges that need to be solved include accurate capturing and interpretation of road geometry through computing intensive sensor fusion; precise vehicle positioning; compensation for vibrations, delays, and jitter; laser projection; driver monitoring via inward facing cameras; implementation of sophisticated algorithms to create precise augmentation content in the driver’s field of view; and others. A holistic understanding of AR/VR use in manual and automated driving is required in order to be able to address and solve these issues.

In conclusion, we greatly appreciate all the authors and reviewers for their contribution to shaping this special issue. We cordially invite you to a fascinating journey through a collection of high-quality research articles assembled in this special issue of augmented/virtual reality for application in intelligent vehicles.

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