Editorial

Driving Simulation & Virtual Reality: Introduction to the Special issue of TRF

1. Introduction

With the advent of more and more sophisticated driving assistance systems on the market, the use of driving simulators to test them has become nearly compulsory. The number of research papers involving simulator studies that were published in recent years testifies such importance. This popularity is also demonstrated through large investments performed by major car manufacturers to acquire state-of-the-art high performance simulators.

Driving simulators permit a large variety of traffic psychological research studies. For instance, they allow testing and validating advanced functionalities of new vehicles in safe and controlled environments. They are also used to study drivers' behaviors against risky or complex driving situations without endangering any user. Simulators therefore provide many benefits, including cost reduction and highly increased safety compared to real settings.

The driving simulation community is also witnessing more and more common use of virtual reality devices such as head-mounted displays. This raises strong yet well-known scientific issues that can affect drivers' behaviors. However, integrating virtual reality tools in driving simulation is a challenge, and one of the motivations for this special issue.

2. Contributions

The current Special Issue gathers 9 high-quality studies. The contributions were chosen among the best papers of the 17th Driving Simulation & Virtual Reality Conference, a now well-established conference in the driving simulation community and published as two-page abstracts in the proceedings of the conference. These contributions cover a wide range of aspects related to the use of driving simulators.

One major issue in driving simulation is to accurately reproduce motions from a perceptual point of view. Especially, simulators are constrained by their physical workspace and their high inertia, limiting their ability to reproduce faithful accelerations and velocities. A more and more popular way consists in using optimization-based algorithms. Katliar et al. proposed an "Offline Motion Simulation Framework" that enables determining optimized simulator motion trajectories offline (Katliar et al., 2019). This minimizes the possible motion incongruence that is usually met with classical motion cueing algorithms. Katliar et al's framework also features the possibility to optimize simulator design parameters such as hexapod leg joints, allowing to define a set of reference motions. Their framework is intended to be used in many simulators and has been made available as an open-source software for the driving simulation community. Ellensohn et al. evaluated a commercially available motion cueing algorithm against a new one they propose to enhance motion fidelity (Ellensohn, Venrooij, Schwienbacher, & Rixen, 2019). The main issue lies in the evaluation process by participants to assess quality. Rating models were considered but results showed that careful evaluation of these models must be done to avoid incorrect evaluation of motion cueing quality.

Motion cueing algorithms generally integrate human perception models. Understanding how drivers perceive and why drivers act in such ways in driving simulation, is of primary importance to derive algorithms allowing high-fidelity motion. Markkula et al. studied visual-vestibular integration and derived a model of driver steering behavior (Markkula et al., 2019). The model is composed of an estimator of needed steering adjustment based on visual and vestibular inputs, which is then used to define a steering angle. This model allows clarifying several previously unexplained empirical findings such as decreased performance and increased steering effort: drivers tend to underestimate yaw rate.

Perception and more generally simulated driving experience can also be affected by a well-known but hardly avoidable phenomenon: simulator sickness. It is well admitted that sickness is induced by a visuo-vestibular conflict. Despite more than 40 years of research, it remains a core research topic. Lucas et al. compared three vibration patterns (no vibration, realistic vibrations and vibrations affecting proprioception (between 60 Hz and 100 Hz)) and studied their influence on the level of simulator sickness (Lucas, Colombet, Paillot, & Kemeny, 2019). Results showed that realistic road vibrations lowered sickness levels compared to no vibration and vibrations affecting proprioception. This finding suggests that simulator's fidelity is of major importance to provide optimal driving experience.

In addition to simulators' fidelity, usability is another important feature that is explored in research work. For instance, Baumgartner et al. explored the use of the Just Noticeable Difference (JND) as a metric to distinguish between several acceleration profiles resulting from different powertrain setups and evaluate drivability in driving simulators (Baumgartner, Ronellenfitsch, Reuss, & Schramm, 2019). As simulators generally involve motion scaling due to workspace limitations, perception may be affected. Baumgartner et al. proposed a law based on Weber's law to transfer JND values from motion scaled studies to real conditions. Romano et al. evaluated the utility of a driving simulator to test low friction driving (Romano et al., 2019). They studied driver behavior both in a driving simulator and in real test conditions on a snowy low friction track. Results showed that motion-based driving simulators could be effective at simulating such situations achieving about 70% realism in simulation, though weaknesses lied in poor restitution of dynamics lateral friction limit on low friction surfaces.

Most of research work involving driving simulators studies consider light vehicles simulation. However, simulating heavy vehicles is also crucial to address challenges in traffic regulation and overall costs reduction, especially considering high capacity transport vehicles. Kharrazi et al. investigated the potential of simulating different high capacity vehicles dynamics on a motion-based simulator that is normally used for conventional heavy vehicles simulation (Kharrazi, Augusto, & Fröjd, 2019). Results showed that such simulators can be used to faithfully reproduce vehicles with quite different dynamics. Especially, subjective evaluations by drivers were found to be positively correlated to objective measurements.

While above-mentioned research work addresses perceptually accurate motion rendering and usability, other work focuses on applications of driving simulators. Aramrattana et al. proposed a framework to simulate cooperation between intelligent transport systems (ITS) (Aramrattana, Andersson, Burden, Reichenberg, & Mellegård, 2019). Several simulation modules (hardware in the loop, driving simulator, network and traffic) were integrated to provide with comprehensive collaborative ITS tools. In Elgharbawy et al. research work, a framework based on ontologies was proposed to test active safety functions in scenario synthesis (Elgharbawy, Schwarzhaupt, Frey, & Gauterin, 2019).

3. Conclusions

The papers presented in this Special Issue provide a good overview of trends in research on driving simulation. They cover a wide range of aspects from the design of motion restitution algorithms to achieve perceptually realistic simulation to applications through usability testing. With the advent of intelligent vehicles and especially autonomous vehicles that require massive simulation during the design process, driving simulation is more than ever an important research topic.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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