International Journal of Virtual and Augmented Reality
Volume 2 • Issue 1 • January-June 2018

Lessons Learned from the Design and Development of Vehicle Simulators:
A Case Study with Three Different Simulators

Sergio Casas, University of Valencia, Valencia, Spain
Silvia Rueda, University of Valencia, Valencia, Spain

ABSTRACT

Vehicle simulators are crucial tools used in a variety of areas, such as aviation, driving, or maritime transportation. International standards require the use of motion-based vehicle simulators in training scenarios. However, the huge variety of applications and requirements makes it difficult for end users to find a motion-based commercial solution that fulfils their needs. On the other hand, commercial solutions are usually expensive as they involve specific hardware and software. Although some ad-hoc solutions have been reported, a generalized design strategy is needed. In this article, the authors emphasize the need for finding a development methodology for these important tools and they propose an overall strategy for the design of vehicle simulators, focusing on the relevant decisions according to the authors' learned experience. The following aspects are considered: use, motion hardware, cockpit, users, display types, cost and physical space. Finally, the authors show three case studies where these decisions have been already taken: a rescue speedboat simulator, a tractor simulator and a driving simulator.

KEYWORDS

Design, Development, Methodology, Motion Cues, Multimodal Interaction, Simulation, Vehicle Simulator, Virtual Reality

INTRODUCTION AND RELATED WORK

Vehicle simulation represents one of the most important mechanisms to train pilots, test new vehicular technologies, study human factors, teach different protocols, practice driving skills or raise awareness about different topics. A large variety of vehicle simulators have been proposed with different applications and vehicle types, such as planes (Advani, Hosman, & Haeck, 2002; Mauro, Gastaldi, Pastorelli, & Sorli, 2016; Reid & Nahon, 1988; Yavrucuk, Kubali, & Tarimci, 2011), helicopters (Schroeder, 1999; Wei, Amaya-Bower, Gates, Rose, & Vasko, 2016; Wiskemann et al., 2014), cars (Chapron & Colinot, 2007; Jansson et al., 2014; Nehaoua et al., 2008), motorcycles (Avizzano, Barbagli, & Bergamasco, 2000; Cossalter, Lot, Massaro, & Sartori, 2011; Nehaoua, Hima, Arioui, Seguy, & Espié, 2007), trucks (Thöndel, 2012), tractors (Lleras et al., 2016), ships (Filipczuk & Nikiel, 2008) or even bicycles (Herpers et al., 2008; Schulzyk, Hartmann, Bongartz, Bildhauer, & Herpers, 2009).

Road safety, pilot training and vehicular design are some of the main areas where vehicle simulators can provide significant advantages over experiments with real vehicles, since they can be used to both save money and human lives, among many other advantages (Casas, Fernández, & Riera,

DOI: 10.4018/IJVAR.2018010105

2017) (availability, pilot evaluation, debriefing, weather control, etc.). In fact, many international regulations and certification standards require the use of full motion-based vehicle simulators to certify a simulator for training tasks (DNV, 2011; ICAO, 2009).

Different vehicles, different features and different uses, imply different requirements. Thus, when an engineer needs to design a new vehicle simulator, there are a lot of decisions to be taken. The huge variety of applications, environments, solutions and requirements makes it difficult to propose a detailed methodology for the development of vehicle simulators. However, most of vehicle simulators share a common framework and a series of features that can be studied in a common way.

There are, of course, commercial solutions, so engineers could opt for purchasing an existing closed solution, instead of building one from scratch. However, it is hard for end users to find a motion-based commercial solution that fulfil all their needs, which usually requires an exclusive or dedicated system. On the other hand, commercial solutions for traditional areas, such as aviation or racing, are typically expensive as they involve specific hardware and software (e.g. cockpits, vehicle controls, gauge display, etc.). For instance, most of the flight simulators used for pilot training are owned by private industries which design them ad-hoc for each specific aircraft. Although some ad-hoc solutions have been reported by the research community, a generalized strategy for the development of vehicle simulators is needed. It is important that this procedure takes into account all the requirements of the simulator, including the end user's needs.

Although there are several studies analysing the validity/fidelity (Burki-Cohen, Go, & Longridge, 2001; Jones, 2017; Kaptein, Theeuwes, & Van Der Horst, 1996; Matas, Nettelbeck, & Burns, 2016) and the features (Philips & Morton, 2015) of different vehicle simulators, there are very few works dealing with the process of actually designing vehicle simulators. The construction of scenarios of a particular vehicle type (Dols et al., 2016) or the study of the use of modular components to the design of distributed virtual environments (DVEs) (Casas, Morillo, Gimeno, & Fernández, 2009) or vehicle simulators (Romano, 2000) are topics that have been dealt with in the literature. However, there is a lack of general guidelines to help designers in the long and difficult task of building a vehicle simulator.

For this reason, and with the accumulated know-how gathered from our research group, which has more than twenty years of experience designing and building vehicle simulators, we propose a series of guidelines for the design of this kind of Virtual Reality (VR) applications. We accompany them with three different case studies: a rescue speedboat simulator, a tractor simulator and a multi-user multimodal road safety driving simulator. These vehicle simulators have been designed and built in our research labs following these guidelines and represent three very different vehicle simulators with different features and requirements. Thus, we think they serve to illustrate the process.

Nevertheless, as the field is really broad, these guidelines cannot constitute a full methodology yet, and we emphasize the need for developing a complete methodology that covers all the possible aspects of vehicle simulation. We believe this paper is a step in this direction.

COMPONENTS OF A VEHICLE SIMULATION

The design of a vehicle simulator is typically split in different modules or layers, so that software cohesion is kept high, the design of these small modules is easier and code reutilization is also possible. Different architectures for the organization of vehicle simulators can be proposed, depending on the goals and particular features of the simulator. One possible generalized approach is the architecture shown in Figure 1.

In this scheme, we can observe the following elements (those in orange represent hardware elements; green is for software elements that are highly dependent on a hardware counter-part; modules in pink are core elements; blue is for modules that are somehow optional):