To Move or Not to Move?
The Challenge of Including Believable Self-Motion Cues in Virtual Reality Applications - Understanding Motion Cueing Generation in Virtual Reality

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EXECUTIVE SUMMARY

This chapter deals with the problem of including motion cues in VR applications. From the challenges of this technology to the latest trends in the field, the authors discuss the benefits and problems of including these particular perceptual cues. First, readers will know how motion cues are usually generated in simulators and VR applications in general. Then, the authors list the major problems of this process and the reasons why its development has not followed the pace of the rest of VR elements (mainly the display technology), reviewing the motion vs. no-motion question from several perspectives. The general answer to this discussion is that motion cues are necessary in VR applications—mostly vehicle simulators—that rely on motion, although, unlike audio-visual cues, there can be specific considerations for each particular solution that may suggest otherwise. Therefore, it is of the utmost importance to analyze the requirements of each VR application before deciding upon this question.

INTRODUCTION

Virtual Reality (VR) could be defined as the process, means and technologies by which one or several individuals experience the sensation of belonging to an alternative reality that is not the one they are actually living in (Casas, Portalés, Vera, & Riera, 2019). This alternative synthetic reality needs to be believable enough so that suitable deceptions of reality are created and accepted as real by the participants. As a complete recreation is sometimes impossible – or even undesirable because the simulated actions could be in some occasions harmful -, it is often acceptable that the perception of belonging to the virtual world be only partial. Nevertheless, although it is not necessary that the recreated virtual reality be indistinguishable from the real one, it is sensible to think that the more perceptual cues are generated by the VR application - generated to deceive the human senses - the better for the sense of immersion.

Therefore, VR applications need to deceive human senses by generating visual, sound, haptic, tactile, and even olfactive or gustatory perceptual cues (Casas, Portalés, García-Pereira, & Fernández, 2017). However, humans have a sixth sense that is often neglected: the capacity to perceive our own motion, which is called kinaesthesia and is mostly (but not exclusively!) captured by the vestibular human system (the whole perception mechanism is not completely understood). This perceptual cue is very important in many VR applications, such as vehicle simulators, but it is, more often than not, forgotten in VR solutions for a variety of reasons. Motion cues are introduced in VR as a way to make the user perceive self-motion that is compatible with their navigation within the virtual world. This is usually accomplished by means of robotic devices that are synchronized with the rest of the VR application software. These devices physically move the VR users so that their experience is consistent with the virtual world depiction. In the case of vehicle simulators, which are, by far, the most commonly use case for motion-based VR applications, these robotic devices consist of motion platforms that move the user's seat according to the movement of the virtual vehicle they are controlling in the virtual world (Reymond & Kemeny, 2000). Treadmills and walking simulators are a different type of device, since they do not move the user but allow them to move somehow freely, so that their navigation is more natural. Unlike motion platforms, which have been used for decades, these virtual walking devices represent a new and interesting research area that is also worth studying.

Contrary to what most people think, VR is not a new technology. There are records of primitive flight simulators as early as 1910 (Allerton, 2009; Page, 2000), although the consideration of these early devices as VR applications is arguable. Only after microcomputers started to be used to create synthetic virtual environments – during the 1970s and 1980s - could these applications be considered true VR systems.

Indeed, the development of VR applications in the last twenty years has been magnificent, especially due to the rapid development of visual techniques and display hardware, such as cheap graphic cards with parallel GPU-based processing power, real-time realistic visualization software, VR-glasses, projectors, stereographic systems, realistic vehicle models, etc. (Boletsis, 2017; Garrett & Best, 2010). Unfortunately, motion generation systems have not followed this pace. Despite of a huge reduction in the price and cost of robotic motion platforms in the last decades, the algorithms, the methods and the problems have not changed much since the first motion-based VR applications were developed in the 1960s and 1970s (Casas, Coma, Riera, & Fernández, 2015) and the motion cueing problem remains the subject of much discussion (Garrett & Best, 2010). The reasons for this apparent relative lack of substantial progress have prompted the proposal of this chapter.

This chapter has three major goals. First, the authors will briefly explain how to generate self-motion cues in VR applications. Second, the chapter will analyse the factors that lead many VR systems to