Sensory Simulation in the Use of Haptic Proxies: Best Practices?

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Figure 1: Shelldon turtle MR, Fin Whale VR, MR Escape room, Chariot simulator, VR Offshore wind turbine.

ABSTRACT

To function effectively, VR applications with haptic proxies rely on sensory synchronicity, i.e. the automatic combination of different sensory inputs that share specific traits. However, they also seem to rely on mechanisms of sensory completion. By making use of these mechanisms, a reduced set of sensory input might be sufficient to simulate a wider range of sensory sensations. Audiovisual media have already developed methods to trigger sensory simulations by way of sensory completion. We are interested in collecting methods for sensory simulation in VR applications from a usability and design point of view. As realistic haptic feedback remains the most difficult sensory input to provide in VR applications, these methods can support the use of simple haptic proxies as triggers for haptic simulation.

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CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; **Virtual reality**; **Haptic devices**.

KEYWORDS

virtual reality, haptic proxies, sensory synchronicity, simulation, illusion, virtual environments.

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1 INTRODUCTION

To function effectively, VR applications with haptic proxies rely on sensory synchronicity, i.e. the automatic combination of different perceptual inputs that share specific traits [3][2]. In these applications, physical objects need to share traits such as position and scale with their virtual counterparts to trigger sensory synchronicity. When interacting with these mixed reality (MR) objects, additional factors such as temporal synchronicity, including duration or intensity become important. For example when hitting a virtual object, the onset, intensity and duration of visual, force and sound feedback need to be synchronized. On the other hand, VR applications with haptic proxies also seem to rely on mechanisms of sensory prediction and completion, i.e. even when one sensory input is only partial or deviating, under certain circumstances it can be perceived as complete. This suggests that by making use of mechanisms of sensory completion, a reduced set of sensory input might be sufficient to simulate actively a much wider range of sensory sensations [6].

2 RESEARCH CONTEXT

Audiovisual media such as film or computer games have developed a diverse toolset of methods to trigger simulations of missing sensory input by way of sensory completion [7]. Currently media design for VR and MR applications is in the process of developing similar methods [5]. Pseudo-haptics is one example for simulating haptics without any physical haptic input that is available in VR [4].

As realistic haptic feedback remains the most difficult sensory input to provide in VR applications, sensory completion holds the potential to support the use of simple haptic proxies, reducing the need for complicated active or passive haptics [8]. As a trigger of sensory completion, everyday objects such as woollen string can turn into powerful haptic simulation tools: In the MR entertainment arcade The Void, haptic contact with a couple of woollen strings simulated haptic contact with a giant spider web [1].

3 PAST RESEARCH

We built opportunities for haptic sensory completion into different types of VR prototypes and tested them over an extended period with more than two hundred users.

3.1 Position, size, shape, weight

In three VR/MR applications, we observed tolerance for shape and weight deviation, but deviation in size and position were less tolerated:

3.1.1 Shelldon. The user carries a physical 3D-printed turtle into a VR underwater scene (see Image 1). The user's hand is tracked with a leap motion and represented by a 3D model. The physical turtle has a tracker and is also represented by a 3D model, i.e. the user can see the virtual turtle and feel the physical turtle in sensory synchronicity. However, the virtual turtle and physical turtle deviate from each other in many details. It seems that synchronicity of position, scale and general shape are sufficient to trigger sensory completion of the missing or divergent haptic feedback of detail or weight [8].

3.1.2 Fin Whale Experience. A full whale skeleton was scanned and implemented in a VR scene. To give users haptic surface information, we experimented with a hand controller in the form of a vertebra, 3D-printed at about 1:10 scale (see Image 1). We hoped to induce some haptic transfer from the touched physical bone to the seen virtual bones, but without much success. The deviation in scale and position between haptic input (hand controller) and visual input (virtual whale skeleton) disrupts sensory synchronicity, even though shape is identical.

3.1.3 MR Escape Room. A multi-functional tool for a virtual space station is represented by a "found" physical tube object with ridges, attached with a Vive tracker. The space station interface is represented by a physical cardboard box (see Image 2). While users barely notice the physical tube has ridges, even though the virtual tool is smooth, just a slight deviation of position between the holes in the virtual interface and in the physical cardboard box causes breaks in haptic sensory synchronicity during hand interaction.

Figure 2: "Found" proxy object with ridges and tracker, corresponding smooth virtual object.

3.2 Temporal Synchronicity and Intensity

Deviation in intensity is tolerated when other factors support sensory synchronicity:

3.2.1 Chariot Simulator. A physical wooden frame with a simple sports vibration plate attached to the platform provides haptic feedback to the user, while steering a virtual chariot with arm movements, tracked by a Kinect (see Image 1). The vibration is roughly synchronized with the virtual chariot's speed, while it passes along an irregular racetrack through a mountain area, with intense up, down and turning movements.

Despite the fact that the physical vibration is of minor intensity, users synchronize it with the much stronger virtual movements and adjust their body position accordingly, by bending their knees and leaning heavily into the wooden frame. Users feel the low-intensity vibrations of the wooden frame as high-intensity movements of the chariot.

However, low-intensity haptic input is not always sufficient to simulate high-intensity haptic input:

3.2.2 VR Offshore Wind Plant. For a VR offshore wind plant, we set up a physical electric fan to simulate wind on a stormy ocean (see Image 1). Several users complained that the mild haptic sensation produced by the electric fan clashed with the loud sound of a stormy sea, resulting in a lack of sensory synchronicity.

Possibly the haptic simulation was more successful in the chariot simulator because of the temporal synchronisation of virtual speed with vibration. Or the low-intensity vibration affected the vestibular system, supporting a high-intensity haptic simulation.

3.3 Simulation methods

Different methods of simulation can be categorized as:

3.3.1 Substitution. One input channel simulates another input channel – e.g. sound for haptic impact

3.3.2 Reduction. A less intense input simulates a more intense input – e.g. vibration simulates weapon impact

3.3.3 Simplification. A reduced or slightly different input simulates a complete input – e.g. a simple object shape simulates a complex object shape … and so on

3.4 Future Research

The success of haptic simulations seems to be influenced by the type of parameter that is simulated, and by the amount of deviation between the physical haptic input and virtual audiovisual input. As these parameters and threshold values for deviation are not immediately evident, from a usability and design point of view, we are interested in collecting a "best practices" catalogue for sensory simulations in VR applications.

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