The Scent of Immersion: Bridging Smell and Learning in Virtual Reality

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Abstract

Virtual Reality (VR) technologies have been on the rise for the past few years, with diverse fields looking to improve their sectors and finding useful applications for this innovation. For instance, this technology has been deemed a powerful asset for education and training, generally improving knowledge acquisition, engagement, and motivation when compared with traditional learning environments. However, despite outstanding research and progress, some key elements are being left behind, when they could very well be the great next step in VR immersion. The goal of this project is to integrate the underdeveloped sense of smell into virtual reality experiences, complementing the already enhanced senses of sight and hearing. The proposed system is a portable, wireless device capable of emitting different scents in real time depending on the proximity of certain virtual objects, through communication with the VR headset.

CCS Concepts

• **Hardware → Sensors and actuators**; • **Human-centered computing → Interaction devices**.

Keywords

Virtual Reality, Olfactory Interfaces, Human-Computer Interaction, ESP32, Sensor Systems, Meta Quest 3

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1 Introduction

Virtual and augmented reality technologies are becoming increasingly present in sectors such as education, healthcare, training, and entertainment. In response to this growth, major corporations have taken it upon themselves to continuously evolve this technology and have attained considerable realism through high-definition graphics, motion tracking [7], and haptic feedback [4]. Yet, the sense of smell, despite its strong connection to memory and emotional processing [1, 3], remains underutilized. Integrating olfactory stimuli into VR environments could transform education by promoting information recall and retrieval, invoking emotions, and improving task performance [2].

2 Motivation and Objectives

Despite the overall progress in VR realism, the lack of olfactory integration limits the depth of immersion possible in virtual environments. Although several commercial attempts have been made to incorporate smell into VR, many have struggled with practical challenges such as delayed activation, bulkiness, and limited mobility [5, 6]. These limitations have prevented widespread adoption. The motivation behind this project is to address these issues by designing a system that integrates the sense of smell in VR in real time while at the same time remaining lightweight and portable. The objective is to develop a more immersive and accessible olfactory VR experience that can be used by students in educational settings.

3 System Design and Implementation

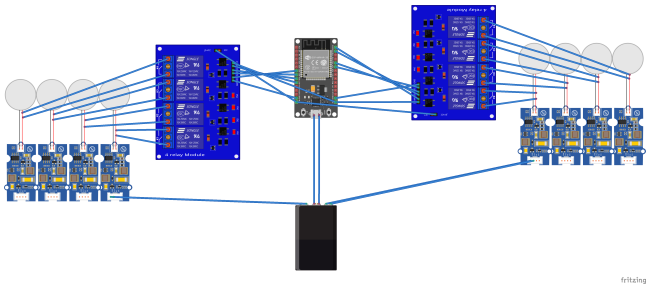

Figure 1: Circuit diagram

The proposed system consists of eight independent ultrasonic atomizers as the scent dispersion mechanism. These elements vibrate at ultrasonic frequencies and, when in contact with a liquid, create a fine mist. For the automatic activation of these atomizers, relay modules act as switches to allow or stop scent emission, which are controlled by the ESP32. The Fritzing diagram shown in Figure 1 illustrates the wiring configuration discussed, while Figure 2 shows the resulting physical prototype.

Within the VR environment, the distance between the user's head and the various scent-associated objects is continuously tracked

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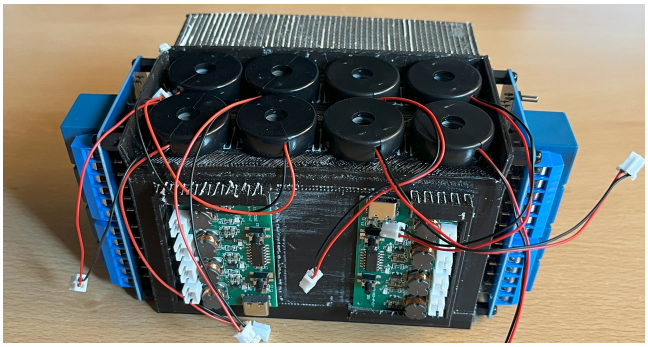

Figure 2: Final olfactory display case with components

and communicated from the VR headset to the ESP32 via WebSocket protocols. When the distance is below a certain threshold, the corresponding scent is released. Moreover, the device can be easily configured by the user with a customized activation distance through a web interface, without requiring any modifications to the code of the VR experience.

Compared to other approaches, this design prioritizes real-time responsiveness and portability, allowing for successful integration into educational and training scenarios.

4 User Evaluation

A user evaluation was conducted to assess the performance, usability and immersive value of the olfactory display. The main objectives were to confirm scent perception, verify synchronization between virtual actions and scent delivery, assess the impact of the threshold configuration, and identify areas for improvement.

Figure 3: Sample VR scenario for user testing

Participants used an Oculus Quest headset in a VR kitchen scenario, shown in Figure 3, where they interacted with the scented virtual objects. The test involved ten participants with varying levels of VR experience, and consisted of an initial interaction with the VR system, modification of the scent activation thresholds, and post-evaluation interviews with open-ended questions.

The results were overall positive, with participants confirming the perception of scents and most finding the experience original and enjoyable. Initial feedback indicated minor delays in scent activation compared to how they were expecting them, but threshold customization solved this and improved user satisfaction and immersion. Some common issues mentioned were the device's weight and the clicking sound produced by relays preceding scent emission, while suggestions for improvement included the implementation of a centralized scent output and variable scent intensity.

In general, the evaluation confirmed that the olfactory display worked as intended, was positively received, and provided meaningful insights for future enhancements.

5 Conclusions

This project proves the feasibility of integrating the sense of smell into VR experiences through a portable and responsive system. Initial testing demonstrated the prototype's ability to emit different scents in real time, triggered by user interactions within the virtual environment. While some limitations remain, the results show clear potential for this technology.

Future work will focus on improving the scent delivery mechanism and conducting larger-scale studies to measure the impact of olfactory stimuli on learning, memory retention, and engagement. In the long term, this line of research could contribute to a more effective educational experience in virtual environments.

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