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Demo of the Extended Wearable Olfactory Display for Multisensory VR Experience

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Abstract

We present a prototype of an eight-channel wearable olfactory display, capable of delivering a diverse range of olfactory stimuli using eight liquid odorants — a configuration that, to the best of our knowledge, is unprecedented. The system is designed to be compatible with various head-mounted displays (HMDs), allowing the integration of olfactory stimuli with visual and auditory inputs for a more immersive user experience. To assess the system's performance, we developed a corresponding virtual reality (VR) application. This system holds significant potential for advancing human-computer interaction by enhancing sensory experiences and offering a more immersive, multisensory interface.

CCS Concepts

• ***Human-centered computing*** → ***Systems and tools for interaction design;*** • ***Hardware*** → *Displays and imagers;*

1. Prototype

The size and weight of the prototype, as a wearable device, are critical factors that significantly influence the user experience. After testing several 3D printing materials such as ABS and PLA, we finally selected carbon fiber for the main body and internal frame to achieve a lightweight yet durable design, as shown in Figure 1.

Figure 1: *Overview of the prototype, measuring approximately 105x160 mm and weighing 360 g.*

Precise control over the ratio of each odor component is essential for generating the target odor. To achieve this, we integrated a total of eight electroosmotic pumps (EO pumps) and eight micro dispensers. As illustrated in Figure 2, each EO pump is connected to a micro dispenser via a Teflon tube, forming eight independent odor channels. While additional channels would certainly enable broader and more precise odor generation, the eight-channel setup provides essential scent blending and reproduction capabilities within a relatively compact design. This setup allows precise synchronization of the flow rate and ejection frequency. The coordination between the pump and dispenser ensures a stable droplet ejection volume, enabling accurate control of the mixture ratio for each odor component.

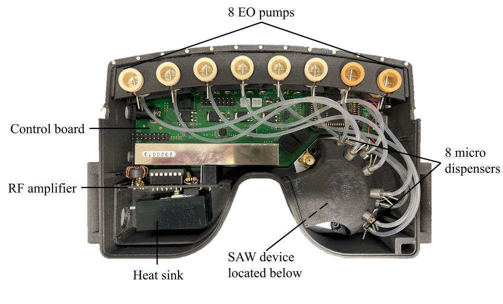

Figure 2: *Internal structure of the proposed prototype. Electrical connections are not shown for clarity.*

The micro dispensers are embedded in a specially designed adapter, with their ejection points directed toward the atomization area of the surface acoustic wave (SAW) device beneath the adapter, which can atomize a low-volatile liquid forcibly [HN16], as shown in Figure 3. On the surface of the SAW device, different

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odor components are mixed and atomized into tiny liquid particles. A DC fan positioned behind the SAW device directs the atomized particles toward the user's nose, allowing them to perceive the olfactory stimuli. Any odor particles not inhaled are removed by charcoal filter placed before an external air pump, which has been validated as effective in [KN19]. The airflow passes over a heat sink mounted on the RF amplifier circuit, which effectively dissipates the heat generated by the system. Experimental results indicate that the heat dissipation can be greatly improved even with a restricted-size heat sink.

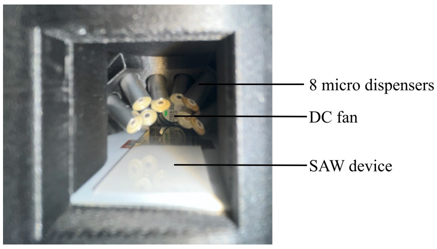

Figure 3: *The SAW device positioned beneath the micro dispensers, with a DC fan behind, generates and delivers the target odor to the user's nose.*

We use a magic band to securely attach the wearable olfactory display to the HMD, which is shown in Figure 4. The attachment was tested with several different HMDs, all of which demonstrated compatibility and stable performance. Thus, we believe that the proposed wearable olfactory display can be integrated with a wide range of general HMDs, rather than being limited to a specific model.

In addition, considering the continuous consumption of odorants, it is possible for them to be fully depleted during operation. Most previously proposed wearable olfactory displays use a pre-installed odor material design, requiring users to remove the HMD to replenish the odor materials. In contrast, our design features an extended front section of the device that includes a separate lid, which is secured by embedded magnets. Beneath this lid are the EO pumps containing the liquid odorants. A rubber mat attached to the underside of the lid provides a seal for the pumps. When the lid is opened, users can easily monitor and replenish the remaining liquid odorants, as shown in Figure 4.

Figure 4: *Wearable olfactory display beneath an HMD. The front lid can be open when the olfactory display is attached to the HMD, and it can be closed by the embedded magnets.*

2. Application

By incorporating olfactory information through an olfactory display in addition to audiovisual content, an even more realistic and immersive VR experience can be achieved. This technology has been applied to VR experiences featuring images of tourist sites from various municipalities across the country, providing users with a fully immersive virtual travel experience.

The user is transported to virtual destinations through images displayed on the HMD while remaining in the real-world environment, as illustrated in Figure 5. In this virtual setting, users can see the scenery, hear the sounds, and smell the scents, creating the sensation of actually being there. Moreover, the scents can be manipulated in real-time based on user interaction. The scent profile changes depending on the scene selected, and the intensity of the scent varies according to the user's interaction within the scene. By stimulating not only vision and hearing but also the sense of smell, this multisensory experience offers a higher level of immersion compared to conventional VR content. We plan to demonstrate that application at ICAT2024.

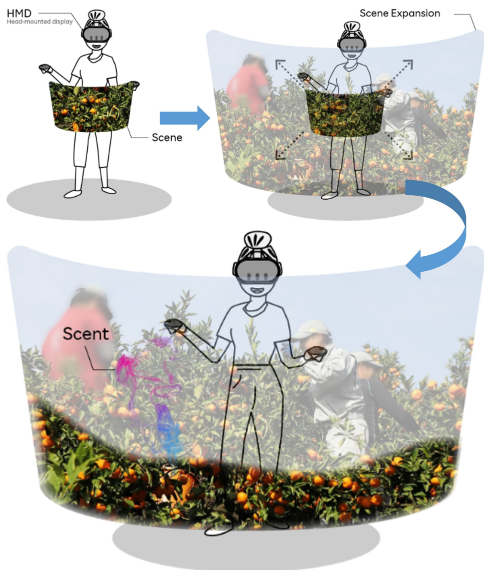

Figure 5: *The additional olfactory stimuli are integrated into a VR travel application, in which the user can interact with the surrounding environment flexibly to get a more immersive experience.*

3. Acknowledgement

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References

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