On Characterizing Olfactory Displays

Jussi Rantala[1], Philipp Müller[1], Timo Salpavaara[2], Jarmo Verho[2], Tomi Ryynänen[2], Poika Isokoski[1], Anton Kondratev[2], Noora Toimela[1], Antti Vehkaoja[2], Jukka Lekkala[2], Pasi Kallio[2], and Veikko Surakka[1]

[1] Faculty of Information Technology and Communication Sciences, Tampere University, Finland

[2] Faculty of Medicine and Health Technology, Tampere University, Finland

One challenge in the research and development of olfactory displays (OD) relates to measurable quantification of the output of the OD. Compared to research with visual, auditory, and even haptic stimulations, it is more difficult to measure, verify, and report the characteristics of olfactory stimuli. This type of characterization would be important in developing, for example, precisely controllable olfactory display technology for assessing the functioning of the sense of smell. In this position paper, we introduce our method to characterize the output of an olfactory display and discuss its applicability to human-computer interaction research involving odor presentation.

CCS CONCEPTS •Hardware~Emerging technologies~Emerging interfaces•Human-centered computing~Human computer interaction (HCI)

Additional Keywords and Phrases: olfactory displays, characterization, odors, human-computer interaction

1 INTRODUCTION

Interaction with computers has been largely based on vision, hearing, and touch, while smell has been less explored. However, recent progress in the development of multisensory interfaces has significantly increased the interest in using the sense of smell and olfactory displays (ODs) in human-computer interaction. While many OD prototypes and even commercial products are being introduced, there are still challenges. Compared to visual, auditory, and even haptic stimuli, it is more difficult to measure, verify and report the output of an OD in a manner that allows accurate reproduction of olfactory stimuli. This is due to the invisible nature of volatile organic compounds [6]. Odors cannot be readily turned on and off similarly to light and sound waves [2] because they are transmitted as molecules that drift, diffuse, and linger [4]. Things are further complicated by perceptual factors such as inter-subject variability, varying olfactory preferences, and cross-sensory influences [5]. Table 1 shows a summary of some challenges mentioned in the literature. Often these challenges are addressed as limitations rather than attempting to introduce solutions for them [2].

Table 1: Some challenges in using ODs.

Challenges	Reference
Invisible, volatile	[6]
Drift, linger, diffuse	[4]
Detection, intensity, delivery, dispersal, distance	[2]
Contamination	[3]
Inter-subject variability, varying preferences, cross-sensory influences	[5]

A possible path towards solving some of the challenges is to provide quantitative and qualitative parameters for the sensory stimulation delivered by an OD [5]. In this paper, we focus on quantitative olfactory parameters that can be measured. By characterization, we refer to the measurement of intensity, as well as temporal and spatial properties of odors presented with ODs. We will next briefly present the functions of ODs to better understand the challenges in odor presentation. Then, we introduce our method to measure the intensity and temporal properties of odors. Finally, we discuss the applicability of the method in human-computer interaction research.

2 FUNCTIONS OF OLFACTORY DISPLAYS

Olfactory displays have three main functions [8]: produce odorized air from the stocked form of odor material (vaporization), switch or blend multiple odors to generate odorized air with desired components and concentration (blending), and transfer the odorized air to the nose (delivery). There are various ways to implement each of these functions, but many of the challenges are similar regardless of the chosen technological approaches.

For vaporization, it is possible to use natural evaporation or accelerate the process by using fresh air or heating [8]. Further alternatives include direct atomization by sprayers, diffusers, or ultrasonic waves [7,8]. Regardless of the technology, the challenge is to quantify the odor output so that reporting does not rely only on subjective evaluations that can vary between people [5]. Measurement technology is needed to *verify the presence, intensity, and temporal properties of an odor*. Blending is needed to mix the desired odor with a carrier gas or another odor. If two or more odors need to be mixed, it is possible to mix the liquid odor material at the desired ratio. However, using premixed materials is a laborious and rather inflexible method. Alternatively, individual odors can first be vaporized and then be blended by controlling odor sources with valves [8]. Mass flow controllers (MFC) and solenoid valves are typically used for this. The main challenge resulting from blending is to *verify which odors are present and at what ratio.*

Odor delivery methods vary depending on the application scenario and number of users. Natural diffusion using a remotely placed odor display can be used to create an ambient odor in an area. For more specific targeting of odors, the odor flow can be directed towards the user by fans [8]. However, odors transmitted over a distance are diffused, and the intensity perceived by the user can be lower than desired. Vortex rings can be used for more precise targeting of odors over a longer distance without loss of odor intensity. The spatial distance between an odor source and user can be reduced by using tubes or body-worn ODs [1,6]. In principle, the shorter the spatial distance, the easier it is to ensure that the user senses the olfactory stimuli as intended. The main challenge in odor delivery is to *verify the odor properties at the user's location.*

3 DEMONSTRATION OF OLFACTORY DISPLAY CHARACTERIZATION

Here we demonstrate the characterization of an OD with integrated sensors. Our aim was to measure the presence, intensity, and temporal properties of odors presented with the OD (Figure 1). The system uses open construction to make it easier to change odor sources, filters, and sensors. The operational principle of the OD is straightforward: the odor source produces either a known concentration or a known mass flow of odorant, which is then diluted with air in a ratio determined by two MFCs or just by the total flow. The current system uses a 5 standard liters per minute (SLPM) controller for the main air supply and a 0.5 SLPM controller for adjusting the odor concentration. We have two possible ways to connect odor sources, but this far we have used mainly flow-through sources.

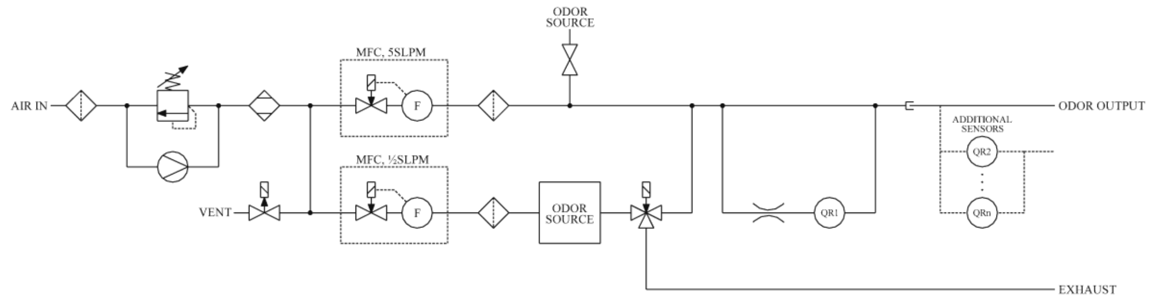

Figure 1: Block diagram of the OD and sensors.

The system includes a photoionization gas detector (PID, QR1 in the diagram), and other sensors (QR2…QRn) can be connected as needed. Further, the system includes a valve for turning the odor output completely off, allowing us to produce odor pulses with sharp edges. The setup uses normal room air for dilution, but the incoming air is first purified with an activated carbon and zeolite filter. Various odor sources have been tested, including saturation chambers, permeation tubes, microfluidic evaporators, and syringe pumps. Figure 2 shows the physical realization of our setup without a pump. We have so far used the system to measure the intensity of n-butanol, phenyl ethanol, and propylene glycol.

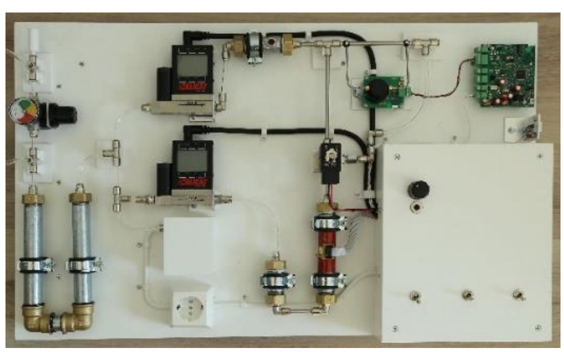

Figure 2: Picture of the assembled setup. The current version is intended for permeation tubes, but saturation chambers have been the most practical source in early testing.

The main advantages of the setup in OD characterization are that the odor concentration is continuously adjustable within a reasonably wide range, the concentration is stable and repeatable, that well-defined odor pulses can be produced, and that we can monitor the outgoing odor concentration in real-time. In addition to the PID, we have also used sensors based on ion-mobility spectrometry (IMS) and differential mobility spectrometry (DMS) to get multidimensional data of the odor sample.

4 DISCUSSION

In this position paper, we have highlighted some of the central concepts and challenges related to the development of ODs which we would be happy to discuss during the workshop. The presented characterization method is one step towards quantitative verification of ODs used in experimental research. In the future, we plan to extend the setup so that it includes a feedback loop that would allow simultaneous measurement and adjustment of odor properties. This would be highly useful, for example, in verifying olfactory stimuli used in the assessment of the functioning of the sense of smell. Also, to understand whether the odor properties change during delivering the odor from its source to a participant, it would be beneficial to have an additional sensor next to the participant's nose. With this addition, it would be possible to measure spatial odor properties such as diffusion and dispersal.

In our view, any study in the field of human-computer interaction utilizing ODs would benefit from the quantitative characterization of presented odor so that replication of study setups would be easier. The complexity of the required characterization system depends on the use of odors in each study. Even a rather simplistic setup such as the one presented in this paper suffices to verify the presence of an odor. However, if the purpose is to identify individual odors, the use of DMS or related sensor technology would be needed.

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