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Poster

Subtractive Mixing of Odor Components from Olfactory White to Generate Various Odors from a Limited Number of Components

H. Matsukura[†1], N. Suzuki[2], R. Chida[2], S. Takahashi[2], Y. Uzawa[2], and H. Ishida[2]

[1]University of Electro-Communications, Graduate School of Informatics and Engineering, Japan
[2]Tokyo University of Agriculture and Technology, Graduate School of Bio-Applications and Systems Engineering, Japan

Abstract

Here we propose a new approach for reproducing a variety of odors using an olfactory display. Replicating odors in virtual reality has been a formidable challenge because odors are generally complex mixtures of abundant volatile chemical compounds. However, a phenomenon called "olfactory white" was discovered, claiming that a mixture of about 30 different chemical substances approaches a certain smell, suggesting that many olfactory cell responses can be saturated with only 30 chemicals. There is a possibility that a wide range of odors can be generated by changing the mixing ratio of the 30 chemicals or subtracting some components from them. We have developed a system that can adjust the vapor mixing ratio of the 30 chemicals so that the response patterns of an electronic nose are matched between the mixed vapor and the target smell. Initial result of human-subject experiment on reproducing several different smells of flavors and fragrances shows the potential of this approach.

CCS Concepts

• ***Information systems*** $\rightarrow$ ***Multimedia information systems;*** • ***Human-centered computing*** $\rightarrow$ *Virtual reality;*

1. Introduction

Despite the olfactory display research over decades, to provide realistic olfactory experience in virtual reality is still challenging. The key problems is the difficulty in replicating various odors we encounter in our daily lives in virtual reality. Although visual display systems can generate arbitrary colors by mixing three primary colors, creating various odors from a limited number of primary odors has not been achieved. Therefore, in typical olfactory display systems, several ready-made mixtures of odorous chemicals are prepared to generate specific smells to be presented [SCM*19].

We discriminate odors by recognizing the response pattern of 400 different olfactory receptor cells in our nose. However, a phenomenon called "olfactory white" was discovered [WSY*12], claiming that a mixture of about 30 diversely different chemical substances approaches a certain smell, as if the mixture of different colors always approaches white in vision. This phenomenon suggests that many olfactory cell responses can be saturated with only 30 chemicals. Considering the large number of components contained in a single smell (for example, hundreds of odorants are contained in coffee smell), it is difficult to replicate a specific odor by adding chemical components one by one from scratch. However, there is a possibility that a wide range of odors can be generated by changing the mixing ratio of the 30 chemicals constituting the olfactory white or subtracting some components from them.

To show the potential of this approach, we have fabricated an odor reproduction system consisting of an odor blender and an electronic nose (e-nose). The vapor mixing ratio of the 30 chemical components constituting the olfactory white is adjusted so that the response pattern of the e-nose is matched to the response pattern to the target smell. Initial result of human-subject experiment is presented with discussions for future improvements.

2. Related Work

A handful of work has been addressed to generate various odors from a small number of components. The most successful results was presented in [HPIN22], reporting that smells of 185 essential oils of plants, e.g., rose and cypress, can be reproduced by 20 odor components. Each component is a mixture of essential oils whose mixing ratio is determined so that the odor components form basis vectors in the mass spectrum space. However, it is not clear to which extent the same approach can be used to replicate a wider range of odors other than plant-based essential oils.

3. Method

The fabricated 40-component odor blender has the same working principle as in [NM07], but can mix vapor of up to 40 different chemicals by rapidly switching the solenoid valves. An electronic

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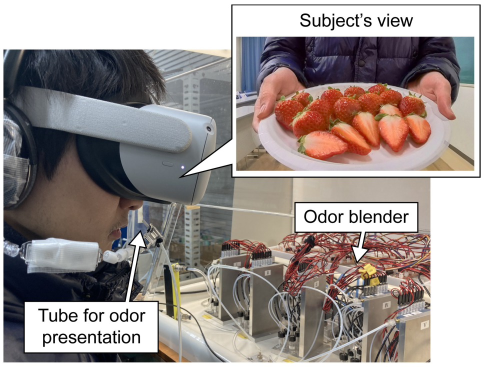

Figure 1: *Human-subject experiment. The smell was presented to the subject while showing an image of the corresponding object.*

nose is a device having an array of gas sensors with different response characteristics, and discriminates odors from the sensor response pattern. We chose Cyranose 320 from Sensigent having 32 gas sensors because most other commercial e-noses have only 8–16 sensors. The vapor mixing ratio of the 30 components is adjusted to have the e-nose response pattern matched to the pattern of the target smell. Eight commercially available flavors/fragnrances (banana, strawberry, grapefruit, green plum, hassaku orange, floral essence, elegant rose, and fresh green) were used as the target smells.

To evaluate the reproduced odors, we conducted human-subject experiment (Figure 1). We chose three target smells (strawberry, elegant rose, and fresh green), and prepared three smells for each target, i.e., the original flavor/fragrance smell, the reproduced smell, and the olfactory white. A subject was asked to wear a head-mounted display showing a visual image of an object corresponding to the target smell. Then, we presented two of the three smells (the target, original, and olfactory white) to the subject, and asked which smell was more suitable to the presented visual image.

4. Results

Figure 2 shows the response patterns of the 32 sensors in the e-nose to the original strawberry flavor and the reproduced smell. For each sensor, the fractional change in the sensor resistance when exposed to the smell was measured. Close match between the response patterns to the original and reproduced smells was attained for 7 out of the 8 flavors/fragrances tested, including this strawberry flavor.

The result of the paired comparison done by 12 subjects (22–37 years old) is summarized in Table 1. We had anticipated that the smell most frequently chosen as suited for the image would be the original flavor/fragrance smell, followed by the reproduced smell. However, the number of times chosen was almost same for the three smells when the strawberry flavor was used as the target, suggesting that the olfactory white and the reproduced smell were close enough to the target strawberry smell to make the subjects confused. For the elegant rose fragrance, subjects were confused between the original smell and the olfactory white, suggesting the possibility of using the olfactory white as generic alternative for flowery and fruity smells. The reason for the smaller number of selection for the reproduced smell needs to be investigated in future.

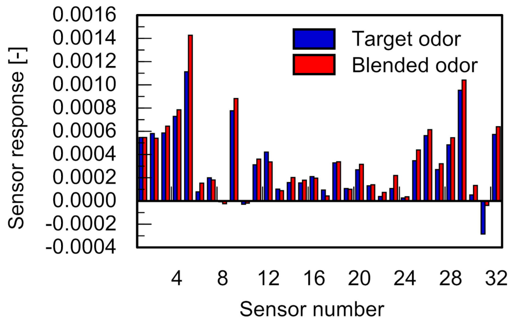

Figure 2: *Response patterns of the sensors to the original strawberry flavor smell and the reproduced smell.*

Table 1: *Number of times selected as more suitable odor in the paired comparison tests.*

	Presented odor		
Video image	Original	Reporoduced	Olfactory white
Strawberry	13	10	13
Elegant rose	18	6	12
Fresh green	23	9	4

For the fresh green smell, the majority of subject chose the original smell as most suited. However, a statistically significant increase in the number of times selected was obtained as anticipated for the reproduced smell compared to the olfactory white.

5. Conclusions

We propose to use the olfactory white as the basis for generating various odors in virtual reality systems. Reproducing the e-nose response pattern was successful for 7 out of 8 flavors/fragrances tested. Promising result was obtained in the human-subject experiment for 2 out of 3 flavors/fragrances tested. Future work will include attaining better match between the target and reproduced smells and trying a wider variety of smell reproduction.

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