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Study of Odor Recorder for Dynamical Change of Odor

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Introduction

Although techniques of recording and reproduction of visual and auditory information are nowadays well established, a corresponding technique for olfaction is still not mature. However, the study of recording and reproduction techniques for smells is becoming more popular in the field of chemical sensors as well as that of virtual reality (Kaye, 2004).

An odor sensor called an 'electronic nose' (Pearce et al., 2003) can be used for olfactory recording. In addition to the odor sensor, a smell reproduction technique is required. We have developed a system called an 'odor recorder' for reproducing the smell recorded using an odor sensor (Nakamoto *et al.*, 2001). The recipe of the smell is obtained using the odor recorder and the smell can then be reproduced based upon the obtained recipe.

We have successfully determined the eight-component recipe of apple flavor using our odor recorder (Yamanaka and Nakamoto, 2003). Although a constant recipe was obtained in most of our previous studies, the actual odor in the atmosphere changes continuously and dynamically. In this paper, a study of the odor recorder for dynamical changes of odors is described.

Principle of the odor recorder

An odor sensing system recognizes the output pattern of a sensor array composed of multiple sensors. The same sensing system is used in the odor recorder. The principle of an odor recorder is illustrated in Figure 1. First, the target odor to be recorded is introduced into a sensor array and its output pattern is memorized. Then, the responses of the sensors to the blended odor, made up of multiple component odors, are measured and are compared with those to the target odor. The recipe of the target odor is obtained from that of the blended odor in the case that the sensor-array output pattern of the blended odor agrees with that of the target odor. Otherwise, the recipe of the blended odor is iteratively modified so that the sensor-array output pattern of the blended odor can approach that of the target odor using adaptive MIMO (multi-input multi-output) feedback control theory. The recipe of the target odor is obtained after the convergence.

Once the recipe is recorded, the smell can be reproduced using the odor blender. The odor blender, remotely located from the odor recorder, can be used to generate the smell in the same manner as the blender inside the odor recorder.

The feedback approach utilized in the odor recorder is essential, since the linear superposition theorem is not completely valid in the case of most of the chemical sensor responses. Moreover, it is also effective in compensating for the drift and aging that are often encountered in chemical sensors.

Record of dynamical change of odor using the real-time reference method

Our group attempted for the first time to use a feedback-error learning neural network to record the dynamically changing odor (Nakamoto and Hiramatsu, 2002). Then, the real-time reference method for recording dynamical change of odor was developed (Yamanaka *et al.*, 2003). This method is useful for recording

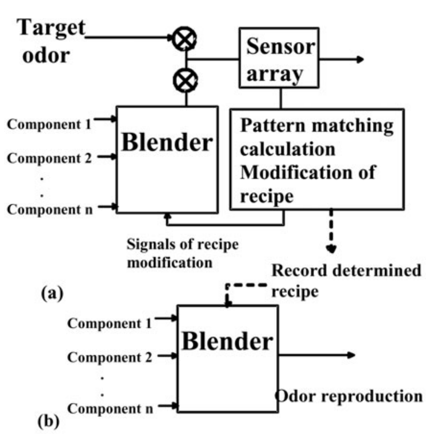


Figure 1 Principle of odor recorder. **(a)** Recording and **(b)** reproduction.

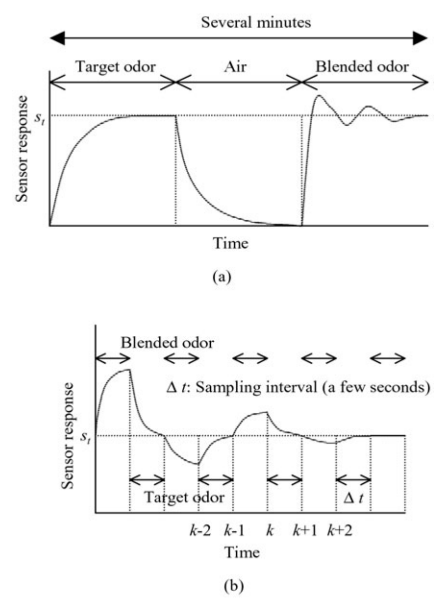
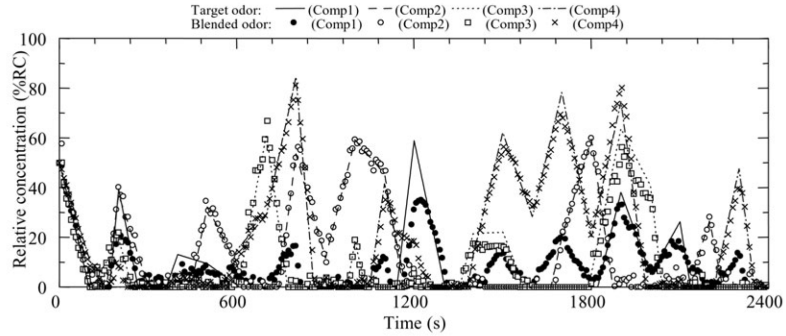
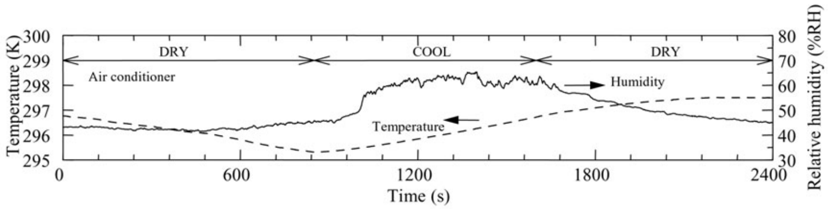


Figure 2 Comparison of real-time reference method with conventional method in odor recorder. **(a)** Previous method and **(b)** real-time reference method.



(a) Comparison between target and blended odors.



(b) Temperature and humidity changes during experiment.

Figure 3 Recorded dynamic concentration change of each component vapor in target odor. Solid line: concentration of each component vapor in target odor, Plot: recorded concentration of each component odor. **(a)** Comparison between target and blended odors and **(b)** temperature and humidity changes during experiment.

dynamical changes of odors, as well as for compensating for environmental changes such as temperature and humidity.

The comparison of the real-time reference method with conventional approach is illustrated in Figure 2a,b. Although multiple component odors and multiple sensors are actually used, only a single component odor and single sensor are shown here for simplicity.

In the previous method shown in Figure 2a, the steady-state response to a target odor with constant concentration is measured for the first time. Then, the recipe of the blended odor is adjusted so that the response to the blended odor can match that to the target odor. Since it takes a few minutes to determine the concentration, the change during the process of the recipe determination cannot be detected.

On the other hand, the target and blended odors are alternately introduced into the sensor array every sampling interval (several seconds) in the real-time reference method illustrated in Figure 2 (b). Although the sensor response to the blended odor deviates from that to the target odor, at first due to the concentration difference, it soon approaches the response to the target odor. Once convergence occurs, the blended odor concentration tracks that of the target odor. The real-time reference method achieves a time resolution of a few seconds to record dynamical changes of odor.

We now describe the experiment on recording the dynamically changing odor using the real-time reference method. The concentrations of four odor components of apple flavor were independently changed in the experiment. The odor components used here were *trans*-2-hexenyl acetate (green note, Comp1), *trans*-2-hexenal (smell of grass, Comp2), isobutyric acid (sour sweet, Comp3) and ethyl valerate (fruity, Comp4). The sensors used here were four quartz resonators (20 MHz, AT-CUT) coated with polphenyl ether, polyethylene glycol 1000, tricresyl phosphate and Apiezon L, respectively. The sampling interval was 4 s.

The temperature and the humidity were intentionally changed during the experiment since robustness against temperature and humidity changes was also studied. Changing the air conditioner mode (DRY/COOL) caused 2.5°C of the temperature change and 20% of the humidity change during the experiment.

The experimental result is shown in Figure 3a,b. The solid and dashed lines are the concentrations of the component odors in the target odor and plots are the recorded concentrations of the component odors. Since the recorded concentrations of each component odor almost agreed with that of the target odor, it was found that the real-time reference method achieves a record of dynamical change of odor even in an environment in which the temperature and the humidity changed, as is shown in Figure 3b.

Conclusion

A record of the dynamical change of the odor was successfully made. The real-time reference method can be speeded up when the blended odor is measured simultaneously with the target odor using the same two sensor arrays. Furthermore, recording the dynamical change of odor together with a movie record will be an interesting topic for further study.

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