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Scent Presentation Technique of Pulse Ejection Synchronized with Breathing

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Abstract

Trials on the transmission of olfactory information together with audio/visual information are currently being conducted in the field of multimedia. However, continuous emission of odor creates problems of human adaptation to the lingering olfactory stimuli. To overcome such a problem we developed an olfactory display. This display has high emission control so that it can provide stable pulse emission of scents. We previously proposed two scent presentation methods synchronized with the user's breathing pattern. The first method presents smell using a breath sensor. The second method presents smell using the ejection interval Δt*, determined by the olfactory characteristics. The results of evaluation experiments and a questionnaire survey of users revealed the proposed methods provide a continuous sense of smell to the user, avoiding adaptation.*

1. Introduction

Information transmission and communication tends to be limited to visual information and audio information. However, transmission of information via all five senses (sight, hearing, touch, smell and taste) has lately attracted much attention [1]. The sense of smell powerfully affects humans since olfactory information is directly transmitted to the cerebral limbic system that governs emotions. Although we receive less information through the nose than through the eyes or ears, olfactory information has a major influence on how we feel. Therefore, olfactory information is expected to further enrich communication media.

However, problems exist in the amount of scent that is emitted to enhance the multimedia experience: too much scent emitted over a continuous period leaves scent in the air and causes human adaptation to the scent.

In efforts to resolve this problem, and based on the hypothesis that a small amount of ejected scent will present discrete and transient bursts of olfactory stimulation thereby reducing the effect of adaptation, we co-developed an ink-jet olfactory display with Canon Inc. The display realizes high-precision emission control of scent by providing stable pulse emission of scents. Since humans can detect scents only when they inhale, it is important that the timing of scent presentation is synchronized with breathing. Therefore, we have proposed two scent presentation methods of pulse ejection synchronized with the user's breathing.

First, we built an ejection method to emit the scent using a breath sensor for breath synchronization [2]. Next, we created a method to emit the scent based on the ejection interval Δt, determined from consideration of the olfactory characteristics [3]. In this paper, we report the results of demonstrating the two presentation methods at the KEIO TECHNO-MALL 2007 event and of user evaluation by questionnaire survey.

2. Scent Presentation Techniques

In this study, we propose scent presentation techniques matched with the individual breathing patterns of the receivers of the olfactory information. To control olfactory time characteristics, the effect of adaptation caused by lingering scent in the air must be removed as quickly as possible. We therefore use pulse ejection to emit scent for a very short period of time. Such pulse ejection enables the quantity of the ejected scent to be reduced. In a previous experiment, we confirmed that the scent did not remain in the vicinity of the receiver when presented by pulse ejection with the wind velocity above a certain level. In addition, pulse ejection presented in discrete and transient bursts of olfactory stimulation has been shown to reduce the effect of adaptation [3]. We realize stable pulse ejection control by using a developed olfactory display.

When humans breathe in, smell molecules in the air are inhaled. When a smell molecule binds to a receptor organ in the nose, we detect a scent. This is the recognition mechanism of a scent. Therefore, it is important that the timing of scent presentation is synchronized with breathing pattern. To ensure satisfactory recognition of scent, we propose two scent presentation methods synchronizing the emission with the user's breathing pattern.

3. Experiment Device and Conditions

3.1. Olfactory Display

We developed an ink-jet olfactory display in conjunction with Canon Inc. Figure 1 shows the prototype display.

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Figure 1. Olfactory display.

Figure 2. Breath sensor.

The display can set up 3 scent ejection heads. Since each head can store one large tank and 3 small tanks, the display can present, in total, 12 kinds of scents. There are 256 minute holes in the head connected to the large tank and 128 in the head connected to the small tank. The display can emit smell from multiple holes at one time, so the ejection quantity is adaptable to 0-255 (large tank), 0-127 (small tank). Thus, the display can emit scent by several picoliters. In this study, we use only one large tank and always use lavender scent.

Ejection control is possible for a unit of 100 msec. To ensure there is no delay, ejection continuance time is more than 300 msec. Also, the display is equipped with a fan and there are 10 phases of wind velocity control in the range of 0.8-1.8 m/sec. For all experiments, wind velocity was set at 1.8 m/s of the display maximum.

3.2. Presentation Conditions

As the shortest ejection continuance time of the olfactory display is 300 msec and all 20 participants we recruited could detect pulse ejection of 300 msec, we set the pulse ejection to 300 msec in this study.

Next, we defined the smallest ejection quantity of smell that all users can detect as the detection threshold. We measured the detection threshold using the following pair comparison method. The olfactory display presented scented and unscented ejections to each participant, and we instructed the participant to indicate which of the two was the scented ejection. Ejection quantity was decreased until the participant selected the distracter. As a result, the ejection quantity of 300 msec pulse ejection of lavender was set to the maximum detection threshold: 10 of the 256 levels.

4. Proposed Method A: Pulse Ejection Using a Breath Sensor

4.1. Olfactory Ejection System

To match the timing of pulse ejection with breathing, we developed an olfactory ejection system that synchronized with breathing. We call the method to present pulse ejection using this system as proposed method A.

The user wearing a breath sensor sits in front of the olfactory display and is presented with scent synchronized with his/her breathing cycle. The breath sensor (Figure 2) we developed senses temperature change in air breathed through the nose. The system acquires the user's breath data via the breath sensor and transfers the value to a computer. The data transfer rate is 10 samples/sec. The computer runs a program to monitor the breath data constantly and to detect the beginning of inspiration. When the program judges the beginning of inspiration, a signal of scent presentation is sent to the olfactory display, which then presents scent to the user. The above process is repeated during the experiments by the olfactory ejection system.

4.2. Experiment 1: System Verification

For proposed method A, we verified whether the olfactory ejection system detected inspiration and presented scent accurately. 20 participants (17 men, 3 women, in their 20s) participated in the verification experiment. In each experiment, the system monitored about 10 cycles of the participant's breath and presented pulse ejection of scent at the beginning of each inspiration. We asked participants to click a mouse button when they began to inhale. After the experiment, we compared the timing of scent presentation with that of clicking the mouse button. From the result we verified the performance of olfactory ejection system by judging whether the scent presentation was synchronized with the beginning of inspiration. Each participant performed this experiment two times. We defined the following two values and calculated them.

$$Detection\ rate = NSDC \div NPI \times 100 \quad (1)$$

$$False\ detection\ rate = NSDW \div TNSD \times 100 \quad (2)$$

$NSDC$: $Number\ of\ times\ system\ detected\ correctly$
NPI : $Number\ of\ participant's\ inspiration$
$NSDW$: $Number\ of\ times\ system\ detected\ wrongly$
$TNSD$: $Total\ number\ of\ times\ system\ detected$

The detection rate of this system was 93.9%, and the false detection rate was 11.3%. As a result, we confirmed that proposed method A could detect the beginning of inspiration with a probability of more than 90% and present scent synchronized with breathing.

5. Proposed Method B: Pulse Ejection Using Interval Δt

Section 4 described a scent presentation technique using a breath sensor, but it is not always practical to use such a sensor during scent presentation. We therefore propose presentation method B, which provides the user a continuous sense of smell without using a breath sensor. A pulse ejection needs to be presented at every inspiration in order to provide a continuous sense of smell. Therefore, we decide the ejection interval time Δt for the emission of scent at every inspiration. Thus, we measured the human olfactory characteristics for pulse ejection.

5.1. Experiment 2: Effective Area in Inspiration

An earlier study confirmed that users can not detect a scent at the end of inspiration [3]. Therefore, it is necessary to examine the detection range during inspiration to avoid wasteful olfactory ejection. We defined the limiting point and the effective area as follows, and then determined the end of the range. The limiting point is the latest time that the user can detect scent. The effective area is the time range between the start of inspiration and the limiting point.

We measured the effective area of 15 participants (14 men, 1 woman, in their 20s). Pulse ejection of scent was presented with the breath sensor for synchronization. Participants responded when they detected a scent, then the start time of ejection changed incrementally every 100 msec. The average limiting point was 66.7% of inspiration length, with a standard deviation of 3.15, where small individual differences were observed. The effective area therefore ranges from the start of inspiration to 66.7% of inspiration duration.

5.2. Deciding the Ejection Interval

Since the aim was to provide the user a continuous sense of smell, the scent had to be emitted during the effective area of each inspiration. From the result of Experiment 2, the ejection interval Δt was decided so that one ejection was made in the effective area.

A typical person inhales for an average of 2 sec at rest [4]. Therefore, ejection interval Δt was decided so that the user could detect a scent in any timing of inspiration. From the result that the effective area was 66.7% of average inspiration duration of 2 sec, Δt was calculated as 1.3 sec.

6. Comparison of Ejection Methods

We compared the total ejection quantity of three ejection methods (Figure 3): the conventional method, proposed method A, and proposed method B.

We acquired data for 50 breathing cycles for each participant, and calculated the total ejection time and the probability of emission in the effective area for each ejection method. Table 1 shows the mean values for 10 participants (10 men, in their 20s). Scent was emitted in each effective area of inspiration with a probability of 94% in proposed method A, and with that of 98% in proposed method B. Thus both of the proposed methods enable the user to detect scent on almost every breath. In addition, total ejection time was decreased by about 90% in proposed method A, and by about 80% in proposed method B compared to the conventional method. Thus, the proposed methods utilizing pulse ejections dramatically reduce the ejection quantity of scent while the users have a continuous sense of smell.

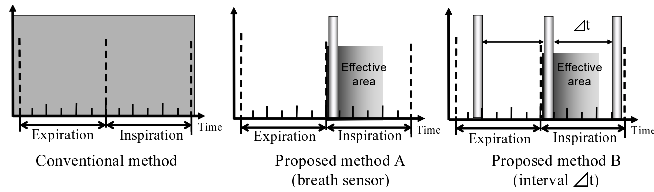

Figure 3. Comparison of 3 ejection methods.

Table 1. Comparison of 3 ejection methods: Total ejection time(X), probability emitted in effective area(Y)

Ejection method	X (sec)	Y (%)
Conventional method	272	100
Proposed method A(breath sensor)	15	94
Proposed method B(interval Δt)	47	98

7. Demonstration

We demonstrated our scent presentation method at the KEIO TECHNO-MALL 2007 event on December 5, 2007. We had 22 visitors (16 men, 6 women, in their 20s to 60s) participate in the experience of scent presentation through both proposed methods (A and B), and then carried out a questionnaire survey to investigate their impressions of use.

In the demonstration, participants first smelled a scent that was emitted by proposed method A, wearing the breath sensor. Next, they took off the breath sensor and smelled a scent by proposed method B. After the experience, each participant was asked to answer the following 3 questions.

1) What did you notice about each scent presented by the two ejection methods?
   ① Noticed continuously
   ② Noticed on every breath
   ③ Noticed that the density alternated between strong and weak
   ④ Noticed that the density gradually got stronger
   ⑤ Noticed that the density gradually got weaker
   ⑥ Noticed it in fragments
   ⑦ Couldn't continue noticing it
2) How did you feel about wearing the breath sensor? (multiple selections)

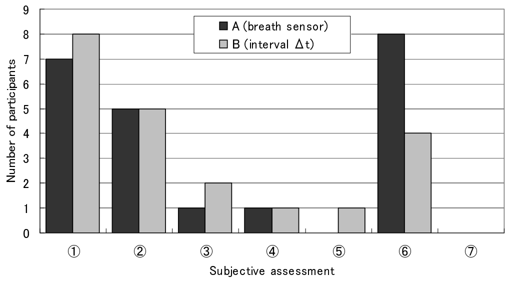

Figure 4. The recognition of scent.

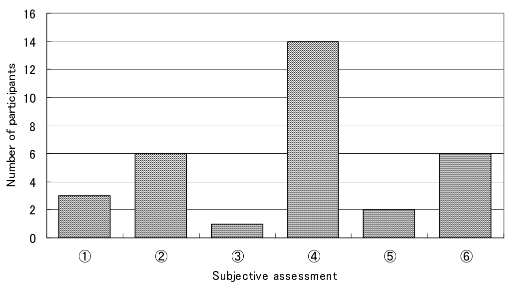

Figure 5. Feelings about wearing the breath sensor.

① Felt it looked OK
② Felt it looked bad
③ Felt it was comfortable
④ Felt it was uncomfortable
⑤ Felt that it was easy to wear
⑥ Felt that it was difficult to wear

3) Which did you prefer, proposed method A or B?

The questionnaire results for Question 1 are shown in Figure 4. For both the proposed methods A and B, the result shows that many participants noticed the scent continuously (①) or on every breath (②). Some participants noticed the presentation of the scent as a continuous emission despite the pulse ejection. These answers are exactly what we aimed at. On the other hand, many participants said they noticed the scent in fragments (⑥). We think the main reason for this is that participants could not detect scent during expiration. Such answers were commonly observed for proposed method A, which we believe is due to the fact that there were some cases when scent was not present because the olfactory ejection system failed to detect inspiration.

It should be noted that there were no participants who could not continue perceiving the scent (⑦), indicating the presentation of pulse ejection synchronized with breathing, regardless of the ejection method, could provide the participants with a continuous sense of smell, avoiding adaptation.

Figure 5 shows the questionnaire result for Question 2. It revealed that most participants felt it was uncomfortable to wear (④). Also, there were some who felt it looked bad (②) or that it was difficult to wear (⑥). Overall, the result of Question 2 showed that there were many negative comments about wearing the breath sensor. However, a few participants responded that it looked fine (①) or that it was easy to wear (⑤). From this result, we found that there were some people who recognized the novelty and usability of the breath sensor, although the number was small.

From the result of Question 3, it was found that 86% of participants preferred proposed method B. Meanwhile, some participants who responded that it looked OK (①) or that it was easy to wear (⑤) tended to prefer proposed method A.

8. Conclusion

In this study, we developed an ink-jet olfactory display that has precise emission control. Since the scent is emitted for very short periods of time during pulse ejection, the timing of presentation is important. Therefore, we proposed two scent presentation methods synchronized with the user's breathing: proposed method A using the breath sensor and proposed method B using the ejection interval Δt.

The result of the comparison of various ejection patterns showed that both of the proposed methods could emit scent in the effective area of each inspiration with high probability. It also revealed that such methods enabled the ejection quantity of scent to be reduced, compared to the consecutive ejection method. Next, we held a demonstration. Most participants stated via the questionnaire that they could notice the scent continuously or on every breath, irrespective of the proposed methods of A and B. There were no participants who could not continue perceiving the scent, thus indicating adaptation did not occur. There were negative comments about wearing the breath sensor, and over 80% of participants preferred proposed method B to A. Therefore, proposed method B is an effective means to avoid use of the breath sensor which is seen as problematic by some users.

Acknowledgment

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