Pulse Ejection Technique of Scent to Create Dynamic Perspective

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Abstract

For transmitting scent together with other media, it is necessary to control the presentation of scent in accordance with changes in images/sounds over time. In movie scenes especially, it is thought that the sense of realism is enhanced by delivering scent adapted to specific images. However, it was previously impossible to express the 'movement' of scent (such as gradually fading away or appearing) since the inability to precisely control scent emission led to scent lingering in the air, causing adaptation to the scent. Therefore, we approached such a problem by using pulse ejection which emits scent for just a very short period of time. We measured human olfactory characteristics for the pulse ejection technique by subjective assessments in order to develop a scent presentation technique that would create a dynamic perspective of scent that could be synchronized with changes in specific images/sounds. Experimental results revealed that receivers reported feeling a dynamic perspective of scent when the ejection quantity of scent was increased(or decreased) stepwise logarithmically. It is expected that the presentation of scent using the proposed method when transmitted together with images/sounds will make the synchronization between media easier.

1. Introduction

Information transmission and communication tends to be limited to visual information and audio information. However, the transmission of information via all five senses (sight, hearing, touch, smell and taste) has lately attracted much attention [1]. Olfactory information recognized by the olfactory organs differs from the information recognized via the other four senses. The sense of smell powerfully affects humans since olfactory information is directly transmitted to the cerebral limbic system that governs emotions. In addition, olfactory information has high importance since it is thought that the presentation of olfactory information is effective as a means to enhance the sense of reality like three-dimensional vision and sound [2]. Therefore trials on the transmission of olfactory information together with that of audio/visual information are currently being conducted in the field of multimedia.

For transmitting scent together with other media, it is necessary to control the presentation of scent in accordance with the changes in images/sounds over time. In movie scenes especially, it is thought that realistic sensation is increased by delivering scent adapted to the specific images being viewed. This study presents a presentation technique of scent that enables the receivers to feel a dynamic change in the perception of scent in accordance with the changes in images/sounds over time.

However, problems exist with regard to the amount of scent that is emitted to enhance the multimedia experience using current techniques. Too much scent emitted over a continuous period leaves scent in the air and causes human adaptation to the scent, and thus, the goal of olfactory information transmission is not reflected in the actual human response. Such a problem means that the conventional presentation technique of scent cannot be changed in accordance with changes in images/sounds over time. The receivers would merely perceive a scent that does not change or correspond to changing events.

To resolve this problem, and based on the hypothesis that a small amount of ejected scent presents discrete and transient bursts of olfactory stimulation thereby reducing the effect of adaptation [3], 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. In general, it is known that humans can detect scents only when they inhale. So, in order to use pulse ejection, it is important that the timing of scent presentation is synchronized with breathing [4]. Therefore, we developed a breath sensor for breath synchronization [5] which we used for presenting the pulse ejection upon each inspiration. The human olfactory characteristics for pulse ejection were then measured to develop a presentation technique of scent such that the receivers can feel a dynamic perspective that changes stepwise in accordance with changes in images/sounds over time. The utility of the developed method was evaluated and its potential application in the multimedia filed is discussed.

2. Related Work

Trials on the transmission of olfactory information together with audio/visual information are currently being conducted. Work first started in the 1950s when Heilig developed Sensorama [6], the first virtual reality (VR) system that presented olfactory information together with audio/visual information. The recently developed virtual space system, Friend Park [7], provides users with an increased sense of reality by generating the aroma of a virtual object or environment, where the aroma is defined as the area in which a scent can be perceived. Kaye's article [8] describes some systems that add scent to web content, and computer controlled olfactory displays such as iSmell [9] and Osmooze [10] are utilized in these systems. Another type of display, the air cannon olfactory display that generates toroidal vortices of scent in order to present it in restricted space, has been proposed in [11].

Nakamoto et al. [12] designed a smell synthesis device that presents the scent of a virtual object remotely. The system analyzes the smell to be transmitted and presents the analyzed data as the composition ratio of the scent elements. On the receiver side, a feedback control changes the ratio of the scent elements owned by the receiver to reproduce the target scent.

A wearable olfactory display with a position sensor has also been developed [13]. By controlling the density of odor molecules, it can present the spatiality of olfaction in an outdoor environment. The olfactory information transmitting system consists of the aforementioned display, a sensing system using three gas sensors, and matching database. The user can experience a real sense of smell through the system by translating obtained olfactory information.

AROMA [14] tries to introduce the olfactory modality as a potential alternative to the visual and auditory modalities for messaging notifications. Experimental findings indicate that while the olfactory modality was less effective in delivering notifications than the other modalities, it had a less disruptive effect on user engagement in the primary task.

The addition of a scent to image media such as movies has been proposed by a number of researchers. Okada et al. [15] measured the viewer's mental state by his/her brainwaves, and analyzed the relation between the scent and the viewer's feelings while watching. A movie that adds olfactory information to the visual/audio information has been created, but because the synthetic perfume did not accord with the image and the scent was not deodorized, the movie could not be widely distributed.

3. Characteristics of Olfaction

3.1. Olfactory Threshold

The olfactory threshold is the value used as a standard to express the strength and weakness of a scent. Three kinds of values are generally used for the olfactory threshold: the detection threshold, the recognition threshold, and the differential threshold [16], usually expressed in units of mol (concentration) and mass percentage.

The detection threshold is the smallest density at which scent can be detected and where the user does not need to recognize the kind of a smell. The recognition threshold is the smallest density at which the kind of scent can be recognized, and its value reflects the ability of the user to express quality and characteristics of the scent. The differential threshold is the density at which the user can distinguish the strength of a scent, where its value reflects the ability of the user to detect changes in the stimulus and to quantify the change. Generally such changes are expressed as the % change of stimulation quantity of the original. In the case of olfaction, it differs with different kinds of scent, but is in the range of about 13-33%.

3.2. Adaptation

Adaptation is the phenomenon where sensory nerve activity is decreased by continuous smell stimulation. Adaptation itself and the speed of recovery from adaptation differ with different kinds of scent. Adaptation is gradually strengthened over time but is restored for a short time (3-5 minutes) by eliminating the scent.

In addition, there are various patterns of adaptation, influenced by the kind of scent and recognition factors.

4. Pulse Ejection Technique of Scent to Create Dynamic Perspective

In this study, we propose scent presentation techniques to create a dynamic perspective for the multimedia viewer. The conventional olfactory presentation method continues emitting scent at high density for a long time. In other words the finely-tuned control of the ejection of scent from one second to another is not accomplished. As such, this presentation method creates various problems of olfactory adaptation and scent lingering in the air, and it is therefore impossible to create a dynamic perspective with scent under such conditions. For example, for visual information using the zoom function of the camera, and for audio information using volume adjustment, we can create a dynamic perspective easily(Figure 1). However, even if the transmitter in scent media presents scent in a method similar to that used for images and sounds(Figure 1-①), the receiver does not actually sense this, as shown in Figure 1-③. For our current purposes of developing a multimedia transmis-

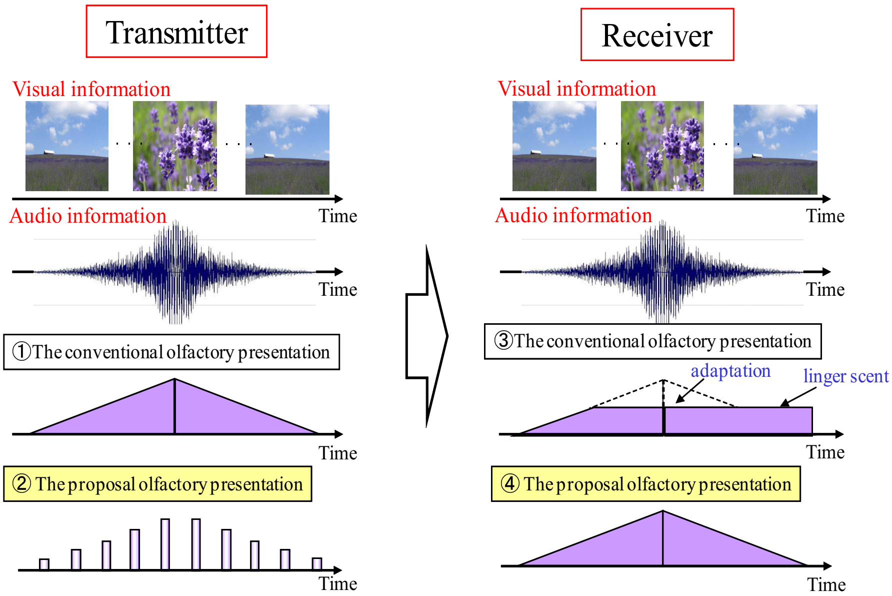

Figure 1. Image of proposal method

sion system for scent alongside visual/audio information, we must overcome olfactory adaptation and scent lingering in the air.

In this study, we developed a scent presentation technique (Figure 1-②) to create the dynamic perspective synchronized with changes in images/sounds where, using pulse ejection, scent was emitted for just very short periods of time. The x axis of Figure 1 shows time, and the vertical axis shows quantity of ejection. In a previous experiment, we confirmed that scent did not remain in the vicinity of the receiver when presented by pulse ejection with the wind velocity above a certain level [17]. In addition, pulse ejection presented in discrete and transient bursts of olfactory stimulation has been shown to reduce the effect of adaptation [3].

However, it is important to synchronize the presentation of olfactory stimuli with breathing pattern, because pulse ejection represents only a very short presentation of scent. In general, it is known that humans can detect scents only when they inhale [18]. So, in order to use pulse ejection, it is important that the timing of scent presentation is synchronized with breathing [4]. Therefore, in the proposed technique, pulse ejection is presented by an ejection method synchronized with the user's breathing, using a breath sensor and taking into account human olfactory characteristics. In order to develop the scent presentation technique to create a dynamic perspective when synchronized with changes in images/sounds, we must consider carefully the olfactory characteristics of humans in relation to pulse ejection. However, to date, as comparatively little information has emerged concerning such characteristics, we first examined these characteristics.

Figure 2. Olfactory display

5. Olfactory Presentation System

5.1. Olfactory Display

We developed an olfactory display in conjunction with Canon Inc. Figure 2 shows the prototype olfactory display. This display is ink-jet in order to produce a jet which is broken into droplets from the small hole in the ink tank.

Figure 3 shows the olfactory display in ground plan. 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 utilizing 3 large tanks and 9 small tanks. There are 256 minute holes in the head connected to the large tank and 127 in the head connected to the small tank. Moreover, the display can emit scent from multiple holes at one time, so the ejection quantity is adaptable to 1-256 (large tank), 1-127 (small tank). We denote

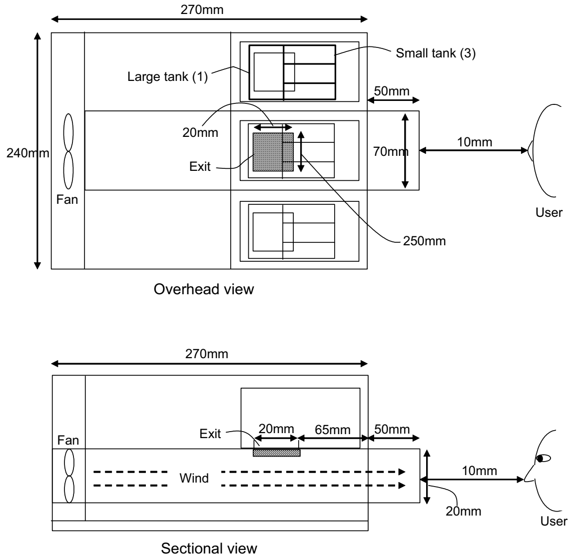

Figure 3. Plain view of the olfactory display

Figure 4. Use of the olfactory display

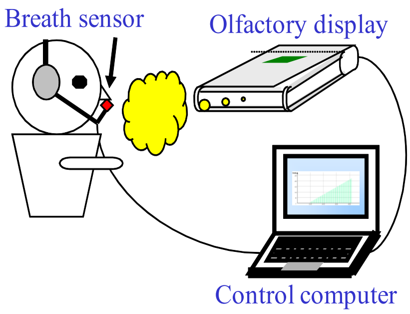

Figure 5. Conceptual diagram of the breath sensor system

the average ejection quantity from each minute hole as the "unit average ejection quantity (UAEQ)", and the number of minute holes emitting at one time as "the number of simultaneous ejections (NSE)".

The unit average ejection quantity from two small tanks is 4.7 pl for lavender scent and 3.7 pl for lemon scent. Examination at Canon Inc confirmed the quantity to be approximately constant without depending on the residual quantity of ink. In addition, the user can set the number of ejection times from one hole in 100 msec to 1-150 times, which we denote the "volume". In this study, we use two small tank and always set the volume to 150 times. Therefore, the ejection quantity (EQ) is calculated as follows.

$$EQ\ (pl) = 4.7 or 3.7\ (pl : UAEQ) \times 1 - 127\ (NSE) \times 150\ (times : Volume) \quad (1)$$

The scent is diluted by 5% with ethanol and water.

$$Scent\ quantity\ (pl) = EQ\ (pl) \times 0.05 \quad (2)$$

Ejection control is possible for a unit of 100 msec. Also, the display is equipped with a fan and there are 10 phases of wind velocity control in the range of 0.8 m/sec-1.8 m/sec. The scent presentation hole is a rectangle of 2 cm length and 24 cm width.

Figure 4 is a photograph showing the use of the olfactory display. The user places the chin on the chin rest, fixing the distance from the olfactory ejection point to the nose at 10 cm.

5.2. Olfactory Ejection with Breathing Synchronization

When we inhale, as already mentioned, we detect scent molecules. To match the timing of pulse ejection with breathing, we developed an olfactory ejection system that synchronized with breathing [5]. Figure 5 shows a schematic of the system.

The user wearing a breath sensor sits in front of the olfactory display and is presented with scent. The system acquires the user's breath data via the breath sensor and transfers the value to a control computer. The control computer runs a program to monitor breath data constantly and to detect the beginning of inspiration. At the point 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 represents the process of smell presentation by the olfactory ejection system. Characteristics such as breathing intervals differ from person to person, and each user must therefore calibrate the breathing sensor before use.

6. Experiment

As the shortest ejection continuance time of the olfactory display is 100 msec and this olfactory display can stably present a scent, we assumed a pulse ejection of 100 msec in the present study. Using this olfactory display it is possible to control 127 phases of ejection quantity. The experiment was conducted using 100 msec pulse ejections of lavender scent and lemon scent.

6.1. Preliminary Experiment

6.1.1 Detection Threshold

The experiment to determine the detection threshold was conducted using 100 msec pulse ejections of lavender scent and lemon scent with 6 participants. Olfactory ejection was synchronized with the timing of breathing of each participant. The participants were instructed to respond when they detected a scent. With the following pair comparison method [19], we measured the detection threshold of the scent. 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. Two kinds of scent were emitted in turn in order to avoid the problem of adaptation, which occurs when smelling the same scent successively.

As a result, the average detection threshold of 6 participants was an ejection quantity of 24 of the 127 phases of lavender scent and of 19 of the 127 phases of lemon scent.

6.1.2 Comparison of the perceived intensity of scent

It is known that the perceived intensity of a stimulus is proportional to the logarithm of the physical magnitude of stimulus [20]. An olfactory stimulus is no exception. So, ejection quantity of lavender scent and lemon scent was increased stepwise on a logarithmic scale, and we measured whether the perceived intensities of lavender and lemon scents were the same at each the ejection quantity.

Ejection level 1 was set to the ejection quantity of the detection threshold determined in the earlier experiment described in 6.1.1, and the ejection levels were increased stepwise logarithmically from ejection level 1 in three levels (Table1). Then, we determined the difference between each participant's perceptions of the intensities of the lavender and lemon scents at each the ejection levels using the pair comparison method [21]. In this experiment, two pulse ejections of two kinds of scent were presented per inspiration, and the participant rated the intensity of the two kinds of scent on a scale of -2 to +2, as shown in Table 2. Order and the ejection level of the ejection of two kinds of scent were set at random.

Ten participants participated for a total of six trials (lavender 1 (level) - lemon 1 (level), lavender 2 - lemon 2, lavender 3 - lemon 3, and 3 trials of the reverse order). Table 3 shows the average score of the scent intensity for each ejection level. The results show that the intensity of two kinds of scent is perceived as approximately equal; the evaluation point of the intensity of the two kinds of scent is almost 0. In addition, there was little difference between individuals since the standard deviation was small. We thus confirmed that the perceived intensities of lavender and lemon scents are about the same, and the ejection quantity was set as shown in Table 1.

Table 1. Ejection quantity (in 127 phases) of each scent toward the ejection level

Ejection Level	lavender	lemon
1	24	19
2	48	38
3	96	76

Table 2. Intensity scores for the two kinds of scent emitted

Score	Judgment of the intensity
+2	Former is considerably stronger than next
+1	Former is slightly stronger than next
0	Intensity of former is the as same as that of next
-1	Former is slightly weaker than next
-2	Former is considerably weaker than next

Table 3. Average intensity of scent score(standard deviation)

scent	level 1	level 2	level 3
lavender	0.25 (0.35)	0.15 (0.53)	-0.20 (0.48)
lemon	-0.25 (0.35)	-0.15 (0.53)	0.20 (0.48)

6.2. Experiment 1: Measurement of the quantity of pulse ejection to create perspectives of distance and proximity

Since the purpose of this study was to develop a scent presentation technique to create a dynamic perspective synchronized with changes in images/sounds, we first measured the quantity of pulse ejection that could create the static perspectives of distance and proximity, that is ”far” and ”near”.

In this experiment, two pulse ejections of two kinds of scent were presented on one inspiration. The pair of fragrances were used for all combinations (a total of 18 trials) of the three ejection levels (Table 1). The participant was instructed to choose one image most fitting to how he or she felt about the fragrances from four images (Figure 6). The four images shown in Figure 6 were combinations of the image in which lavender appears in the distance or in close proximity and the image in which lemon appears in the distance or in close proximity. The order and the ejection level of the two kinds of scent were presented randomly.

Figure 6. Image selection for the participant

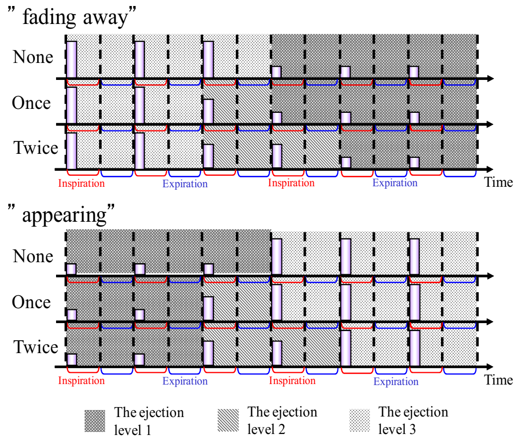

Figure 7. Method for creating a dynamic perspective using a breath sensor

Twenty subjects participated in a total of 18 trials for each combination of order and ejection level of scent emitted. As a result, all of the participants chose the "far" image when they smelled a scent at ejection level 1, and all of the participants chose the "near" image when they smelled a scent at ejection level 3. Thus, scent presented at ejection level 1 givean impression of distance while that presented at ejection level 3 gives an impression of proximity. In contrast, at ejection level 2, there was variation in the participants' choices, suggesting that ejection level 2 gives an impression of "middle distance".

6.3. Experiment 2: Presentation technique of creating a dynamic perspective using a breath sensor

In Experiment 1, we decided upon the quantity of pulse ejection needed to create a static perspective of distance and proximity. In this next experiment, we examined the effectiveness of the pulse ejection technique to create a dynamic perspective, with a fragrance "gradually fading away" and "gradually appearing". In this experiment, we tried to created the dynamic perspective during six breathing cycles. As already mentioned, when we inhale, we detect scent molecules [18]. In this experiment, for breath synchronization, olfactory presentation was controlled using a breath sensor, as explained in section 5.2. One pulse ejection occurred for each inspiration of the six breathing cycles. Then, we developed six kinds of pulse ejection scent presentation techniques, as shown in Figure 7. Ejection level 2 was changed between 0-2 times to indicate each event of "gradually fading away" and "gradually appearing". Also, the rest of the number of ejection allotted the number of times of ejection level 1 and level 3 equally. Each participant was presented at random with the six different kinds of presentation technique for each of the two kinds of scent, and was instructed to choose the most suitable item from seven evaluation items as follows.

①The fragrance has suddenly gone

②The fragrance is gradually fading away

③ There was no change in feeling the scent was "far" or "near"

④ The fragrance is gradually appearing

⑤ The fragrance has suddenly appeared

⑥ The fragrance irregularly changed from feeling "far" or "near"

⑦ There was no fragrance since the middle point

We defined that a presentation technique that would create a dynamic perspective would not to result in the receivers feeling a fragrance "has suddenly gone away" or "suddenly appeared", but rather resulted in them feeling it "is gradually fading away" or "is gradually appearing". Therefore, we determined that the presentation techniques required to create a dynamic perspective is the ejection method with the most number of the answers for ② and ④.

Twenty-two subjects participated in a total of 12 trials for each presentation technique and kind of scent. Figure 8 shows the number of the answers for ② for three kinds of scent presentation techniques to create the impression of "gradually fading away". Similarly, Figure 9 shows the number of answers for ④ for three kinds of scent presentation techniques to create the impression of "gradually appearing". As can be seen from these two figures, 90% of the answers related to the presentation technique of 2 times at ejection level 2 and has the highest number of answers for the three kinds of presentation techniques. The results of Experiment 2 indicate that the receivers could feel a dynamic perspective when the ejection quantity of scent was increased or decreased stepwise logarithmically.

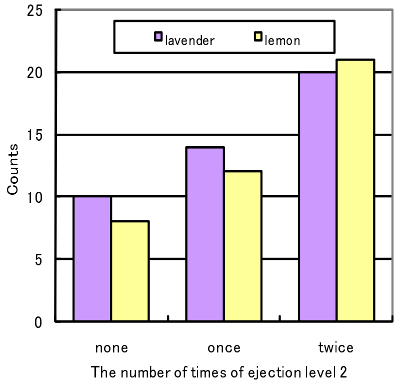

Figure 8. Sensory perception differences for different numbers of level 2 ejections for (② The fragrance is gradually fading away)

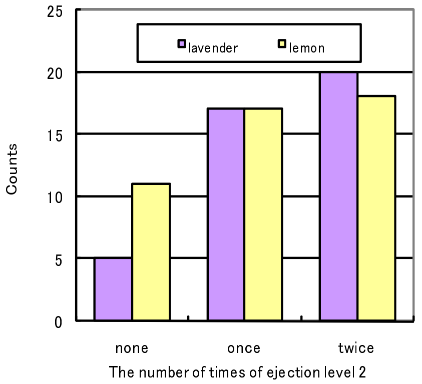

Figure 9. Sensory perception differences for different numbers of level 2 ejections for (④ The fragrance is gradually appearing)

6.4. Experiment 3: Presentation technique of creating a dynamic perspective without using a breath sensor

In Section 6.3, we described a successful scent presentation technique using a breath sensor: however, it is not always practical to use such a sensor during scent presentation. In this section, we therefore propose a different presentation method for creating a dynamic perspective of smell without using a breath sensor.

In our previous study, receivers could detect a scent at any timing of inspiration when scent was ejected in 1.3 sec intervals [3]. It is known that one breath cycle at rest in able-bodied people takes about 5 seconds. In this experiment, to allow the receivers to sense a fragrance between six breath cycles, scent was ejected at intervals of 1.3 sec over a 30 second period. In Section 6.3, it was revealed that presentation 2 times of ejection level 2 is suitable for creating a dynamic perspective during six breath cycles when

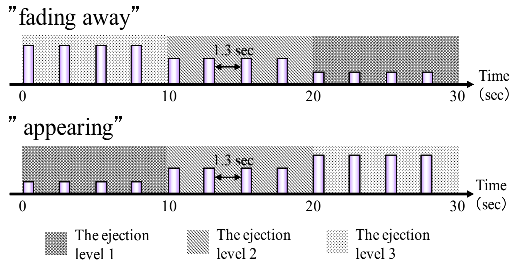

Figure 10. Method of creating a dynamic perspective using human olfactory characteristics

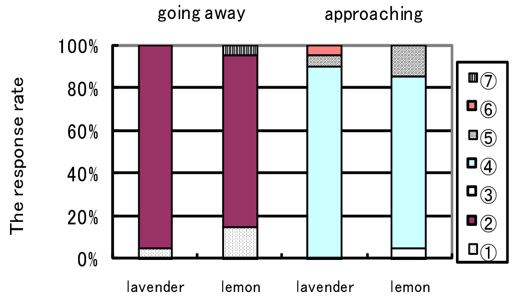

Figure 11. Response weighting toward creating a dynamic perspective using olfactory characteristics

using a breath sensor. Therefore, we developed a technique to present the pulse ejection at ejection level 2 between 10-20 seconds, as shown in Figure 10, in order to match the presentation technique of 2 times of ejection level 2 used in Experiment 2.

Twenty subjects participated in a total of 8 trials for each presentation technique and kind of scent. The presentation techniques is two presentation methods as shown in Figure 10 and an ejection method of uniform density, and an ejection method of uncertain density. During the randomly presented eight kinds of presentation technique for each of the two kinds of scent, the participant chose the most suitable item from seven evaluation items.

Figure 11 shows the results of Experiment 3. When scent was presented by the developed method, 80-95% of the participants chose "② The fragrance is gradually fading away" and "④ The fragrance is gradually approaching" Thus, we have developed a presentation method without the need for a breathing sensor that enables users to feel the dynamic perspective of scent.

7. Conclusion

For transmitting scent together with other media, it is necessary to control the presentation of scent in accordance with changes in images/sounds over time. This requires resolution of the problem of scent remaining in space that results in adaptation. Therefore, we approached the problem using pulse ejection which emitted scent for just very short periods of time. In this study, we confirmed that a user could feel the dynamic perspective of scent. The experimental results revealed that the receivers could feel such a dynamic perspective when the ejection quantity was increased logarithmically. In addition, they could feel the dynamic perspective when the ejection quantity was increased stepwise logarithmically. Our developed pulse ejection technique of scent which was determined based on a study of human olfactory characteristics for pulse ejection, enabled about 90% of participants to feel the dynamic perspective of scent.

It is expected that the presentation of scent using the proposed method when transmitted together with images/sounds will make the synchronization between media easier.

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References

[1] Ministry of Posts and Telecommunications in Japan. *Reports of the Association for Information and Communications Technology Using Five Senses* (in Japanese), 2007. 1

[2] Hirose M. Fragrance Journal Ltd., 2007. *Aroma Science Series 21 Smell Information and Communication*(in Japanese), 1

[3] Kadowaki A., Sato J., Bannnai Y., Okada K. Presentation Technique of Scent to Avoid Olfactory Adaptation. *Proc. of ICAT2007*, pp97-104, 2007. 1, 3, 7

[4] Tonoike T. Recording and analysis of olfactory evoked potentials on the human scalp. *Summaries of Reports of the Electrotechnical Laboratory 863* (in Japanese), pp.1-76, 1968. 1, 3

[5] Kadowaki A., Ishizawa M., Okada K., Effective smell emission method for synchronizing it with breath. *Information and Communication Engineers IEICE Technical Report Vol.11 No.2* (in Japanese), pp. 35-40, 2006. 1, 4

[6] Retrofuture: Sensorama's pre-virtual reality. http://www.retrofuture.com/sensorama.html 2

[7] Shigeno H., Honda S., Osawa T., Nagano Y., Okada K. and Matsushita Y. A virtual space expressed the scent and wind -A virtual space system "Friend Park". *Journal of Information Processing Society of Japan* (in Japanese), Vol. 42, No. 7, pp. 1922-1932, 2001. 2

[8] Kaye J. Making Scents: aromatic output for HCI. *Interactions Vol.11 No.1* pp. 48–61, 2004. 2

[9] D. A. Washburn, L. M. Jones, R. V. Satya, C. A. Bowers, A. Cortes, Olfactory Use in Virtual Environment Training. *Modeling and Simulation Magazine, 2, No.3*, 2004. 2

[10] http://www.osmooze.com/osmooze/osmooshop_gb.html 2

[11] Yanagida Y., Noma H., Tetsutani N., and Tomono A. An unencumbering, localized olfactory display. *CHI '03 Extended abstracts*, pp. 988–989, 2003. 2

[12] Nakamoto T., Nakahira Y., Hiramatsu H. and Moriizumi T. Odor recorder using active odor sensing system, *Sensors and Actuators B*, 76 pp. 465–469, 2001. 2

[13] Yokoyama S., Tanikawa T., Hirota K. and Hirose M.: Olfactory field simulation using wearable olfactory display, *Tans. of Virtual Reality Society of Japan* (in Japanese), Vol. 9, No. 3, pp. 265-274, (2004). http://www.cyber.rcast.u-tokyo.ac.jp/project/nioi_e.html. 2

[14] Bodnar A., Corbett R., Nekrasovski D. AROMA: Ambient awareness through olfaction in a messaging application. *ICMI '04 Proceedings*, pp. 183- 190, 2004. 2

[15] Okada K., Aiba S. Toward the actualization of broadcasting service with smell information. *Institute of Image information and Television Engineering of Japan Technical Report*(in Japanese), Vol. 27, No. 64, pp. 31-34, 2003. 2

[16] A term and a commentary of a odor(in Japanese) Odor Control Association of Japan, 2003. 2

[17] Kadowaki A., Sato J., Bannai Y., Okada K. Measurement and modeling of olfactory responses to pulse ejection of odors. *Japan Association on Odor Environment Vol.39 No.1* (in Japanese), pp. 36-43, 2008. 3

[18] Shibuya T, Tonoike T. *Aroma Science Series 21 Odor Receptor*(in Japanese), Fragrance Journal Ltd., 2002. 3, 6

[19] Japan Association on Odor Environment *Odor Simplified Measurement Guidebook*(in Japanese), 2005 5

[20] Kawasaki T., Nakajima M., Tonoike T. *Aroma Science Series 21 6*, Fragrance Journal Ltd., 2003 5

[21] Ohnishi S., Kurioka Y., Okabayashi Y., Kawasaki T., Takashima Y. Analysis on the odor intensity using the paired compariosn method. *The Japanese journal of taste and smell research* (in Japanese), pp.109-112, 1991 5