5-2 Aroma that Enhance the Reality of Visual Images

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When a large display produces images and the sound effects matching those images, viewers will feel as if actually there in the reproduced scene (given the realistic images). By adding a matching aroma to accompany such images and sound effects, viewers will feel an even more acute sense of reality. To make that reality possible, appropriate aromas matching the images must first be provided. This study demonstrated that: (1) subjects share the same aromas that enhance reality, (2) the names of *contents* of an image allow people to estimate aromatic materials that enhance the reality of that image, and (3) people can identify aromatic materials that enhance the reality of the same *contents* from the "adjectival characteristics." These findings are expected to help general users lacking aroma knowledge to easily select aromatic materials matching a specific image.

Keywords
Method to choose aroma, Aroma characteristics, KANSEI evaluation

1 Introduction

In recent years, the spread of the Internet and advances made in software technology have made it possible for common people to easily prepare, edit and publish images and pieces of music to be enjoyed by others. However, it remains difficult to produce expressions that appeal to the olfactory sense. One reason is that people lacking knowledge about aroma (meaning "good smells") find it difficult to select aromatic materials matching a specific image.

The smells of foods are generally familiar to people (not having a weak sense of smell), and in many cases, one can prepare synthetic aromatic materials infinitely similar to those of the actual things. Consequently, the mere availability of synthetic aromatic materials for foods expressed by images makes it easy to select and present those aromas. Conversely, for images of scenery where nothing emits strong smells and for which remembering a particular smell is difficult, the kinds of suitable aromas are not even known.

We are conducting studies toward proposing a method that enables common persons to select aromatic materials matching a specific image from among existing aromas. With the expected spread of image presentation and stereoscopic acoustic presentation on large displays in the future, the viewers of such projected images will be able to enjoy a surround feeling, a three-dimensional feeling, and other feelings. Our study group collectively expresses such feelings with the term "reality." The more advanced the technology for presenting the visual and auditory senses, the more important the technology for presenting the olfactory sense (aroma) that should be included, in order to enhance reality.

This paper begins by demonstrating that aromas proven to have enhanced the reality of visual images are common among subjects who have seen the associated images. It then shows that specific components of images are useful in estimating aromatic materials that enhance reality, even for images of scenery that

do not readily remind people of particular aromas. Moreover, this paper discusses the "aroma characteristics" suggested as being useful in easily estimating the group of multiple aromatic materials that purportedly enhance reality for the contents of a certain image. These findings are then used to clarify the commonality of aromatic materials that enhance reality among viewers, and properly select from among those aromatic materials based only on the image information presented to viewers.

2 Aromatic materials that enhance the reality of visual images that do not readily remind people of particular aromas

For images of foods and other objects that readily remind people of particular aromas, many people unanimously associate similar kinds of aromatic materials as "aromas that enhance the reality of visual images." This section clarifies whether the aromatic materials that enhance reality are common relative to images representing things that do not readily remind people of particular aromas.

2.1 Experiments

We provided six images that readily remind people of particular aromas and six images that do not. Nine human subjects were then presented with 12 aromatic materials, one at a time, for each of the 12 images mentioned above. The aromatic materials were presented in random order, depending on the image. These subjects were then divided into three categories: those who found the aromatic materials to enhance the reality of visual images, those who found the aromatic materials not to enhance reality, and those who found the aromatic materials did neither[1]. At that time, the subjects could determine all aromatic materials as "aromas that enhance reality" or "aromas that do not enhance reality" for a certain image.

Each image was provided on the assumption that it "readily reminds people of a particular aroma" among images showing roses, milk coffee, cereals, fruits, cream puffs, and soap bubbles. As aromas readily recalled by people from each image, we provided six synthetic aromatic materials—roses, cocoa, milk, tropical, vanilla, and shampoo. Each image was provided on the assumption that it "does not readily remind people of a particular aroma" among images showing the sea, maple leaves, terraced rice fields, binoculars, feathers, and a stationary crystal object. As the remaining six aromas, we provided aromas that people generally find difficult to identify, specifically synthetic aromatic materials (musk, sandalwood and olive) and natural aromatic materials (rosemary, geranium and tea tree).

2.2 Results

We examined whether the aromatic materials that enhance the reality of visual images are common among the subjects based on the number of people who determined the presented aromatic materials as "aromas that enhance reality." As a result, we found that, out of five images assumed "to readily remind people of particular aromas" and four images assumed "not to readily remind people of particular aromas," 12 aromatic materials showed significant differences in the number of people who determined them as "aromas that enhance reality" (the rate of determination) (Cochran's Q test). In other words, aromatic materials relatively common among the subjects were determined as "aromas that enhance reality."

We then also examined whether an aromatic material determined by the most people as "an aroma that enhances reality" in each image accounted for significantly more than half of all aromatic materials. As a result, the images of milk coffee, cereals, and cream puffs were found to account for significantly more than half of the aromatic materials of vanilla, milk, and vanilla, respectively (in a two-item examination).

2.3 Reasons for determination and observations

We asked the subjects why they determined specific aromatic materials as "aromas that enhance reality." For "images that readily remind

people of particular aromas," a predominant majority determined the aromatic materials as "aromas that enhance reality" because each is "an aroma associated with the thing in the image" (46 out of 54 comments). For "images that do not readily remind people of particular aromas," many respondents indicated that it was because the aromas matched the concepts readily evoked by the images, such as "transparency" and "softness" (34 out of 68 comments). Interestingly enough, the second most predominant reason was "aromas of the things shown in the images" (21 comments). The subjects determined the aromatic materials as those that enhance the reality of, for example, an image showing terraced rice fields because the "tree-like aroma" and "soil-like aroma" are those of "trees" and "soil" shown partially in the images.

Matching the concepts readily evoked by an image to those readily evoked by an aroma may produce great differences among individuals. However, the "things included in the image" such as "trees" and "soil" are considered to be recognized almost commonly among individuals as well. These results suggest that even images that do not readily remind people of particular aromas can enhance the reality of images by means of presenting to the subjects aromatic materials that are similar to those of the things partially included in the images shown in Fig. 1.

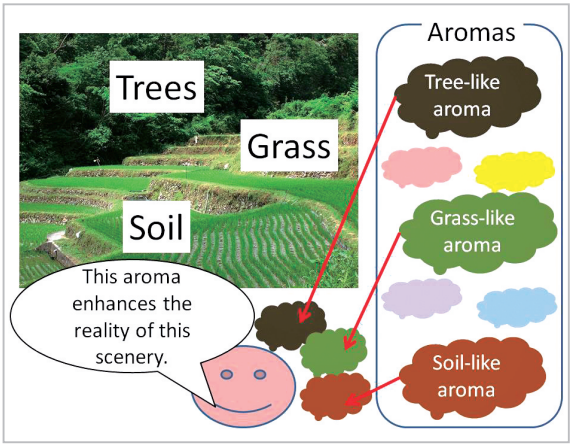

Fig.1 *Aroma and reality of things included in images*
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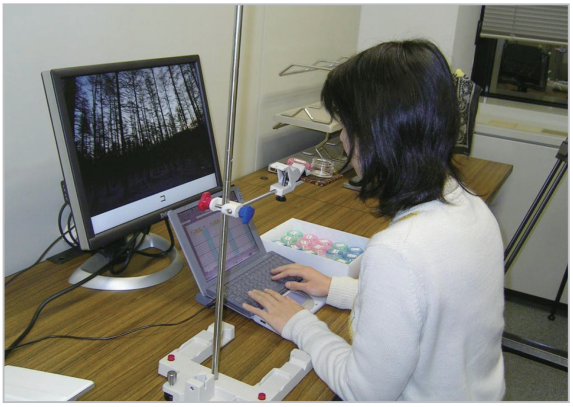

Fig.2 *Experiment in progress*

3 Estimating aromatic materials that enhance reality based on the things in images

Is it possible to estimate the degree to which the reality of an image representing each aromatic material based on words representing the things included in the image can be enhanced? We examined that possibility by using a multiple regression equation[1].

3.1 Experiments

We presented an aromatic material to the subjects while showing 40 images, one at a time (Fig. 2). The subjects were asked to evaluate how much the aromatic material enhanced the reality of each image in five ranks, ranging from 1 (unreasonable) to 5 (realistic). For this experiment, the subjects evaluated a total of 15 aromatic materials. Once these evaluations were completed, the subjects were again shown the 40 images, one at a time, and then asked to state the name of at least one thing they noticed among the things included in each image. There were 21 subjects.

14 out of the 15 aromatic materials were extracted from natural plants. From seven systems used in the classification of aromatic materials, two kinds were provided at a time. The remaining kind is an animal-based synthetic aroma. The 40 images were all represented with those including nature or food, because this experiment used natural aromatic materials. We provided the images while referring to words

Table 1 *Results of multiple regression analysis*

Aromatic material	Lemon	Citronella	Ilang-ilang	Star anise	Peppermint
adjusted R2	0.85792	0.55473	0.88274	0.65084	0.44209
F statistic	0 **	0.02626 *	0 **	0.0041 **	0.10197

Aromatic material	Celery seed	Tee tree	Pine	Benzoin	Galbanum
adjusted R2	0.67588	0.67952	0.71341	0.77032	0.70034
F statistic	0.00217 **	0.00197 **	0.00071 **	0.00008 **	0.00108 **

Aromatic material	Clove	Vanilla	Rose	Lavender	Musk
adjusted R2	0.61083	0.87723	0.84208	0.73079	0.7471
F statistic	0.00983 **	0 **	0 **	0.00039 **	0.00021 **

** denotes $p < 0.01$; * denotes $p < 0.05$.

included in code numbers "0: nature" and "92: foods" in the "System Table of Vocabulary Classifications[2]."

3.2 Results

We performed multiple regression analysis using the average evaluation of each image with each aromatic material and the "description rate" of each word to indicate the possibility of estimating aromatic materials that enhance the reality of visual images based on "things included in the images" described by words (hereafter called "*Contents*"). The description rate is the percentage of people who stated a specific word, with the total (gross) number of people who stated the specific word in response to a certain image as the denominator. A total of 211 words (375 in gross number) were stated as *Contents*. First, we assigned a code number to each word based on the "System Table of Vocabulary Classifications" of the thesaurus[2], and narrowed it down to 79 words. In conducting multiple regression analysis, we considered 79 descriptive variables to be excessive, and thus conducted hierarchical cluster analysis to narrow it down to 12 clusters.

Of the 12 clusters, seven included more than one word (code number). Among those seven clusters, words having the highest description rate were called "representative words." The representative words from the 12 clusters were as follows: sky, river, lake/swamp, timber, fish/seashell, room, mountain, vegetable, grass, flower, confectionery, and tree.

We conducted multiple regression analysis using the average evaluation of each aroma in each image as an objective variable, along with the description rates of all 12 clusters as explanatory variables. Table 1 lists the results. In 13 of the 15 aromatic materials, the contribution rate with its degrees of freedom adjusted was greater than 0.6. The 14 aromatic materials other than "peppermint" also showed an effective degree of contribution ($p < 0.05$). This experiment thus demonstrated that assigning *Contents* of a certain image to 12 representative words makes it possible to estimate which of 14 aromatic materials tends to enhance the reality of that image. In other words, we learned that even an image for which aroma is difficult to identify can help in estimating aromatic materials that enhance the reality of visual images from *Contents* indicated by words.

3.3 Typical combinations of images and aromas that enhance reality

Here, we will describe images with which a specific aroma highly enhances reality. The aromatic materials of ilang-ilang (exotic*), star

* Aromatherapy classifies aromatic materials into seven systems according to the region of extraction from plants and the kind of plant: orange, floral, exotic, resin, spice, tree or herb. (See "A Guide to Aromatherapy" at http://www.aroma100.net/100/.)

anise (exotic), rose (floral), and lavender (floral) received high scores with part of an image or images showing flowers all over, such as those of "a florist shop with many red roses," "salvia fields all over," "fields of field mustard with groups of buildings in the background," and "lavender fields all over." "Benzoin (resin-based)" and "vanilla (spice-based)" received high scores with images of "a coffee shop with pancakes on a table," "assorted peppermints and fruit drops," and "a room in a Western-style house with orchid flowers." "Celery seeds (an herb)," "tee trees (a tree)," and "pines (a tree)" received high scores with images including trees, such as "a timber storage" and "a narrow mountain path with thick groves of Japanese cedar." "Galbanum (resin-based)" received high scores not only with images of trees but also with those of "a grassland on top of a mountain," "a park with trees with lively green leaves and green grass," "fields with eggplants grown in raised soil," "the veranda-like porch of a Japanese house," "dead leaves," and other images including soil and grass.

Some images, however, did not receive more than three points in evaluating the degree to which an aromatic material enhances reality. For those images, such water-related things as sea, lake, river, pond, snow, and water puddle were cited as *Contents*. Since water is virtually odorless, it is considered difficult for images representing clear water to remind people of a particular aroma in the first place.

3.4 Observations

In the experiment, we used 40 images. Dividing *Contents* described in words into only 12 clusters and turning them into explanatory variables established multiple regression equations. Using *Contents* described in words will thus establish a system for estimating aromatic materials that enhance the reality of visual images. By selecting from *Contents* prepared in advance instead of freely entering *Contents*, one can eliminate any ambiguity of a given word, thereby facilitating the estimation of aromatic materials. The experiment apparently suggested that the presence of detailed information about "things" in words representing *Contents* makes it possible to estimate even more appropriate aromatic materials. For example, information that enables the identification of materials such as "thatched roof" and "stone wall" instead of the mere mention of "house" will undergo a change in the aromatic materials estimated.

4 To increase aromatic material options

Devices for providing multiple aromatic materials have been developed to present aromas in households (olfactory displays)[3]. But providing many aromatic materials also imposes a financial burden. For that reason, hopes run high for possibly providing the maximum degree of reality with the minimum variety of aromatic materials. For example, the availability of multiple candidate aromatic materials that enhance reality for one item of *Contents* in a specific piece of footage raises the possibility that one aromatic material in it may be identical to one that enhances the reality of other *Contents* in the same footage. For that reason, an aromatic material supported as enhancing the reality of a certain item of *Contents* should be indicated with a set of multiple aromatic materials.

4.1 Candidates for "aroma characteristics" helpful in estimating the degree of reality enhancement

A subjective evaluation of the degree to which the reality of various *Contents* is enhanced for every kind of natural aromatic materials traded in the market and covering about 150 kinds of plants (relative to about 1,500 existing aromatic materials extracted from plants and about 500 kinds that aroma suppliers typically keep in stock) entails the difficult evaluation of the "number of kinds of aromatic material × number of items of *Contents*." A method of estimating the degree to which the reality of various *Contents* is enhanced can therefore be obtained from the "aroma characteristics" possessed by the aromas. This method allows one to estimate a combination of aromatic materials

that enhances the reality of a particular piece of footage with the fewest aromas from the list of *Contents* given in the footage.

The candidates for aroma characteristics effective in estimating the degree to which the reality of *Contents* is enhanced are as follows:

Color characteristics: Characteristics based on the relation between aroma and color. The relation between aroma and color[4]-[7] has thus far been widely discussed.

Noun characteristics: Characteristics based on the names of things (nouns) of which an aroma reminds people. The "quality of an aroma" may be expressed in noun-like terms such as "like a lemon."

Adjectival characteristics: Characteristics based on the impressions (adjectives) people get from an aroma. Studies on a method of evaluating aromas using a pair of mutually opposed adjectives (semantic differential method) are now underway. Examples include pairs of such adjectives as "thick and plain," "mellow and acrid-smelling," and "glamorous and simple."

Characteristics of chemical components: Characteristics based on chemical components that constitute an aroma. Studies on matching the terms representing chemical components to terms representing the qualities of aromas are now underway[8].

This section describes an experiment that examined which characteristic is most effective in estimating the degree to which the reality of *Contents* is enhanced[9].

4.2 Experiment

First, in order to verify the color characteristics, we had 24 subjects look at images representing *Contents* with different colors, while allowing them to smell 20 aromatic materials and, by using the seven-item method, asked them to evaluate the degree to which reality is enhanced. We converted four images representing trees with green leaves into red, yellow, and dead-leaf color, and provided four kinds multiplied by four colors (for a total of 16 images). Among the 16 images, four images of trees with different kinds and colors of images were shown to the subjects. Next, to verify the adjectival characteristics, we had the subjects smell the aromas based on aromatic materials only (without images), and make responses using the seven-item method regarding which of 15 pairs of adjectives a specific aroma matches (the SD method). At that time, in order to verify the noun characteristics, we asked the subjects to freely state the names of things they can recall based on aroma. Moreover, to verify the characteristics of chemical components, we conducted analysis by using written materials published by the chemical distributors as chemical components constituting the aromatic materials used which were verified through gas chromatography-mass spectrometry (GC-MS) or similar means.

4.3 Results: color characteristics

Based on the results of evaluations by the subjects regarding the degree to which the reality of each aromatic material was enhanced for each image, we conducted dispersion analysis by using three factors: the kind of image (trees), the kind of color, and the kind of aromatic material. Having determined the significance of the F value, we found that only the main effect of "the kind of aromatic material" was at a level less than 1%, thus making it significant [$F(19, 1520) = 19.84$]. One could say that in this experiment, it was difficult to estimate aromatic materials that enhance the reality of a specific image based on the color of *Contents* of an image (color characteristics). Many studies on the relation between aromas and colors have thus far involved experiments where the subjects choose aromas matching the concept and impression of a color itself by using color cards, colored water solutions, and a room with differently colored walls[4]-[7]. And no experiments have yet to verify the degree of reality by using images with specific *Contents* having different colors as in this experiment. However, from the results of this experiment, one can consider it difficult to estimate aromatic materials that enhance reality based on a particular color regarding images having *Contents* recognized by the subjects as a particular object.

4.4 Results: noun characteristics

There were nine types of aromatic materials that received higher scores than the overall average— aromatic materials that increase the reality of *Contents* for trees: hiba, cedarwood, galbanum, petit grain, black pepper, vetiver, myrrh, Patchouli, and pine. Based on these results, we had the subjects describe each aroma of 20 aromatic materials in isolation without looking at the images (if those images reminded them of the aroma of something). Regarding the nine aromatic materials described above, the number of people who stated the name of a thing related to trees totaled nine out of 24 people for hiba, and eight for cedarwood. Conversely, less than three people accounted for the seven other aromatic materials. It was therefore determined that the aromatic materials reminding people of trees increase the reality of a image when people smell the aromatic materials in isolation, and that even aromatic materials not readily reminding people of trees when smelled in isolation may increase the reality of a image if presented with an image including trees as *Contents*. In other words, we learned it is possible to estimate some aromatic materials that enhance reality based on the characteristics of aromas indicated by the names of things of which the aroma of a specific aromatic material reminds people, but difficult for many other aromatic materials.

4.5 Results: adjectival characteristics

To examine whether the adjectival characteristics of an aroma is effective in estimating the degree to which the reality of *Contents* is enhanced, we conducted cluster analysis (using the ward method) based on an evaluation of each pair of adjectives for each aromatic material. Figure 3 shows the results divided at a distance of 5.5. The numbers under the aromatic material names indicate the evaluated rank in enhancing reality. It can be seen that all nine aromatic materials with high reality scores were classified as two of the six clusters, while all other 11 aromatic materials were classified as four clusters. One can see that there is particularly high agreement between cedarwood and hiba—the two highest scoring aromatic materials—and between the fourth, fifth and sixth highest scoring items (namely petit grain, black pepper and pine).

This suggests that, at least when *Contents* are about trees, the impressions of an aroma (adjectival characteristics) obtained by evaluating the aroma with an adjective corresponds to a particular item of *Contents* and readily enhances the reality of an image including those *Contents*.

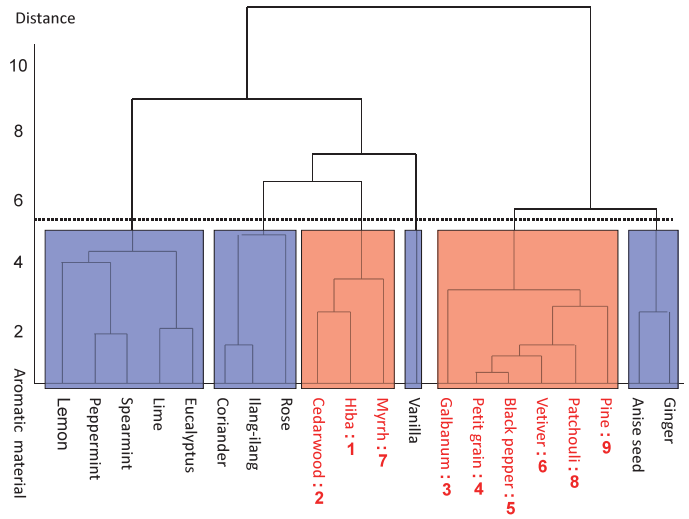

Fig.3 Dendrogram

4.6 Results: characteristics of chemical components

We examined whether the chemical components included in the aromatic materials were effective in estimating the degree to which reality was enhanced. A typical aromatic material contains 100 to 400 ingredients, often generally identified by using gas chromatography-mass spectrometry (GC-MS). Analysis data is centered on the main components present in large amounts, but the components present in large amounts do not necessarily contribute most to the characteristics of a specific aromatic material[10].

Of the nine aromatic materials obtained from the results described in Section **4.4**, both the aromatic materials of cedarwood and hiba contained thujopsis and cedrol. These two are known aroma components found in Cupressaceae plants. These two chemical components were not identified in other aromatic materials. Note that α-pinene and β-pinene are said to have resin-like and pine-like characteristics[11], and are found in many aromatic materials regardless of whether those aromatic materials support reality. However, we could not find common chemical components contained only in the nine aromatic materials supported as aromas that enhance reality, and even if they include resin-like and pine-like chemical substances, they did not necessarily increase the reality of images including trees as *Contents*.

These results demonstrated the difficulty in estimating the degree of reality enhancement based on the chemical components contained in an aromatic material.

4.7 Observations

The color of *Contents* was found not to affect the degree to which the reality of an aromatic material is enhanced. This suggests the concepts that people derive from *Contents* affect the kinds of aromas that enhance reality more than the concepts that people derive from colors.

We had the subjects identify the names of things of which the aroma of each aromatic material reminds people. Among the aromatic materials that enhanced the reality of images including trees as found in *Contents*, and among the nine aromatic materials obtained from the results described in Section **4.4**, seven aromatic materials (except cedarwood and hiba) reminded only a few people of things related to trees. Unfamiliar aromas are considered not to readily remind people of things or more diverse things when such clues as visual information do not exist. One can therefore consider that these seven aromatic materials had no strong characteristics.

The results of comparing chemical components included in aromatic materials and applicable to reality enhancement also indicated the possibility that a hypothesis of chemical component characteristics only holds true for some aromatic materials (cedarwood and hiba) having strong characteristics in chemical components. It does not hold true for many other aromatic materials.

The results of evaluating a pair of adjectives with each aromatic material presented to the subjects in isolation also revealed that the nine aromatic materials supported as aromas that enhance the reality of images including trees as *Contents* belonged to two of the six clusters based on cluster analysis results. These results indicate that, at least in images including trees as *Contents*, it becomes possible to cite more than one candidate aroma that enhances reality. In other words, by identifying the adjectival characteristics of each aroma, the aromas whose adjectival characteristics are similar to those of aromas that enhance the reality of a certain item of *Contents* identified in a prior subjective evaluation become alternative aromas that enhance the reality of particular *Contents*.

In experiments that verified the noun characteristics, even aromas not identified with names related to trees when smelled in isolation sometimes enhanced the reality of images of trees. This suggests that some subjects do not necessarily recall "trees" when a specific aromatic material is presented to them together with an image including trees as *Contents*. A similar example is background music used in

TV and radio dramas. As background music, instead of using sounds generated in *Contents* in the footage, we used a piece of music invoking an impression approximating that of the particular scene. And although the aromas enhance the reality of a specific image, the relation between aroma and image where *Contents* are not reminded even when presenting an aroma simultaneously with an image is consequently considered similar to the relation between background music and the footage. On the other hand, we can cite sound effects used in TV and radio dramas as examples similar to the case when people recall trees. Sound effects are not necessarily used in the form of a recording of sounds generated by the real thing. There are many cases where imitative sounds (sound effects expressing real sounds by using sound sources other than the real thing) are used. Moreover, when hearing an imitative sound in isolation, it may be difficult to recall a thing expressed by that imitative sound. However, when one hears the sound at the same time as in the footage or when the source of the sound is clear based on the context, one can easily recall the thing expressed by that imitative sound. The relation between aroma and image when one can recall "trees" when presenting such an image is considered similar to the relation between sound effects and footage.

5 Conclusion

This paper presented three experiment results in order to propose a method of easily selecting aromas that enhance the reality of visual images from existing aromas. Chapter **2** explained that even images not readily reminding people of particular aromas cause them to unanimously determine particular aromatic materials as enhancing reality. Chapter **3** evaluated the degree to which the reality of each aromatic material was enhanced for various images. Since multiple regression equations were established with the kind of *Contents* as explanatory variables and with the kinds of aromatic materials as objective variables, it was found that aromas that enhance reality were common among the subjects, and that it was possible to estimate the kinds of aromatic materials that enhance reality from the names of *Contents*. In contrast, Chapter **4** demonstrated that an aromatic material that enhances the reality of an image does not necessarily remind people of its *Contents*. However, several aromatic materials that enhance the reality of *Contents* for trees agreed with the classification in cluster analysis based on an evaluation of aromatic materials with pairs of adjectives. These results determined the method of easily selecting aromas that match the images, even for general users lacking aroma knowledge. Moreover, the results of Chapters **3** and **4** suggested the possibility that *Contents* replaced by "grass," "trees" and other nouns may be captured as impression changes (concepts replaced by adjectives and other words) common among the subjects. Moreover, the kinds of aromatic materials that enhance the reality of visual images can be estimated from image *Contents*, but the kinds of aromatic materials selected are considered based on the adjectival characteristics corresponding to specific *Contents*.

We wish to present aromas matching images (that enhance the reality of visual images) together with images and sound effects, in an effort to study the subsequent biological and behavioral changes in viewers.

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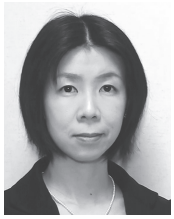

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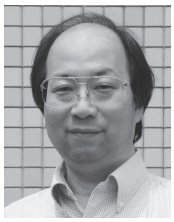

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