Scentgraphy - Interactive Installation of Scent Communication

Xiaotian Sun(✉) and Kiyoshi Tomimatsu

Kyushu University, Fukuoka, Japan
ginasun@foxmail.com, tomimatu@design.kyushu-u.ac.jp

Abstract. This paper presents an analysis on the interactive installation of "Scentgraphy", which could compute, interpret, simulate and store scents behind scenes. It acts like an original camera or gramophone to capture and save pictorial memories. It not only enriches the interactive experiences, but also establishes a closer relationship with the combination of smell, vision and emotion. Meanwhile, Scentgraphy also provide an interesting interaction conducive for immersive experience of breathing aromatherapy. This project explores new experiences about the senses, sensory boundaries, storing and reproducing of the sense of smell. Based on ancient perfumery techniques, a closer bond is developed between memory and sense of smell. Scentgraphy project explored a way for computing, simulation, and telecommunication of odors by visual and olfactory conversion. This is a preliminary exploration on olfactory informationization, and this research ensures that the feasibility of converting visual and olfactory and digital odors can be spread and applied in media and information technology.

Keywords: HCI · Olfaction · Experience design · Digital scent

1 Introduction

One of the prior reasons to the development of cameras and gramophones is that people want to capture and reproduce beautiful memories and moments. Currently, people are no longer satisfied with the sole reproduction of visual and auditory sense and started to wonder if it is possible to find a technological solution in capturing other parts of human senses for scenes, emotions and memories. So far to the current stage, many scientists, engineers and artists have begun to explore the multi-sensory field. However, constrained by the form how smell exists, none significant breakthrough has been made. Currently, the designs of simulated smell can be paired up with a lot of real-life scenarios. However, the full application of scentgraphy still requires further exploration in calculation, storage and reproduction of scents.

At the same time, urban residents in the city confront overwhelming pressure from their rapid lifestyle, putting considerable portion of them into sub-health condition. This abnormal state of health can influence emotion and spirit of people while gases and scents breathed into body can stimulate aberrant change among neurons and cerebral sections. Scentgraphy, in this case, can provide a functional solution similar to that of the ancient aromatherapy that helps people relieve stress and relax. With

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development of scent technology, digital scent not only deeply expands multimedia experiences and immersive scenes, but also calculates, reproduces and stores scents. This is closely related with the future wellness of humans. Meanwhile, it is also closely related with marketing and entertainment.

2 Scentgraphy Design

2.1 Smell as Communication

German writer and screenwriter has written in an internationally famous novel *Perfume: The Story of a Murder* that "Odors have a power of persuasion stronger than that of words, appearances, emotions, or will. The persuasive power of an odor cannot be fended off, it enters into us like breath into our lungs, it fills us up, imbues us totally. There is no remedy for it".

Human's sense is infatuated with smell. The emotion and memories of human are tightly correlated with the smell of surroundings. However, with current technology, it is still impossible to store or replicate the scent of encountered environment.

For animals, foraging and breeding serve as the most important two things in life. Most animals rely on smell to differentiate the food and also to identify the position. Performance of animal instincts also relies intensively on the sense of smell. Case in point, the action of mating by a lot of primates is based on the capacity of nose to perceive the possible courtship.

Every creature can breathe. It is a natural performance of metabolic activity by the respiratory system associated with the olfactory system. That is to say, every creature has a sense of smell. Smell is also one of the most important characteristics of a substance and the most representative essence of the substance. Every substance has its own distinct smell while no two different substances with the same smell has been confirmed to exist. The smell of substance does not normally change when the biological components remain the same. It is only through qualitative reactions that changes of smell take part on substances.

As a common language in the world of biology, the sense of smell of every single creature has specific perceptual range. Every creature has its blind area in terms of smell. This specific range of the sense of smell for each creature is only related to its survival needs. It is positively related to its survival benefits while negatively related to its survival harmfulness. There are also special cases, such as oxygen, vapor, carbon dioxide, carbon monoxide, the major components of air in the living spaces on the Earth. People have no specific senses for them because they exist in the air all the time while they don't have to deliberately seek or guard against them. The human olfactory center removes the smell signals. On the other hand, the substances linked to creatures' survival are usually the ones arising sensual reactions. For example, the camel in desert needs to find water. The nose of camels holds the ability to retain its sensitivity to the water vapor. A recent study finds that people who have experienced carbon monoxide poisoning have recovered their sensitivity to carbon monoxide as compared to their previous conditions. The smell of animals also changes temporarily with diet, disease,

and mood. The creature can consciously release special smell for use of information exchange, such as offensive and defensive messages.

With the previous studies in biology, it has been testified that humans and animals rely on their past experiences to establish a sense of smell information, which also implies that smell serves as one of the basic ways of biological exchange.

2.2 Sensory Are Interlinked

Five senses of human are interlinked. People can feel the melody inside a room by looking through the window even when you are not actually inside. People can feel the taste of the meal by observing it even when you cannot catch the smell. People can experience different feelings bringing by the warm and cold colors. In real life encounters, connection of senses always takes part, case in point, people associating certain colors with tastes (or flavors). For example, strawberry-flavored candies and strawberry ice-cream can always make people associate it with pink or red coverings while orange-flavored candies and orange-scented pens make people think of orange outliers.

In the study from Department of Psychology, Gettysburg College, people's internalized linkage between scent and color is explored comprehensively by classifying the link into three different levels:

I. Probability links: if a color and a taste often appear together, they usually would be connected together automatically.
II. Semantic links: if the color and scent have some common meanings or identities, they might be put together. This can be supported by the example of interconnecting the taste of orange and the orange color.
III. Structural links: If the color and scent are similar in intensity or extensity, they might be linked [1].

Such association relies intensively on the scenarios these two types of stimulus appear together. As it has been testified by the prior study, common identity of color and scent affects the internalized connection across senses. Therefore, we have chosen the common colors often used in basic painting. Through the analysis of scenes and concerning colors, we can simulate the smell behind the scene. In the perfumery industry, the Michael Edwards' fragrance wheel invented by Edwards is taken as the authority in terms of perfume classification. The fragrance classification widely used in the perfume industry is composed by four branches, including floral fragrance, oriental fragrance, woody fragrance and delicate fragrance, and the fragrance has 14 notes. Based on this fragrance wheel, a test regarding the optical and smell senses of users was carried out.

The use value of Scentgraphy can be verified by proving the link between color and smell. Availability of Scentgraphy can in turn be thoroughly manifested. To do so, the research team of ours conducted the following experiment. Smell sense is the feeling mostly close to memory. Therefore, we, the researchers, regarded scene (or object) as the medium in the process of building up the relation between color and odor. Referring to Edward's fragrance wheel, the research team identified 12 colors as the basic colors and meanwhile add the color dark blue, grey, white and black commonly

seen in the daily life. We designed an online questionnaire involving relevant 4 or 5 scene pictures in similar colors with only one of the pictures showing up for each time in front of the responding subjects. There was no word appearing in the questionnaire. What respondents needed to do was to quickly choose the picture according to their first impression. The respondents for this test were from 7 countries (China, Japan, Britain, Netherlands, Germany, United States and Brazil). Altogether, they submitted 416 questionnaires. Among all respondents, female accounts for 63% and male accounts for 37%. The eldest respondent is a female aged 42 and the youngest respondent is a male aged 4. Please refer to Table 1 for the statistics of the collected answers from the respondents.

Table 1. Table captions should be placed above the tables.

Color								
Scenes								
smell	red pepper	Berry	rose	orange	lemon	basil	moss	water
Color								
Scenes								
smell	lavender	soil	woods	coffee	tobacco	mysterious	vanilla	Night sky

We, the researchers, used natural fragrance or compound fragrance to choose odor for each scene. However, we also found that the scents of certain kinds of odor was closely related to their smellness. Therefore, we endowed these certain kinds of odor with colors more likely in arousing synesthetic thinking within the respondents' minds. According to prior research, we matched color white with icecream. To echo the scene in dark blue sky at night, blue Lotus Oil was chosen as the color for scents of air with heavy humidity. Because the scene in black corresponds to the sense of mystery, we specifically chose black as representing the smell of Myrrh oil, the one with heavy hints of smoke and bitter taste of traditional Chinese medicine. Likewise, since water corresponds to the light blue, we decided to take light blue as the color standing for water.

2.3 Olfaction and Informationized

From the 1950s to the 1980s, filmmakers were constantly on their tryout in producing relevant scent devices used for the creation of immersive atmosphere. The world of technology, however, was lagged behind as compared to the film-making industry.

iSmell, developed by DigiScents, did not float to the surface until the hatch of the new millennium. This device is a stereo-like speaker that contains a cartridge with 128 "main scents" that can be mixed to replicate natural and artificial scents. DigiScents has indexed thousands of common scents that can be encoded, digitized and embedded in web pages and emails, allowing a wide range of scent exchanges on the electronic network. [3] oPhone, designed Harvard University, allows users to tag scents alongside with their photo from OS-NAP, a smart phone application. Sharing the caught scents behind scenarios via email and social platform has presented new interactive ways through. [4] In recent years, the scent synthesizers for VR devices has also appeared. It is believed that smell is an important factor for the medical treatment, commerce, entertainment and arts, for it not only represents fantasy but also communicates directly with cerebral consciousness and memories, so as to evoke uncontrollable emotions and establish more effective communication.

In fact, smell has now received more and more chances to be fully informationized and pushed to the verge of commercialization. There are already massive business organizations paying great attention to the marketing strategies based on the use of smell. For example, high-end hotels and shopping malls usually choose a set of scents conducive to arising the attentiveness of consumers. The scent might bring customers a sense of belonging, pleasure and more cheerful memories. On the other hand, through the smell, customers may get more excited and more eager to spill their money upon various goods.

2.4 Scentgraphy

This study is conducted with an aim of exploring a new experience connected to the daily breath of people. The study of related works has revealed that there are preset scents in most olfactory devices. Those devices do not have the capability to analyze and formulate scents regarding the change of surroundings. Based on the image recognition technology, a change can be brought to this circumstance. The color distribution of a famous painting, a scene or even a crowd is calculated through the correlations between colors and scents to eventually get the sensually felt emotion underneath each scene. The olfaction calculation of this concerned scene will be, by the end, helping to form the corresponding scents. However, due to the current technical limitations of scent analysis, only the dilute essential oil is used as the "ink" behind each scent. In fact, in our life, there are not only the scents, but also "stench" and "odor". To bring out more realized restoration of scents behind the scenes, future production and digitalization of the scent "ink" should focus on the optimization for a more diversified set of smelling experiences.

3 Prototype

3.1 Design Process

The major design of the whole device adopts the chemical equipment of traditional glass technology, 3D printing and SCM. Regardless of the material, visual or

interactive way, it reflects a traditional but modern feeling. Based on the spectrum of color and scent, this system calculates the color pixelated distribution of landscapes, images or even a person, through recognition of landscape and image. According to the quantity of colors, this device controls the concerning air-flowing time of the corresponding (according to Fig. 1: Color and Scent Spectrum) scent "ink" bottle attached to a solenoid valve. With the liquid release being longer, the flow of scent "ink" will be larger, and vice versa. The scent "ink" that is identified when passing through a mixing funnel which has an "ink" electric stirrer that could blend mixing scents evenly. After blending, the mixing funnel will open the solenoid valve to release the mixed scent liquid which has already been smoothly divided into two separate parts.

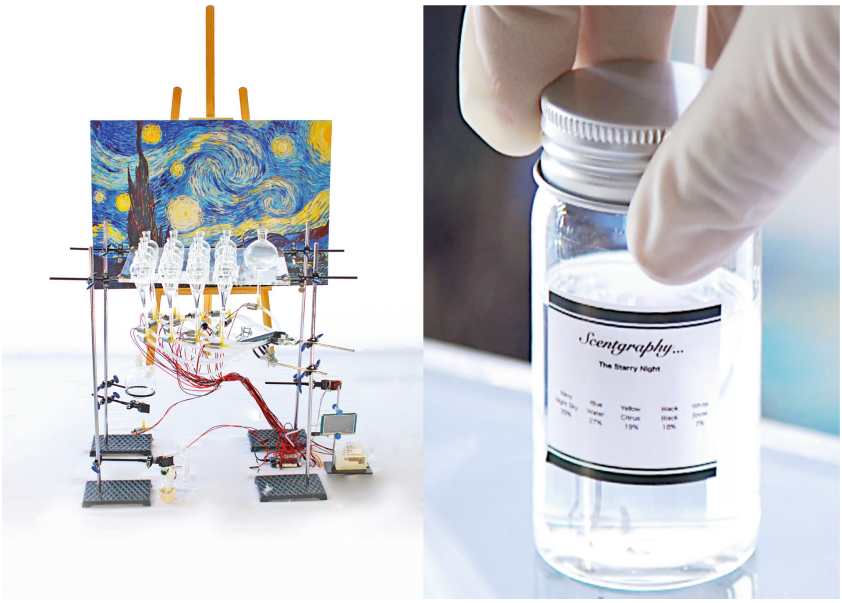

Fig. 1. Prototype and the computed perfume (Color figure online)

One part of the aforementioned two is immediately atomized into a gas atomizer to release into the air so that users smell and experience the scent constantly. The other part could be stored for later release. When running the device, the user can experience the scents changing accordingly with respect to the environment. Besides of this experience, a bottle of "scent liquid" will be generated in analogy to that of a photo taken from a camera. The scent data printed from the printer can be stored for the later building of database and reproduction of pre-existing memories. This process seems like a record for the gramophone, which brings a precious and ritual feeling.

3.2 Scent Ink Production

Scent ink is formulated through a "Color Smell Table", during which a base odor liquid is used. The scent "ink" is produced with the essential oil correspondingly spared from the "Table". When use, the "ink" is stored in the pear- shaped bottle at the top of the aparatus. The "ink" is scentgraphy's source of "energy." In the predictable future, with increased matching precision of scent "ink", Scentgraphy's sensory transformation experiences will be greatly enhanced. During the manufacturing process of the scent "ink", the ancient method used by perfumery has been researched. The research team expected to get "scent ink" to be able to be stored for a long time without being diluted or turned into a messed mixture filled with alcohol taste. When testing the result of the tryouts, the research team takes *the Starry Night* of Van Gogh as the major object. The scents were generated correspondingly regarding the existed colors in proportion on *the Starry Night* during the following three tests.

1. The first test: The research team directly used alcohol and pure water to dilute the pure essential oil. It took approximately a month to get a fully diluted and blended mixture without alcoholic scent.
2. The second test: According to the color ratio, the research team mixed pure essential oil with alcohol and purified water. The final scent of essential oil became weaker with a bit of hint of alcoholic smell.
3. The third test: In accordance with the color ratio, the research team first mixed pure essential oil with well water. By the final stage, it has been found that the essential oil was hard to be dissolved fully into water.
4. The control-group test: The research team used essential oils, no distinct reaction has been found during atomizing process.

As a result, it can be concluded that all the basic scents can be diluted into 95% alcohol. With the odor of alcohol disappears, the resulted gas can be used as the "scent ink". However, at the same time, some side-product scents may be produced (Fig. 2).

Fig. 2. Scent ink

3.3 Hardware

The chemical apparatus serves as the main structure of the product. The interaction among human, machine and environment is adopted through the sensor, solenoid valve, Raspberry Pi, camera, screen, printer and atomizer. The camera gathers the environment (picture) data. Such data are processed and calculated by the Raspberry Pi. The connected computer conducts calculation regarding the captured scenes to achieve pictorial recognition. Subsequently, the permutation and combination of scents correlated with the pixel scale of color are accomplished. The major color can be identified in priority while the corresponding scent "ink" are controlled to be released. All scent "inks" are blended through the rubber pipe. Part of mixed liquids are discharged using the atomizer bottle, which can immediately generate the scene or picture smell, while another part is reserved as a copy for later reproduction. Meanwhile, the printer will print the adhesive label with color data, which could be attached to the bottle of copy for reconfiguration. The user controls the operation of the whole device by controlling the touch screen. Eventually, the user will smell the calculated scents discharged by the atomizer and reproduce the scents with one bottle of liquid mixture. Throughout the whole operation process, a set of interactive systems guiding the user step by step has been achieved to optimize the user experience.

3.4 The Color Detection

The research team of ours have also taken into consideration of the vision recognition functionality involved in the application process of Scentgraphy. The color models, HSL and HSV, are used as the cylindrical coordinators for the color adjustment module. HSL and HSV are the most common color models of cylindrical coordinates. Compared with the previously popular RGB model, these two sets are more visually intuitive. The application of the HSL and HSV models will help the research team to better identify the hue, saturation and brightness of colors under different light conditions. HSL and HSV models for each selected 16 color has been established for the later calculation of their associated values. After being photographed, the captured image will be pixelated and analyzed the computerized system. Each pixel will be matched with the corresponding color value to count the percentage of each pixel in the pixilated image.

With the future establishment of the database, it can be anticipated that more well-founded recognition ability will be achieved.

4 User Study

4.1 Method

To find out whether respondents could correlate specific colors with particular scents among two groups of odors, an exploratory study was conducted by the research team of ours. The research team recorded all experimental procedures through video, including the interviews with the participants after the experiment. In the interview, we asked about the impression of the users on Scentgraphy, including questions regarding

the user experience and the value of later development of smell informatization. Experimental data, interview videos, and results from the questionnaires were used as the bases for this later research.

The first experiment: 15 respondents are all aged between 22 and 36. Before the task, the 'Color, Scent and Scenes table' was not exposed to respondents. At the same time, we made a brief introduction to the test flow and conduct a 10-min instruction to every respondent to help them fill in the questionnaire and smell odor. The testers smelled the odor in the numbered bottle. There were 16 scent inks being placed in the bottled and labeled with numbers. Four people are in a group and four scent bottles were provided to each person. The colors are identified by smell correspondingly with the given options. The testers' choices are documented by the research team for later test upon the accuracy. After discerning the odor on the test paper, respondents are required to write down the number of corresponding color on the questionnaire. At the interval between the first and second test, we removed the objects with odor, for obliging the scenario of letting the existing odor affecting the next test. After completing the full tests, we hold a five-minute interview with every respondent and film a video for this.

The results of the first group are listed as below. Among the 15 individuals, 53% of them correctly identified the odors. Scents that frequently appeared in life, such as Floral, Fruity, Purple, Wood Oriental, Citrus, etc., can be easily recognized. Colors with more specific features, such as fog and green, are relatively easy to be identified. In the interview, testers have reflected that understanding of the tested odors will easily be felt in an atmosphere dominated by this color. The color of Fog was created using the smell of Cuban tobacco to produce a feeling of smoke and blemishes. The color of Green was created using Basil smell to create a soothing nerve. As for the colors of Dark Mossy, Navy, Black, White, etc., concerned scent ink were made to inhibit the nerve excitation, making the related odors relatively hard to be identified. It can be explained that people do not have a consensus upon this set colors to relate them to a specific smell in their life. It is only through frequent life encounters, consensual correlation between colors and scents can be established. The results of the second experiment, are listed as followed. The accuracy rate for recognizing the Great Wave off Kanagawa is 54%; the rate for Still Life with Sleeping Woman is 43%; the one for Auspicious Cranes is 36%; the one for Starry night is 27%. As a contrast in terms of this accuracy rate, the color of pumpkin appeared as hard to be identified, the accuracy rate for this color is only 11%. Through the interviews with the testers, a conclusion has been reached that people's sense of smell actually is trained after the birth. Nose has not yet been considered as an organ that can accept information. In regard of this fact, the production of scent ink should also be more specialized. The choice of odor may be correct during the time of test. It is undeniable that the non-specialization of the commissioned essential oils would also affect people's judgment in correlating the odors with real-life colors. However, when the researchers told the testers about the right related color behind the odors, the majority of the testers were able to show an immediate realization and recognized the smell.

The second experiment: There are 15 participants in the second group, whose ages range from 24 to 32. Before the test, all the 15 participants will join the smell test which lasts 40 min at the same time. Through initial learning of the Colour Scent Wheel,

elementary memories can be generated. Scents of the five famous paintings generated by Scentgraphy are numbered. The 15 testers smelled the odors in the numbered bottles, and corresponds the smelled scents to the paintings. The accuracy of the tested subjects' verdict was documented to prove the connection between the mixed smell and the scene. By the end of the color recognition test, the respondents all accepted 5-min interview regarding their choices in the prior tests.

During the interview, some of our participants expressed that they had not smelled certain scents that were included beforehand of our test, but those scents did trigger different part of memories related to their personal experiences. For example, one of our participants who is a 25-year-old male going through his graduate study on economics said the woody smell reminded him of the massage shop in the Southeast Asian style. Another 28-year-old architect expressed that the woody smell made him think of the smell of a laser cutting workshop. Most of the participants believed that, despite the differences between the vaguely recalled memories during the two tests, this kind of training can help people establish unified ideas and smell languages. Some testers said it is hard for them to discern the smell of smoke from that of soil as these two smelled extremely similar. However, people believe that they can tell the smells apart after frequent tests for a long time.

Two kinds of conclusions can be reached following the test. After the 40-min training, participants' recognition ability of scents can probably be relatively sharpened to a level higher than the accuracy rate of 42% which is the result we had for the tests. What's more, the scents on the smell wheel's right side is easier to be recognized than those of the smell wheel's left side. As is shown in the Fig. 3, the number of correctly recognized scents decreases following the direction of the arrow (Fig. 4).

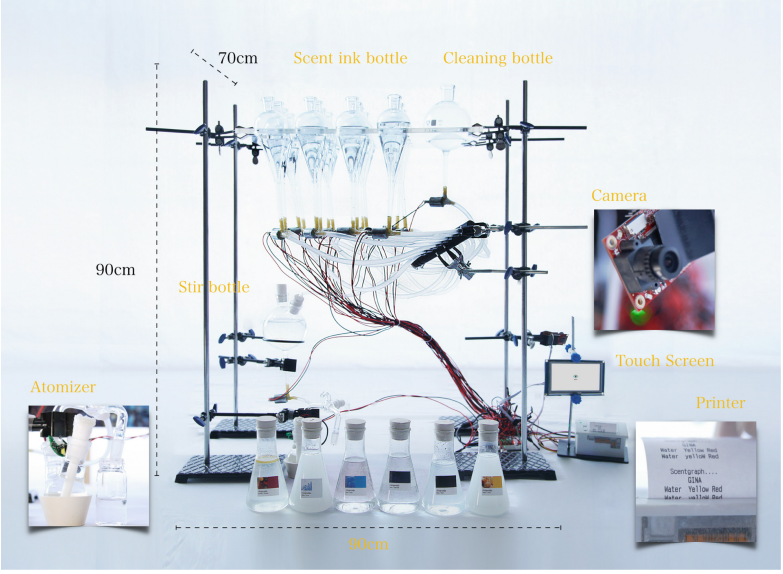

Fig. 3. Details of Hardware

Fig. 4. The user smells and identifies the color. (Color figure online)

4.2 Results

In the experiment process, we, the researchers, also found out that respondents' deviation in color and odor perception is as a result of cultural difference. It could also be generalized as that people do not have a synthetic sensation or consensus about each color and correlated smell as a respect to their own specific life experience. In the future, the experiment design can be optimized with adding up more prepared odors into the testing sessions, and a consensus standard for color and smell can be established. But what we could be sure of is that the scent is the medium between the sense of smell and the related color in mind. Scent communication is feasible, but a more in-depth application in real life should be based on the scent cognition training for each and every user. At the present phase, we have established 16 matching relations between color and odor in the database and plan to further construct an entire color-odor matching database and integrate Scentgraphy so as to realize initial exploration in scent communication and scent Informatization.

5 Conclusion

Scentgraphy acts like an original gramophone to capture and save memories for us. It can generalize the scent of specific paintings, the one of a landscape, and even the one of a photograph. A closer relationship can be established between color and smell by simply breathing in the reproduced scents behind each captured scenario. The goal of Scentgraphy is to bring users unique breathing experience. A scene can be pixelated

and later calculated to better unveil the relationship between color and scent to help embody the underneath emotion based on the image recognition technology.

Olfactory information can be counted as a kind of sensory data. In the future, such data can be applied to immersive entertainment, multimedia handheld devices, and even medical and beauty industries. The research team truly believes that the future sensory design will permeate into all aspects of life. In addition to obtaining more accurate scent data, the team of Scentgraphy needs to explore deeper to better understand the mechanism for scents to affect the user's emotions, emotions, and memories.

This research will make the media and information technology spread in a more effective way. Making the current device more applicable to immersive entertainment, multimedia handheld devices, and even medical and beauty industries. There is reason to believe that in the near future, this set of sensory input objects will get deep into all aspects of daily life, rather than just stay in the current visual and auditory. In addition to requiring more accurate odor information, the developing team also needs to explore upon the mechanism that how the odor affects the user's emotions, emotions, and memories more than they are now. Scentgraphy serves as the touchstone of the digitization of scents. In the short future, scents can not only be calculate, saved and reproduced, but also can be remotely shared. Controlling people's emotional well-being through nostalgic odors by using certain functional products through odor memory, smell and scent will be applied across the world like any other physical products that have already been widely accepted.

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