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Using Olfactory Displays as a Nontraditional Interface in Human Computer Interaction

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ABSTRACT

Smell has its limitations and disadvantages as a display medium, but it also has its strengths and many have recognized its potential. At present, in communications and virtual technologies, smell is either forgotten or improperly stimulated, because non controlled odorants present in the physical space surrounding the user. Nonetheless a controlled presentation of olfactory information can give advantages in various application fields. Therefore, two enabling technologies, electronic noses and especially olfactory displays are reviewed. Scenarios of usage are discussed together with relevant psycho-physiological issues. End-to-end systems including olfactory interfaces are quantitatively characterised under many respects. Recent works done by the authors on field are reported. The article will touch briefly on the control of scent emissions; an important factor to consider when building scented computer systems. As a sample application SUBSMELL system investigated. A look at areas of human computer interaction where olfaction output may prove useful will be presented. The article will finish with some brief conclusions and discuss some shortcomings and gaps of the topic. In particular, the addition of olfactory cues to a virtual environment increased the user's sense of presence and memory of the environment. Also, this article discusses the educational aspect of the subsmell systems.

Keywords: *Olfactory Displays, Olfaction Output, Human Computer Interaction, User Interfaces, Smell*

INTRODUCTION

Smell is an underused sense in human-computer interaction (HCI). In our daily lives, smell tells us whether food is safe to eat, if a fire is breaking out in the next room, and, as evidence increasingly shows, if we find a potential mate attractive (Jacob, McClintock, Zelano, & Ober, 2002). In HCI, however, smell is an almost entirely unexplored medium. There are reasons for this: technical difficulties in emitting scent on demand, chemical difficulties in creating accurate and pleasant scents, and issues of research focus and direction. However, it is now possible to purchase off-the-shelf, easily controllable hardware for aroma output, and incorporating scent into HCI is now comparatively simple.

The vast majority of work in HCI involves our senses of sight and hearing, with occasional forays into touch. Much of HCI has assumed a single user at his desk with a single screen, controlled by a single keyboard and mouse. The vision of ubiquitous computational power has led to a corresponding emergence of ambient and calm media: efforts exploring distributed input and output for distributed computing. Scent is an excellent medium for ambient or calm display; a scent can "move easily from the periphery of our attention, to the center, and back" (Weiser, & Brown, 1996). Users rapidly acclimate to an ambient scent, but a change in aroma calls attention to itself. Although inappropriate for rapidly changing information, and limited in bandwidth, our sense of smell is well evolved, accurate, and valuable as aninterface (Kaye, 2004).

Conventional computer systems utilize visual and auditory perception to convey information to its users. Olfaction output is commonly regarded as a minor sensory modality. As a result, many systems do not have olfactory ability at all. Yet, scents are extremely evocative; they can also shift attention, add novelty, enhance mental state and add presence (Gutierrez, 2004). But then what is the reason behind the deficiency of smell as an interaction channel? To understand this, one must delve deeper into the current research of olfactory displays usability. This article will present one of the main problems in integrating smell into computer

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interfaces, the lack of classification schemes for smell.

From 1916 until now, there were many researchers trying to add scent to the movies and other multimedia with different methods such as; Scentovision, iSmell, Smellevision, Aroma-Rama, Scenoroma, Scentware, Odoram, Smell-OVision system and Scratch and Sniff cards. Each method had its limitations. This was very regrettable for the film owners and the audiences. Movies makers missed keeping their scent accompanying their movies and making their movies better. This also made movies audiences miss the scents. There were many movies which had scent as their main character such as perfume movies, cooking movies, etc. This was not only with the movies in the offline world, but also in the online world. Online movies also tried to accrue smell via the server and sniff smell to the website. Although some methods were not suitable for the movies, they were good for using with some advertisements. For instances scratch and sniff cards idea was used for business card. Several methods are still used in the real world and also they are trying to improve them and overcome their limitations (Pornpanomchai, Threekhunprapa, Pongrasamiroj, & Sukklay, 2009).

At first glance, it may seem that combining different scents to convey information is more useful than attempting to manipulate intensities, but the problem of mixing different smells is far more complex. Some smells seem to mix, while others remain distinct. Furthermore, unpredictable effects can occur such as the creation of new smell that was not intended. The tendency for smells to linger behind after emission can add to this problem.

Many efforts have been made to find "base-odours" that are, at the same time, general enough to describe all odours, and as few as to be manageable. Research on this topic started in the 1960's, but still no generally accepted way of representing odours has been found. Some hints can come from food science which has worked out the relationship between smell and the colour of food or even the crunching emitted during eating (Davide, Holmberg, & Lundström, 2001). Many researchers used many techniques to develop an olfactory display, such as Sensorama, head-mounted olfactory display (HMD), arm-worm olfactory display, DigiScents, Aromajet, ScentAir, Trisenx, Scent Collar etc. (Chen, 2006; Washburn, & Jones, 2004).

Smell-O-Vision is the most popular method, which is used to be a master model to create a better methodology by using the pipeline system to release scent to the audience (Smell-O-Vision, 2007). Could olfactory displays augment data visualization, that is, communicate information relevant to many fields? Perhaps incorporating underutilized modalities such as haptics (touch), olfaction, and gustation (taste) as data visualization aids is the next logical step to optimizing human information processing.

SENSE OF SMELL: OLFACTION

In comparison with the ear and the eye, the human nose is much more complicated, at least regarding the mechanisms responsible for the primary reaction to an external stimulus. The human olfactory system is very complex, and is not yet fully understood. A simple scheme of how the olfactory system Works can be seen in Figure 1.

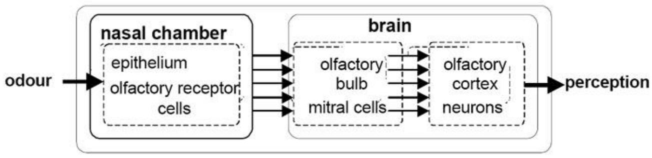


Figure 1. Scheme of the human olfactory system. A large number of olfactory receptor cells (»10 million) but with a limited amount of selectivity classes (~ 10-100). An odour produces a pattern of signals to the olfactoryvcortex via the mitral cells (~ 10 000). The brain interprets the signal pattern as a specific odour (Adapted from Davide, Holmberg, & Lundström, 2001).

There are approximately ten million sensory receptor cells in the nose, each of them sensitive to a great number of compounds. The response of a receptor is due to the activation of biochemical processes in the cell and/or ion channels in the cell membrane. The response time, i.e. the time it takes for a receptor to give a significant response when exposed to a new odour, is in the order of seconds. Neighbouring receptors have similar selectivity profiles, i.e. are sensitive to almost the same molecules. Since the number of receptors is so great, the total variation in selectivity is, however, great enough to make us experience quite different sensations from different odours. Compare for instance how you react to the smell of ammonia and to freshly made bread.

In order to utilize the information in the receptor signal, it has to be processed in a suitable way. Electrical signals are transferred from the receptors to the olfactory bulb through axons and dendrites. The signals then reach simple signal processing cells called neurons. A neuron has (in general) many inputs but only one output, which can either be excited or not. There will be a signal on the output if there is enough excitation on its inputs, with different importance (weight) being attached to the different inputs. These weights can be changed in a learning process, making it possible for us to learn to better recognise odours we are often exposed to. In the olfactory bulb there are many neurons, together forming a whole network. This network processes the information and then transfers the processed data to the olfactory cortex. This is where the final processing is made, by another network of neurons, and also where the communication with the rest of the brain takes place. The brain can then use this new information together with stored knowledge and tell us, e.g., to run away from or approach the odour source (Davide, Holmberg, & Lundström, 2001).

An electronic nose is an electronic system that, just like the human nose, tries to characterise different gas mixtures (Gardner, Bartlett, Dodd, & Shurmer, 1990). It uses currently a number of individual sensors (typically 5-100) whose selectivities towards different molecules overlap. Since the number of sensors is so small and the sensors are often carefully chosen, the overlap is usually much smaller than for the receptors in the human nose (Figure 2).

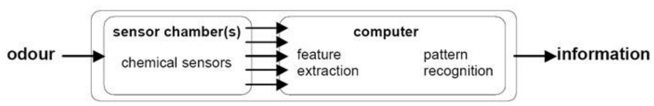


Figure 2. Schematic of an electronic nose. A limited amount of chemical sensors (10-100) with partly overlapping selectivity profiles. A computer is used to extract the features from the sensor signals and to recognise the patterns belonging to a given odour or gas mixture. (Adapted from Davide, Holmberg, & Lundström, 2001).

NEED FOR SMELL

It seems reasonable that adding the sense of smell to a virtual environment (VE) would enhance the environment's presence or "realness." The olfactory nerve is the only sense organ that connects the external world directly to the brain, in particular to the limbic system. The limbic system is composed of structures involved in emotion, motivation, and emotional association with memory. From the evolutionary point of view, the limbic system is one of the oldest structures in the brain and has evolved as part of the olfactory (smell) sense (Washburn, & Jones, 2004).

It is commonly accepted that smells influence how we act and feel. The sense of smell can stimulate the memorization of concepts or experiences. Odors are well known for their high influence as contextual retrieval cues not only for autobiographic memories, but also for various other types of memory, including visuospatial memories. For example, a recent study has shown that the use of olfactory stimuli for cueing memories during sleep is useful for memory consolidation. Strong correlations have been found between smell and attention, reaction times, mood, and emotional state. The sense of smell was addressed by one of the first Virtual Reality systems, the Sensorama that filed in 1961 (Figure 3). Studies show that olfactory stimuli can enhance the sense of presence by recalling previous experiences and modifying the emotional state of the user (Gutiérrez, Vexo, & Thalmann, 2008).

Figure 3. Advertisement for Heilig's Sensorama, courtesy of Scott Fisher's Telepresence (Adapted from Heilig, 1962).

In his patent for the Sensorama, Heilig stresses the pedagogical potential for the device, discussing, for instance, the armed services, who, "must instruct men in the operation and maintenance of extremely complicated and potentially dangerous equipment, and it is desirable to educate the men with the least possible danger to their lives and to possible damage to costly equipment". The default experience that shipped with the short run of Sensorama, however, was not a replication of the battlefield, but a series of journeys, including a motorcycle ride through Brooklyn (complete with seat vibrations mimicking the motor of the bike, the smell of baking pizza, wind from strategically placed fans, voices of people walking down sidewalks) and a view of a belly-dancer (with cheap perfume) (Heilig, 1992). Although Sensorama failed to catch on, and faded away due to financial issues, the machine still remains the pinnacle in some aspects of immersive experience, notably in utilization of olfactory stimulus (Payatagool, 2008).

Virtual technology needs devices to produce odorants, related to target odours, in a controlled way: the virtual olfactory display (VOD) is the answer, a system made of hardware, software and chemicals, able to present olfactory information to the virtual environment user. The last concept is Teleolfaction, defined as the act of smelling a mixture of odorants, whose composition is related to a mixture present in a remote place. Teleolfaction is a form of virtual olfaction, but it makes a distinction about the source of the olfactory information. Teleolfaction deals with making copies of reality, and involves the problem of fidelity (Davide, Holmberg, & Lundström, 2001).

Virtual environments need virtual olfaction for many reasons. The most obvious is that we live in a world full of smells, whose effect is strong, especially at the subliminal level. The importance of olfaction comes out clearly from the analysis of the competence domain of the human senses: smell and taste are the only onesable to perceive information from the chemical domain. Further, smell has the tremendous power of having long range, and it has been far more important for survival during the evolution than sight and hearing, as witnessed by the incredible amount of genes codifying olfactory receptors in humankind (nearly 1000 over 100.000 involved, an enormous percentage among the others gene families (Axel, 1995)

At present in communications and virtual environment, smell is either forgotten, or improperly stimulated (because of non-controlled odorants, off odours, present in the physical space surrounding the user, that provide olfactory cues conflicting with the user's feeling of presence in the virtual environment or of being part of a communication session). Nonetheless a controlled presentation of olfactory information can give advantages in different application fields, as the following two examples prove:

- Training of users for complex skills in shared virtual reality environments: this implies displaying computer-generated objects that may or may not resemble the real world. Barfield, Rosenberg, and Lotens (1995) reported that olfactory information, paired with virtual images, allows these synthetic objects to be learnt more accurately and recognised (say, smoke is associated with an engine, pollution with the street) even if their real counterpart is odourless (the odour may be related to an invisible but relevant characteristic of the object, such as temperature).

- Exploration of real environments in teleoperation, i.e. guiding a remote robot, for example inside a nuclear power plant, or in a craft at the bottom of the ocean or in a spacecraft in orbit round the earth. Virtual olfaction gives an invaluable help in broadening the sensory bandwidth of the pilot's brain. It has been proven that the smell modality may vehiculate further information related to the environment when the visual and auditory modalities are saturated: practical examples are the odorants added to the natural gas to allow people recognise leakage (Sanders, & McCormick, 1993), or released in mines through the fan to raise the alarm.

However, olfaction has played a significant role in human learning and memory. Adding an olfactory component to an environment could reduce stress, increase information processing, enhance memory performance through better problem solving, reduce response times, produce fewer errors, increase recall, recognition, and retention, and enhance productivity, alertness, and physical performance (Washburn, Jones, Satya, Bowers, & Cortes, 2003). Virtual olfaction, providing essentially for an enrichment of the sensory modality range, is able to be fruitfully inserted in many of the possible systems, except when transmitted information is involved, as well as when the model source of the interaction is derived from scanning of real settings, or when time and space of scanning and display should be aligned (Figure 4).

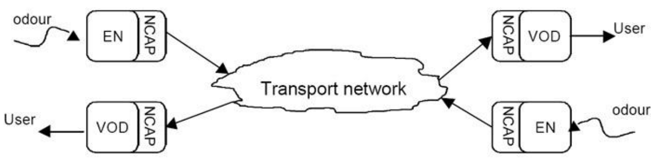


Figure 4. Scenarios for including olfactory information in virtual technologies. Olfactory enabled communications, a symmetric situation in which emphasis is on transporting sensorial cues relevant to human communication (Adapted from Davide, Holmberg, & Lundström, 2001)

In this scenario the virtual olfactory display should receive information about the type of smell, its concentration, its temporal dynamics and its spatial localisation. This information should be provided by the electronic nose, when present, otherwise by a computer simulator. This introduces the problem of smell coding. To codify information in order to transfer it has always been very important to man.

CHARACTERISTIC OF SCENT

How long does an odour last before fading a way and when should the display represent it? The common strategy is to avoid smell habituation, using repeatedly short or smoothly varying exposures (Davide, Holmberg, & Lundström, 2001).

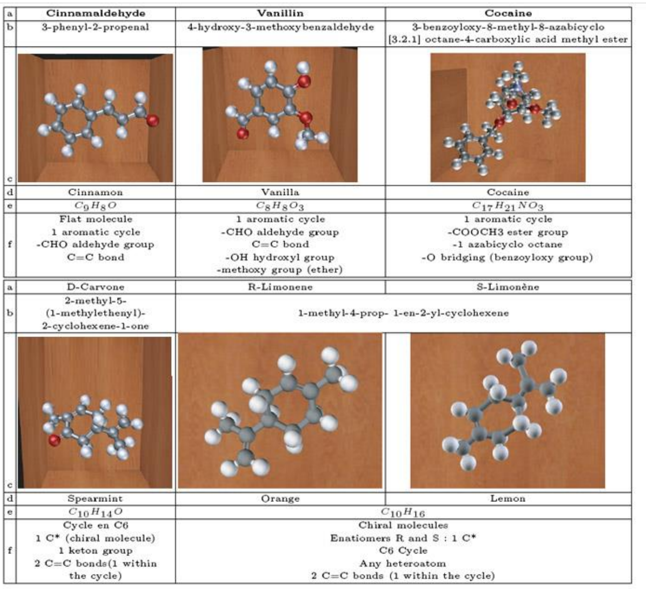
Smell researchers refer to smell quantity and quality as the metrics in measuring the bandwidth of olfactory displays (Kaye, 2004). The bandwidth of smell is limited, as compared to vision and hearing (Bodnar, Corbett, & Nekrasovski, 2004). This means that conveying information through scent must rely on the qualities, not the quantities, of the scent. The same instance of a smell with a different intensity may smell completely different (ETSI, 2002). Coupled with our inability to sense levels of a scent, and variability in doing so across individuals, information must be displayed by the presence or absence of a scent (Kaye, 2004). This is one of the reasons why other modalities, for example visual, are more effective. For instance, a bright flashing light is more important than a dim flashing light.

However, studies by Brewster, McGookin, Miller, and Olfoto (2006) showed that people could recognize three levels of smell. However, Kaye (2004) disagrees with some of the results, stating levels of the smell intensities used in their study vary extensively, both across the population and across individuals; fluctuations in individuals studied over time have been shown to be as much as the variation in a population as a whole. Therefore, it is important not to rely on scent intensity for any information display.

The study by Brewster, McGookin, Miller, and Olfoto (2006) described earlier, did not fully take into account the low bandwidth of scents. The scents that participants used to tag their photos had to be stored away, to be used again for the recall test two weeks later. The researchers did not anticipate the scents losing their intensities during this period. As a result, the scents actually smelled different during the recall test and many participants had a difficult time recognizing them. Combining different scents to convey information is more useful than attempting to manipulate intensities (Kaye, 2004).

It has been recognized by many experts in the field that smell is inappropriate for conveying rapidly changing information (Kaye, 2000). Smell is generally appropriate for displaying slow-moving, medium-duration data because they tend to linger, and the duration of a smell may vary due to variations in air supply or ventilation (Hamnes, 2002).

There is increasing evidence to support that smell is a potent trigger for emotional memories (Gutierrez, 2004). According to Kaye (2001), odors evoke more emotional memories than other stimuli. Herz and Cupchik additionally showed that if the cue for recall is hedonically congruent with the object to be remembered, the memory for the original emotional experience can be enhanced. There is also evidence to suggest that an unpleasant odor can have negative effects on task performance, mood, and health. However, there is no actual statistical data to confirm this (Figure 5).



a	Cinnamaldehyde	Vanillin	Cocaine
b	3-phenyl-2-propenal	4-hydroxy-3-methoxybenzaldehyde	3-benzoyloxy-8-methyl-8-azabicyclo [3.2.1] octane-4-carboxylic acid methyl ester
c			
d	Cinnamon	Vanilla	Cocaine
e	C_9H_8O	$C_8H_8O_3$	$C_{17}H_{21}NO_3$
f	Flat molecule 1 aromatic cycle -CHO aldehyde group C=C bond	1 aromatic cycle -CHO aldehyde group C=C bond -OH hydroxyl group -methoxy group (ether)	1 aromatic cycle -COOCH3 ester group -1 azabicyclo octane -O bridging (benzoyloxy group)
a	D-Carvone	R-Limonene	S-Limonène
b	2-methyl-5-(1-methylethenyl)-2-cyclohexene-1-one	1-methyl-4-prop- 1-en-2-yl-cyclohexene	
c			
d	Spearmint	Orange	Lemon
e	$C_{10}H_{14}O$	$C_{10}H_{16}$	
f	Cycle en C6 1 C* (chiral molecule) 1 keton group 2 C=C bonds(1 within the cycle)	Chiral molecules Enatiomers R and S : 1 C* C6 Cycle Any heteroatom 2 C=C bonds (1 within the cycle)	

Figure 5. "Olfactive Molecules": common name (a); chemical name (b); « ball and stick » style representation (c); associated odor (d); raw formula (e) and structural characteristics (f) (Adapted from Tijou, Richard E., & Richard, 2006).

OLFACTORY DISPLAYS

A variety of attempts have been made over the past 50 years to develop an electronic nose capable of detecting and recognizing smells. This article is not the place for an overview of these technologies, but in considering an output device, it is important to consider the corresponding input. These devices use a set of polymers, each of whichbond to varying degrees with different molecules, producing characteristic changes in electrical resistance. A variety of electronic noses are used in research and manufacturing. Artificial noses have not come close to the accuracy and versatility demonstrated by our noses, let alone those with more specialized olfactory apparatuses, such as dogs (Kaye, 2004).

Smell interfaces are also called olfactory displays. In general, an olfactory display consists of a palette of odorants, a flow-delivery system, and a control algorithm that determines the mixing ratios, concentration, and timing of the stimulus (Gutiérrez, Vexo, & Thalmann, 2008).

Some commercial companies already sell olfactory displays, also called “odour generators”, for personal computer use. Examples are AromaJet, DigiScents, and TriSenx. They all use a number of chemicals stored in a type of cartridge, and upon receiving a signal describing an odour, they release a mixture of these chemicals. This is done for example by using pumps similar to the ones used in ink printers. The resulting gas mixture is then blown towards the user with a small fan. So far, no standardised way of describing the odours has been created, so, one smell will be represented in different ways by different manufacturers.

The structure of an olfactory display is shown in Figure 5. It is a layered structure made of three tiers. The lowest is the odorant formation and storage tier, with the task to provide in the vapour phase the specific odorant giving the required olfactory sensation, regardless of concentration, and other smell qualities. It contains chemical reactants and reactors, vaporisers, the carrier gas for dilution and a waste storage. If the odour codification for prototypes is adopted, this tier should store a specific odorant per prototype, resulting in a severe constraint on the number of prototype odours.

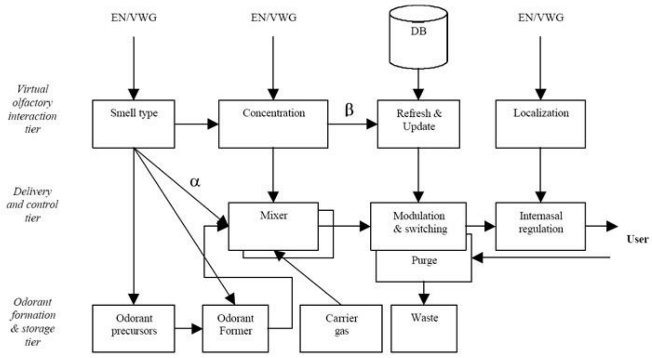


Figure 5. Schematic of a virtual olfactory display. The structure is layered, with three tiers identified.

Remarks: EN/VWG means that input can come from an electronic nose or from a virtual world generator; arrow α is a control given only in case of prefetching of alternative smells; arrow β represents information about concentration and type of the actual smell, both needed for refreshing properly; the rightmost pile, Localization – Internasal Regulation is present only if a head mounted display is concerned (Davide, Holmberg, & Lundström, 2001).

In general, there are two types of olfactory displays, multiuser and individual. Multiuser olfactory displays are used in special rooms. An airflow within the space is generated by an array of fans. Moving air is then controlled by a series of diffusion screens. Individual olfactory displays generally include devices and use an air cannon that track the user's nose to present smells. This fires a focused vortex of air so that other users do not smell anything. However, the system had some problems, one of the most important was that the temporal duration in which users could detect the smell was too short. The smell would not be perceived if the users exhaled when a scented vortex reached their noses (Gutiérrez, Vexo, & Thalmann, 2008).

An experiment by Bodnar, Corbett, and Nekrasovski (2004) compared the effectiveness and disruptiveness of olfactory output modality with visual and audio, as a notification mechanism in a messaging application. A number of different scents were used as notifications. scent notification was much less disruptive than both the visual and audio notifications.

Another study by Brewster, McGookin, Miller, and Olfoto (2006) yielded similar observations. The study looked at smell for searching digital photo collections. An experiment was setup which requires participants to tag their personal digital photo collection with both scent and text. They returned two weeks later to use the scent and text tags to help remember the tagged photos. Observations during the tagging stage showed that some scents were only identified by certain people. This implies that individual differences play a large role as some people are better at using smell than others. The researchers concluded that **smell** has potential, and the reason for the low performance with scent tagging is due to the participant's lack of familiarity with using olfaction in a computer interface (Figure 6).

Figure 6. Photo one of the latest-version olfactory display (Nakamoto, Kinoshita, Murakami, & Yossiri, 2009).

In this study personalized olfaction devices researched because of their small size and the ease of dissipation and control of odors.

DigiScents

A pioneer in this area, DigiScents developed iSmell, a device consisting of pots of oils infused with different scents. The developers believed they could generate any smell from a combination of a few basic smells, but it is unclear whether anyone has scientifically proven this claim. Unfortunately, the iSmell device was never commercially available, and DigiScents declared bankruptcy and closed down in April 2001.

Aromajet

Aromajet [www.aramojet.com] also developed a prototype aroma-dispensing device. Users could wear or place a small device called Pinoke in front of a monitor. Aromajet also has a kiosk system that lets users create their own fragrances from a custom combination of scents.

ScentAir

ScentAir Technologies [www.scentair.com] has created many olfactory systems, but its primary focus is on retail-space, or ambient, odors. Recently, it developed technology for providing multiple scents on cue in coordination with training or simulation systems. Called the ScentKiosk Scent Dispenser, the system dispenses precise fragrance volumes direct to a user via a tube.

Trisenx

Trisenx [www.trisenx.com] released a beta unit of its Scent Dome system in 2003 (see Figure 3). The device is small and has 20 different scents in its scent cartridge. Users can mix the scents in any amounts to create different odors.

Scent Collar

The Institute for Creative Technologies (ICT) [www.ict.usc.edu/disp.php] and AnthroTronix [www.anthronix.com] have developed the Scent Collar, which fits around a user's neck.8 It holds four scent cartridges and is controlled by a wireless interface.

Projection-Based Olfactory Display

The Advanced Telecommunications Research Media Information Science Laboratories [www.mis.atr.jp/~yanagida/scent] wanted to create an unencumbered olfactory display. The projection based olfactory device emits a clump of scented air from a location near a user's nose through free space rather than scattering scented air by simply diffusing it into the atmosphere. To implement this concept, the labs used an "air cannon" to generate toroidal vortices of scented air (Yanagida, Kawato, Noma, Tomono, & Tesutani, 2004).

SAMPLE APPLICATION: SUBSMELL SYSTEM

SubSmell is like a subtitle in the movie which the movie maker accompanies the text title to the movie, to describe what the actor/actress is saying. In this case scent is accompanied to the movie to describe what scent is in that scene. It is called the SubSmell system. The SubSmell system works similarly to other media player application forms. SubSmell application has to be opened on the computer which is connected with an olfactory display. The system is divided into two parts: software and hardware. The software, SubSmell, is the main module which would read SubSmell in the movie, and then send the signal through ports of an olfactory display to release scent to the audiences. The olfactory display is a prototype that releases scent using fans. The audiences have only to play the movie which has the SubSmell logo with the SubSmell program, and then they would sniff the movie. The system overview is shown in Figure 7.

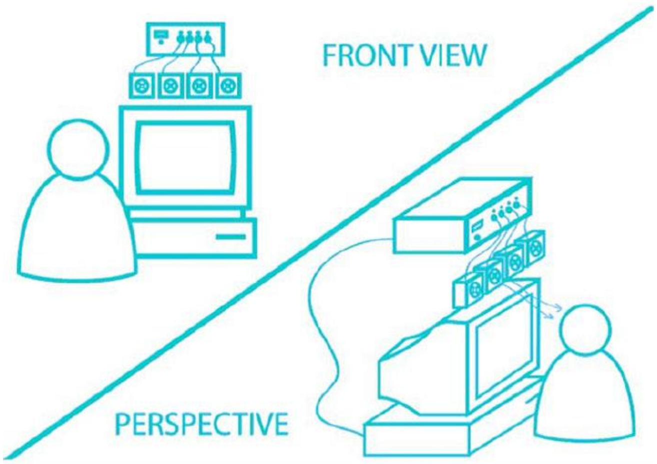


Figure 7. SubSmell System Architecture Overview (Adapted from Pornpanomchai, Threekhunprapa, Pongrasamiroj, & Sukklay, 2009).

To provide a better understanding and more detail of each operation of the SubSmell system, system structure chart is introduced (as shown in Figure 8) and elaborated on how each model works. The SubSmell system consists of four main process modules. They are 1) Controlling Movies, 2) Read SubSmell, 3) Release Scent, and 4) Olfactory Display Monitoring. The second level of the structure chart gives the main tasks which have to be done in each component (Pornpanomchai, Threekhunprapa, Pongrasamiroj, & Sukklay, 2009).

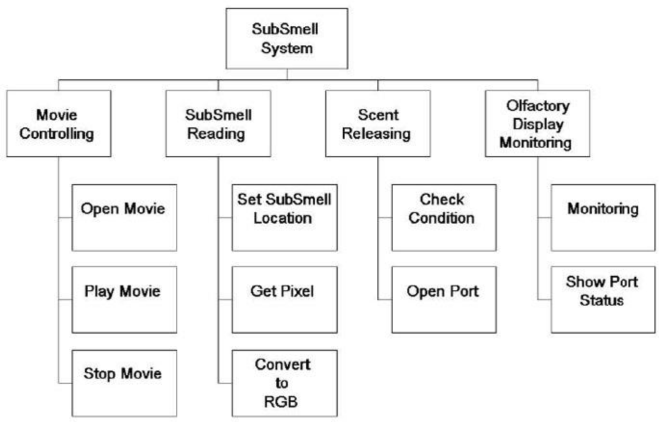


Figure 8. SubSmell System Structure Chart (Pornpanomchai, Threekhunprapa, Pongrasamiroj, & Sukklay, 2009)

For the SubSmell system, three main control instructions are provided for seeing the movie. They are in the form of buttons (as shown in Figure 9). The first is Open Movie, which is normally open. A pop-up window will appear for user to choose a movie file that they want. After choosing the file, the system will load the movie to the buffer and show the chosen file name in the title text field. The second control is Play Movie, which plays the chosen movie. The last control is Stop movie. User can click on this button to stop playing the movie. This stop is not like other stops in most programs. It does not go to the end of the movie and then stop it. To stop is like to pause the movie and then play back or play other movie files (Pornpanomchai, Threekhunprapa, Pongrasamiroj, & Sukklay, 2009).

Figure 9. SubSmell System User Interface view

To release the scent of the movie, there should be a machine, as shown in Figure 10, which can release each scent as what user like. There is example of the olfactory display with three scents and one clear state. The architecture of the olfactory display comes from a basic idea to keep the scent source in a small box, and then use a fan to blow out a scent, and blow in to clear a scent (Pornpanomchai, Threekhunprapa, Pongrasamiroj, & Sukklay, 2009).

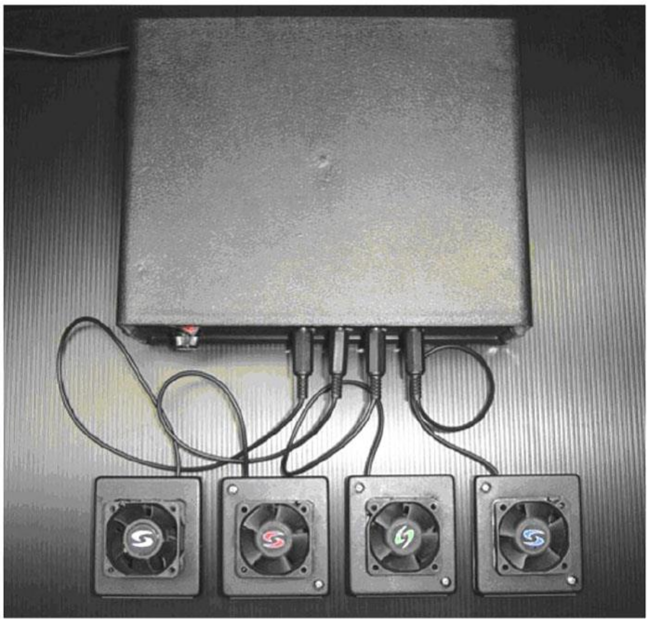


Figure 10. Olfactory Display Model

DISCUSSIONS

In order to have a closer look to the technology, let us start from the functional specifications that a general-purpose olfactory display should match, paired with the relevant psycho-physiological issues. The first specification is: how many and which odours should be provided in a certain application domain. The answer cannot be given on the technical basis that in principle places no constraint, but it should come from physiological studies, most of which agree that untrained subjects are able to make absolute identification of 15 to 32 common odours without training and noise, and of 60 (at the best), after training and still without noise (Desor, 1974).

As mentioned previously there is no counterpart of the three primarycolors in olfaction; this means that it is difficult to provide virtual alternatives, and one might always have to use real scents (Yanagida, Kawato, Noma, & Tetsutani, 2003). However, it is possible to create virtual scents with current technology, such as the commercial mixing systems developed by Kaye (2004), but the degree of precision at which this is done is poor. Consequently, fake smells smell fake. This is why any currently available system for computerized scent output will rely on having a small selection of already mixed scents that can be emitted on demand.

The lack of odor classifications and standards can lead to the subjectivity of smell interpretations, due to cultural and individual differences. To elaborate, the same smells can mean different things to different people (Kaye, 2004).

Cultural differences can also lead to misinterpretations with scents. Davide, Holmberg, & Lundström (2001) states that associations with smells can also vary by culture. For example, the scent of root beer is considered pleasant in the United States, whereas the same aroma is associated with a strong disinfectant in the United Kingdom. However, this did not seem to have a large impact on both of the studies. Cultural variations usually take the back seat as the variations across individuals are far greater and usually more predominant. For instance, hypersensitivity to scents is a common problem for many people (Gutierrez, 2004).

Another factor is that human olfactory capabilities differ by gender, age, number of odors used, whether odors mix, and the time it takes to detect an odor before automatically becoming desensitized or, worse yet, sickened by it. (Washburn, Jones, Satya, Bowers, & Cortes, 2003). For the business to take off, it may be necessary to create a standard way of describing odours, like MP3 is used for music. This might happen in the near future, either by adopting one of the companies' solutions, or by creating a common platform. Since these products have only been on the market for a very short time, it is too early to say if the quality is high enough, and if there is a large enough demand for these products.

Research shows that there is a need of investigation on olfactory displays. An interactive model of sub-smell system might be designed to teach organised bodies of knowledge for long-term retention. Regarding multiple intelligence theory, many of the feelings like audiory, visual and kinestatic are covered; however, there is a lack of research about olfactory. In this sense, olfactory might be considered as a new kind of intellegince and more research might focus on this issue. New subsmell systems might increase learning and teaching activities in different learning environments. Also, subsmell systems might be integrated into different 3-d and digital materials. In this way, learners might increase their learning experience. For example, retetion, motivation and focus on learning level might be increased.

CONCLUSION AND FUTURE WORK

Smell has its limitations and disadvantages as a display medium, but it also has its strengths and many have recognized its potential. Extensive research is still needed in the field, but previous studies have given us valuable information in building successful scented computer systems.

It may be concluded that the SubSmell system supports the following:

- The movies audiences can view the pictures with aesthetic quality, which means they can see the scenes and smell the scents simultaneously,
- The audiences get more detail of the movie, either scene, sound or smell, which makes it more entertaining and interactive.

Olfactory displays should rely on users distinguishing different smells, not the strength of smells. Smell is generally appropriate for slow-moving, medium-duration data. Despite these problems, smell is an excellent medium for ambient media. Other strengths include its ability to trigger emotional memories, and improving learning and memory abilities in subjects. Like any other interaction medium, smell has its affordances, but it also has a great deal of potential and make for a valuable interface.

With studies into this field by many different researchers, it is easy for results from different studies to contradict without a standard set of guidelines for which olfaction can be evaluated against. I believe it is crucial that at the research stage there be some clear guidelines to compare olfaction with visual and audio displays.

This research recommends that motivation and focus of student learning using olfactory systems might increase retention and academic success. Using olfactory systems in education seems to be a new technological aspect to increase student learning. Researchers must focus on new methodological issues in education like olfactory systems. The enrichment of the environment in the educational activities enables both the understanding of the subject and the learning activities of the learners. In this context, supporting the teaching environment with subsmell system that will serve different kinds of intelligence is of great importance in terms of seeing the students with different dimensions.

On the other hand, according to Youngblut: "odors can be used to manipulate mood, increase vigilance, decrease stress, and improve retention and recall of learned materials" (Youngblut, Johnson, Nash, Weinclaw, & Will, 1996). In the near future people can transfer each other by means of a computer and a mobile phone not only multimedia messages, but also various smells, the Japanese scientists declare The group of researchers of the Tokyo institute of technologies led by Takamichi Nakamato has declared creation of the special device, capable to identify and translate aroma in the digital form. It will be interesting to watch research progress as such devices become readily available and affordable. There are hundreds of patented researh in “methods and apparatus for odor transmission and reproduction” topics in United States as well.

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