

Smell As Media

Joseph 'Jofish' Kaye

MIT Media Lab

20 Ames St E15-413

Cambridge, MA 02142 USA

+1 617 253 9396

jofish at media dot mit dot edu

ABSTRACT

In this paper, I envisage a world where smell can be controlled by computer as easily and effectively as we currently control sound and video. I explore the history of smell, and pay particular attention to the history of combining smell with other media, with a view to noting and understanding mistakes made, and learning from them. I present a prototype system, inStink, that uses smell as an ambient medium to communicate presence and activity information at a distance. I look at the current and future state of technology to manipulate smell under computer control and outline user interface guidelines for the use of smell as a media.

Keywords

Smell, scent, ambient media, presence awareness, activity awareness, communication.

INTRODUCTION

New media take time to develop and be used for to their full potential. Initial uses of a new medium frequently echo the most recent widespread medium, as evidenced by early television programs, and corporations initial uneasy use of the web.

Computer controlled devices for producing scent have been announced and are starting production. However, most of the uses proposed see aromas being used to support other media: smelltracks for movies, the smell of gunpowder during shoot-em-ups. I am exploring other uses for smell in the context of users and computing, leveraging in particular the attributes that make it ideal as an ambient media. I am interested in understand the process by which smell becomes a medium for information exchange.

Smell As a Medium for Information Exchange

Smells have always conveyed information, from warnings – burning, damp, gas – to more positive scents – cooking, wine, perfumes. The change that comes with computer control is the ability to freely map input onto output regardless of data origin, in the manner of tangible [4] and ambient [16,33] media. Smell-output devices are a calm technology [32], moving easily from the periphery of our

attention to the center and back. It is this quality that gives smell such potential as a medium.

Why Now?

Technology

Over the course of the last year, a number of companies – notably Digiscents and TriSenx - have issued press releases saying they will market products that release smell under computer control. At the time of writing, only TriSenx claims a device available for purchase, but a great deal of publicity [23, etc.] has been generated by these announcements. I feel that the technology has reached the stage where it will start to become commonly available with desktop and console systems over the next few years, much in the way that the speaker has become a common computer peripheral with the increasing availability of high quality sound production on the PC.

It is worth understanding that the technology itself is not revolutionary. There are a number of patents implementing a variety of multimedia-linked scent systems, dating back over the last thirty years. [11,27...] What has changed is the manner of interaction with computers, which is primarily a change in society.

Society

In addition to this technological change, I also see a change in the role of entertainment and experience in society. From virtual reality and IMAX to extreme sports and a swell in global tourism, we are seeing the desire to have rich, full experiences. [22] and an increase in the importance of immersion. Smell is possibly our most emotionally loaded and powerful sense[13]; it has a great deal of potential in a society placing increasing emphasis on rich experiences.

HOW WE SMELL: A BRIEF PRIMER

A brief understanding of the mechanism of smell is necessary to understand some fundamental facts about how computer generated smell can and cannot work.

We have approximately a thousand different kinds of receptors in our nose, each of which reacts to a small group of odors. [10]. Compare this to vision, in which we have only four different kinds of receptors - red, green, and blue cones plus rods. This is the fundamental problem of computer smell production

Any given molecule will combine with some number of receptors to varying degrees and produce a characteristic

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response. An entirely different smell will combine with another but perhaps intersecting set of receptors, each to a varying degree. It is for this reason that smell is fundamentally not additive: smell A and smell B combined will not necessarily smell like A and B, but can smell like C, an entirely different scent. [19].

Thus, in theory, a palette of about a thousand [8] key odors be will exhaustively generative; from these all others can be mixed. One company, Digiscents, has proposed a device using 100-200 basic scents [23], and it seems likely that such a selection, due to the combinatorial nature of scent, would give a large number of useful smells.

One of the problems, however, is creating a rigorous and reproducible classification scheme for smell that is not input or output device specific. The science of smell¹ has a history of various classification schemes. At best, they are consistently descriptive although arbitrary; at worst, merely arbitrary. If a single company creates a scheme for a single output device, they have control over the exact smells it can produce, and exactly what is meant by 'cinnamon' or 'chocolate' or 'Smell #22'; this is the approach Digiscents is undertaking. [23] I feel there is a need for a MIDI-like industry-wide standard to codify the quantification of odors; I also recognise that this is not a trivial undertaking.

A Brief Word on Input Technologies

A variety of attempts have been made over the past fifty years to develop an electronic nose capable of detecting and recognising smells [21]. 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. The majority of these noses work in one way or another similarly to a human nose: they have a set of receptors which bond to varying degrees with different molecules with varying changes in electrical or chemical properties. A variety have been produced and are commercially available and used in research and manufacturing. Artificial noses have not come close to the accuracy and versatility demonstrated by our noses, let alone more those with more specialized olfactory apparatus, like such as bloodhounds. [8]

PROS AND CONS OF SMELL AS A MEDIUM

The advantages and disadvantages of smell as a medium for information exchange frequently intersect. Smell is fundamentally an ambient medium and shares the advantages and disadvantages of other ambient media. There is a basic problem in all media that it's hard to verify that the message has been received, and it's even harder in ambient media. However, this is problem that rests in choice of message, not medium; smell is rarely suited for mission-critical information representation except in the simplest of forms.

¹ Osmotics, delightfully enough.

Pros

Smell has the advantage that it's ambient, can be subtle, and hard to ignore. It can linger over a period of time, and is powerfully evocative: individual smells can bring back deep, strong memories. It is intrinsically powerful. We can be effected by smell and recall memories without having to consciously identify the aroma; we can focus our attention on smells or, at least to some degree, ignore them.

Cons

These same qualities can be disadvantages. It is possible for users to be temporarily or permanently unable to receive smell information – having a cold, or anosmia. The slow refresh rate of smell can be a problem, such as the smell of grass in the desert above. Furthermore, differentiating different smells can be hard: if three smells are already in a room, it's hard to determine the presence of the four.

There is also the problem of dispersal. Office cubicles are currently designed with the express purpose of controlling the dissemination of video and audio. [2] Smell, on the other hand, spreads: you may be aware when the coworker next to you is drinking coffee. As such, smell is perhaps more useful in a context where enveloping the user to give a total experience is more important than privacy of information.

Current smell output technology has are technology-, rather than medium-, specific. . For example, many of the smells seem unpleasantly artificial, and can sometimes be overwhelming. Furthermore, there is currently no directionality in smell production, although some evidence shows that stereo smell could have real advantages, particularly in the field of VR.[34] Fundamentally, we do not yet understand what the users' expectations of smell as a medium will be.

Why Fake Smells Smell Fake

A typical natural smell will have hundreds [7]of molecules that combine together to make the distinctive aroma of that natural smell. This can be shown through gas chromatography. A flavorist or fragrance scientist will take the twenty or thirty primary odors within that set and work with them to produce an approximation of the original smell which can then be relatively easily produced chemically. [7] The limitation comes in the fact that it is hugely difficult for a human being to keep a hundred different parameters in mind when adjusting a smell, and even thirty requires a great deal of training. However, as computer technology for sensing smells improves, it will presumably become possible to more closely map original smells.

Allergic Reactions

One issue that arises with respect to any use of airborne fragrance is allergic reactions, such as asthma. There exists industry self-regulation that is of limited use, as actual fragrance formulas are trade secrets and therefore the U.S. FDA's authority (and similar non-US bodies) is limited.

There is a small handful of products that may not be used [30] in fragrances, and ingredients commonly used are tested by the Research Institute for Fragrance Materials. However, materials patented and/or proprietary to a single company are not tested, other than by the company itself.

It is reasonably clear that current fragrance testing is inadequate, at least for the 1-2% of the population who are sensitive to fragrances. It is also clear that the percentage of allergy and respiratory disease sufferers is increasing. There has been an increase in grassroots efforts to bring awareness to this problem, most notably the Fragranced Products Information Network. [9] I consider it important for researchers to work with such organizations to minimize side effects as a basic Universal Design principle.

SMELL IN HISTORICAL CONTEXT

The amount that is written on a given subject is not an exact measure of how much there is to say. About smell, a great deal has been written. (Boring, 1942, in [5].)

1952 saw the publication by the Airkem Company of an exhaustive bibliography on odors and the sense of smell, with over three thousand references [5]. Much more has been written since then. Over the course of history, scents have held varying degrees of societal importance. We currently use smell far less than other cultures have in other times, and I feel there is an understanding and appreciation for possible uses to be gained from study of its uses in different contexts. With this in mind I present a look at historical uses of smell before addressing more recent approaches to aroma in conjunction with other media.

Smell in History [7]²

I have divided the last few thousand years of smell into three stages. To the Greeks and Romans, smell, scents, and perfumes were far more important than they are today. During the Middle Ages, the importance of smell for pleasure decreased, becoming something that was considered primarily for medical reasons. The fundamental awareness of scent was as an indicator of disease. Intrinsically, the Middle Ages saw smell (of plague, for example) treated not as a *sign* of disease but as the disease itself. In today's world, with our knowledge of germs and viruses, this seems nonsensical, but this was once assumed to be a fact of life. The use of perfumes and fragrances as we know them today – rather than to cover up and thus avoid disease – is a notable change from this attitude.

It is interesting to note that throughout history, changes in use of smell have started with expensive and specialized applications and trickled down to everyday life. I see an analogy with the way that other computer-controlled output media have emerged; the SoundBlaster card was initially a product for high-end gaming systems, and has now been accepted as a standard peripheral, even being integrated

into the motherboard. I project a similar path for computerized smell.

Smell in Antiquity

Aristotle's student Theophrastus is generally acknowledged to be the first person to write a treatise on odors, but Aristotle earlier wrote that pleasant odors preserved health. History is full of references to the connection between smells and health, culminating in aromatherapy today. In both Greece and Rome, personal use of perfume was common, even to the degree of having different body parts scented with different scents. Households were also heavily fragranced: even animals such as dogs and horses were sometimes perfumed. Reasons were both aesthetic and practical: cedar, heavily used, kept away moths, and smoke (from burning incense) kept away rodents. At banquets, there was much use of fragrant garlands, flowers, and incense; the guests were often both fed and perfumed. Roman theatres were frequently scented with saffron and other strong smells.

Roman gods delighted in fragrant ambrosia, while in Christianity, saints were frequently cited as having heavenly fragrances: either by exhaling them or making their presence known by some pleasant aroma. Fifth-century monk Simeon Stylites, who lived on top of a pillar, was reported surrounded by a sweet fragrance, growing in intensity until he died. One of the more common miracles accepted by the Catholic church is that the bodies of saints emit the scent of lilacs, leading to a practice of digging up the bodies of saints to check for appropriately aromatic purefaction.

Middle Ages to the Eighteenth Century

Heavy use of fragrance was denounced as 'pagan sensuality' and discouraged by the Church. The bodily odor was viewed as 'honest reek' allotted to the body by the maker.. As the Black Plague hit Europe, encouraged by this increased urbanization, it was generally believed that the disease was passed by the stench of death: the ring-of-roses and pocket-full-of-posies in the childrens' rhyme were to overcome the smell and thus ward off the disease.

Late Eighteenth Century to Today

The late eighteenth century saw a sanitary revolution: a revival of the bathhouse, moving towards private baths and showers, starting with the upper classes and moving down. A process of increasing attention to cleanliness and sanitation continues today, possibly to an extreme, and we have seen a return over the course of that progress to increased use of scent, but (ideally) in a personal and intimate manner.

Smell in Print: Literature

Victor Hugo, Honore de Balzac and Emile Zola, 'set out to depict the olfactory landscapes of their novels as graphically as the sanitary reformers detailed those of the streets and cities they wished to cleanse.' [7] Notable in particular is a passage in Proust's Remembrance of Things

² I note and apologise in advance for a Western bias in this history.

Past [23], in which the taste and smell of a tea-soaked *petite madeleine* evokes similarly rich and detailed sensory memories of childhood. Aldous Huxley describes a sensory performance in his *Brave New World*, in which the scent organ plays 'a delightfully refreshing Herbal Capriccio' before accompanying a 'coloured, stereoscopic feely,'

Even an overview of smell in literature this brief would be amiss if it were to leave out a mention of Patrick Süskind's 1986 novel *Perfume*, [26] a book entirely concerned with the topic of smell, starring an olfactorily talented yet socially deviant protagonist.

SMELL AS MEDIA

The last hundred years have seen a variety of experiments combining smell with other media. It has recently had some success in museums, and I chart the progress from there through its conjunction with performance, film and previous work with computers.

Smell As Media: Museums

There has been some use of smell to accompany exhibits in museums. Sometimes the smell is a focus unto itself, such as the Odorama exhibit in the Pompidou Center, or the Aquivit exhibit at the Wine & Spirits Museum in Stockholm. Perhaps more interesting is the approach taken at the Jorvik Viking Museum in York, England, in which Viking-appropriate smells were piped into exhibits, a process that researchers found aided remembering the information shown in the exhibit. [1] This study is a very interesting example of the use of smell in comparatively informal education, and I think it has some interesting parallels when similarly implemented in a virtual medium.

Smell as Media: Theatre

Roman theatres were often richly scented with saffron or other scents; amphitheatres had fountains spray scent into the air. The perfumes helped mask the many unpleasant odours arising from the entertainment of the time: not just the smell of the crowd, but the blood of wild animals spilt on the sand or of burning flesh. [7]

Use in theatre in more recent times has been rarer. The role of smell in a performance is generally to increase the immersive effect of the experience, to encourage the audience to accept on a deeper level the events that occur onstage. There is, however, a problem: audiences can be brought out of the scene by the novelty of scent, commenting on it, rather than being further immersed as desired.

The German choreographer Pina Bausch's 1982 show *Nelken* involved the scent of carnations wafting out into the audience. Moses Pendleton's 1985 ballet *Baseball* had the aroma of fried onions and marijuana wafting out into the audience, with the intention of setting the scene for a baseball match. 1988 saw English National Opera staged a production of *Love for Three Oranges* where audiences

were provided with Scratch-n-Sniff³ cards. The opera was later televised, and the BBC-run *Radio Times* magazine included cards for the home audience to smell while watching.

Smell As Media: Film

Smell has probably been most explored as an experiential medium in conjunction with film. 1906 saw the first documented use of smell in conjunction with movies, when a Pennsylvania cinema owner added the scent of roses to a screening of the Rose Bowl football game.[18] AromaRama was the first attempt at combining smell and film, relying on industrial perfumes being wafted through the cinema's ventilation system: it arrived in 1959 with *Behind the Great Wall* and was quickly forgotten. 1960 saw the introduction of Smell-O-Vision, piping scents directly to the seat of each viewer. Critics were not impressed: one New York Times review began with the phrase 'If there is anything of lasting value to be learned from Michael Todd Jr.'s 'Scent of Mystery', it is that motion pictures and synthetic smells do not mix.' [29]

John Waters was the next director to attempt the use of smell, with deliberately kitsch scratch-n-sniff cards handed out to the audience for his 1981 film *Polyester*, a technique also used by the Independent Cable Network in 1999 who sent viewers 'decoder cards' for a special edition of the animated series *Cow and Chicken*. [17] It is important to distinguish between the immersive nature of the preceding smell devices and the disassociative relationship of Scratch-n-Sniff cards to their accompanying media.

These technologies have gone to the graveyard of dead media, remaining one-off novelties. I feel it is significant that despite the fact that both AromaRama and Smell-O-Vision flopped after a single movie, the technology has stuck deep in the popular memory.

Understanding how and why they flopped is, important in looking at the future of smell and computers. The 1959 Time Magazine review of *Behind the Great Wall* [29] lists their complaints: 'To begin with, most of the production's 31 odors will probably seem phoney, even to the average uneducated nose. A beautiful old pine grove in Peking, for instance, smells rather like a subway rest room on disinfectant day. Besides, the odors are strong enough to give a bloodhound a headache. What is more, the smells are not always removed as rapidly as the scene requires: at one point, the audience distinctly smells grass in the middle of the Gobi desert.'

These issues remain endemic to the smell domain: they are key problems that it will take time and experience with actually implementing devices to fix. The goal of solving

³ Scratch-and-sniff as a technology, particularly in the form of stickers, enjoyed a period of great popularity over the early 1980s, with pre-teens trading and collecting hundreds of stickers.

serves as the closest to a blueprint for good smell interface design that I have seen.

Smell As Media: Computers

There is a small amount of prior work on using smells with computers. Most notable is Morton Heilig's device, 'Sensorama', patented in 1962 [11] – and brought back to the attention of the public by Rheingold in 1991. [25] Sensorama looked like an arcade game and gave the user the experience of a ride through Brooklyn: the feeling of rattling over the cobblestones, of going around corners on a motorbike, the sounds of children playing and the smell of an Italian pizza shop as one passed by. Sensorama never received the funding it need to scale up to beyond the near-prototype level, and the technology quietly passed away.

There is some work on smell in virtual reality, although perhaps less than one might expect. Much of it has concentrated on the field of firefighter training [6], where smell gives valuable and potentially life-saving information about what is on fire, and where. There appear to be a few other research efforts looking at implementing smell in virtual reality, but they seem to be limited in scope. [34]

There has been some work in wearable aroma-producing applications, by Jenny Tillotson. These are currently limited to demonstration models, but I see potential for wearable applications, particularly as both wearable computing and dynamic aroma generation become more common.

There is a notable absence of use of smell in the ambient media literature, which I feel is strange, given that smell is such a perfect ambient media: it can move easily from our periphery to the center of attention and back out again. [16,33] Strong & Gaver's 1996 short paper 'Feather, Scent, and Shaker' looks at the possibility of a single device that produces scent so one party knows another is thinking of them. The piece leverages smell's quality of 'lingering like a memory'. [26]

INSTINK⁴

Patricia is working late at the office. She starts to smell turmeric, cumin, cardamom, wafting across her desk. That's right; she promised she'd be home tonight for dinner. Her husband Jose is cooking Indian food and the neighbors are coming over. Better finish up that email and head home.

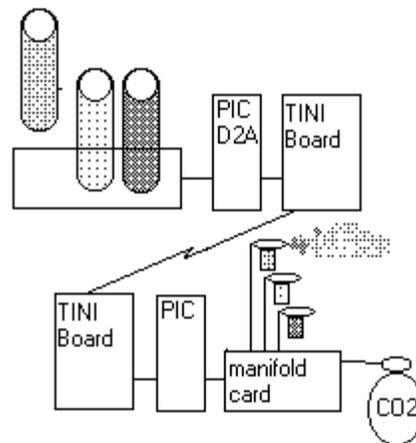
Imagine walking into your kitchen, and smelling gingerbread cooking- the cinnamon, the ginger, the nutmeg. There's something very comforting about coming home to the smell of Mum making gingerbread – even when she lives in Tokyo and you live in Boston.

⁴ inStink's name references both inTouch [3], and the deep, instinctual qualities of smell. There is no intended reference to the near-homophonic pop group inSync.

I originally wanted a method to enable a furthering of communication between kitchen spaces. The current state of both input and output technologies prohibits trying to replicate the exact smell of this particular chicken roasting, or that particular stir-fry. I wanted to avoid the use of artificial fragrances – 'Baking Bread', or 'Vegetable Soup', as they frequently smell artificial and unpleasant. In addition, by using the spices as abstract smell icons – 'smicons', if I may – we can create a generative set of scents, where a smell's meaning can start be detached from its conventional associations.

Implementation

Our solution consists of two components: a spice rack as a tangible input device, and a set of airbrushes under



computer control as an output device.

The input device looks and feels like a normal spicerack. Jars are inconspicuously tagged with resistors for identification, and can be placed anywhere in the spicerack and recognized as containing a given spice. A PIC chip does requisite analog-to-digital conversion and outputs the status of the rack at intervals to a TINI board, a single-board computer. When a spice jar is removed from the rack, the TINI board sends the spice name to the output device.

The output device consists of a TINI board, a PIC, a tank of CO₂, a manifold card of computer-controllable valves, and a set airbrushes in a rack. Where pots of paint usually go, these airbrushes each have a glass jar filled with an essential oil, a solvent (ethyl alcohol or water), and a dissolver to guard against separation of oil and solvent, 'Tween 20'. When the TINI board receives notification that a given spice has been used, it opens the appropriate valve for two seconds, allowing the gas to flow past the spice's essential oil and release the smell into the air.

I decided to only try and track whether a spice was used or not, rather than actually determining quantity. The crude



Figure 2: inStink Output

resolution of our output means that it's hard to distinguish between the smell of one teaspoon and one tablespoon of ginger; the important information is that ginger has been used. However, if a spice is used, returned to the spicerack, and then used again later then the smell is output twice.

User Studies

I did not gather formal information on user responses to the inStink technology. I discussed the project with many colleagues during development – often in response to the question ‘What’s that smell?’ In general, people were excited about the project but expressed concern about the quality of the smell and potential allergic reactions, issues that I have continued to research.

inStink: Analysis

I feel that inStink was successful in demonstrating the viability of computer-generated smell. The system is versatile enough to be adapted for other uses: I have proposed but did not implement a system whereby tagged, badged or otherwise computer-identified users entering one location would have their signature spice released into the air at the remote location, in the manner of much work in the field of CSCW (computer supported collaborative work).

Our informal user studies showed disappointment with the quality of smells generated: I had hoped that relying on natural essential oils would give satisfying results, but whereas some aromas were pleasant and full (mint and black pepper, for example) others remained thin and unpleasant (notably cinnamon). I regret not performing more strenuous user testing. However, I felt and still feel that I wish to concentrate on potential uses for similar commercial technologies, rather than duplicate current commercial effort in attempting to produce a viable and scaleable technology.

I note for the record that our prototype smell producing device, inStink, whilst it has advantages such as natural scents and increased volume over commercial products, will likely be obsolete within a year or two as commercially available smell units come on to the market.

POTENTIAL USES FOR SMELL AS A MEDIUM

Learning

Perhaps the most interesting application for smell technology is as an aid to learning and education. Several experiments have shown that an ambient odor present at encoding and retrieval facilitates memory, although there is some dissent. [7, 14]. Herz [13] concludes that novel odors and contextually inappropriate smells help in memorization.

The majority of this research has been conducted within the domain of cognitive science; however, I feel the most powerful use of such research is in areas outside of formal learning, where the desire is to acquire and retain information. Computer-controlled smell output gives the individual a simple method to invest their own cognitive processes with the advantages of smell-assisted learning.

Presence and Activity Awareness

The connecting-to-the-kitchen scenario is an abstract and limited example of an attempt at WYSmIWISm work. WYSmIWISm of real-world locations is difficult with today's input and output technologies, as there is a fundamental disconnect between the two ends. Much easier is output of similar scents at different locations, ignoring the ambient scent of the location (which, arguably, would not be noticed by the user after a period of time anyway.) For example, I envision chat rooms that allow their users ‘signature scents,’ emitted upon entry to all users of the chat room. Particularly intriguing is the idea of combining signature scents, stereoscopic smell output [34] and a physical chat room layout, such as Chat Circles.[31]

Alertness + Affect

There exists some work on the use of smell to induce alertness, such as in the case of drivers falling asleep at the wheel. [20] Unfortunately, it appears that the scents tested so far are only effective in cases where the driver has had sufficient sleep the night before. In general, even strong scents are ineffective at waking subjects from sleep, which has been shown both experimentally [20] and anecdotally – the 1666 Pudding Lane fire, starting in a sleeping baker's oven, resulted in the destruction of all of London.

In Conjunction With Other Media

The majority of uses proposed by companies making smell-producing devices involve their use in conjunction with other media to produce a richer sensory experience, rather than the ambient media-based solutions presented here. Such uses include smelltracks on DVDs, websites with signature scents, and output combined with food-related shows and websites. I have also had interest from musicians interested in creating a deeper and more immersive experience at concerts.

In fact, I expect this – particularly gaming - to be the primary reason why smell-releasing devices are purchased. Much of the development of PC-based sound systems for the consumer market was aimed at gaming, and the current

widespread use of computers to play music rests on that backbone.

Evocative & Whimsically

It has been shown that odors are equivalent to other stimuli in their ability to elicit accurate recall of memories, but differs in that odor-evoked memories are deeper and more emotional [13]. I propose evoking the smells of old perfumes or other similar scents to prompt storytelling: a version of this was done by Herz and Cupchik [15] and Rubin, Groth and Goldsmith, but with a purely analytical rather than historical and creative aim.

Free-Media Mapping

An intrinsic feature of ambient media is that it is possible to map any piece of information onto any output medium. Wisneski [33] demonstrates mapping stock prices onto a device that can become hot and cold. I am currently in the purpose of implementing a similar system that conveys the same information through smell, called 'Dollars & Scents.' In the event of your stock or portfolio rising, it outputs roses; falling prices smell like lemons.

One area that has been suggested is that of medical compliance: a smell from a small device to remind you to take your pills, perhaps implemented within a house or as part of clothing or a bag. The ambient and diffuse nature of smell is well suited to this task; however, I feel that it should be in conjunction with other media as a backup to ensure reliability.

Other Identification

There are a number of possibilities for the generation of smell in cases where smell currently already conveys information, yet is geographically limited. For example, waking up to the smell of coffee or bacon frying can be a delight, but depends on one's bed having some physical proximity to the kitchen – and someone else making breakfast.

I do expect to see an increased association of physical locations with scents. This is one area where the emotional associations can help: for example, if one's parking level is marked with the scent of cut grass, it only serves to further remind you if you associate cut grass with going to your grandfather's house every Sunday. There is also the potential for physical and virtual locations to have similar smells: there is potential marketing value in the Body Shop and bodyshop.com having identical smells, particularly if this continues into other domains, such as print advertising.

Smell has a great deal of both advantages and disadvantages in this field in particular. Smell does have the advantage of being evocative; on the other hand, I recognise that it can and frequently is overused, which is far from pleasant.

CONCLUSIONS

I feel that there are a great deal of potential for the use of smell as an output medium; however, it is a medium with

the potential to be extremely intrusive, and care must be taken to avoid gratuitous and brassy use. In particular, I think there is a great deal of potential the fields of learning technologies and ambient media, although I expect initial uses to be for gaming applications – despite the emphasis of manufacturers on 'scented websites', which I do not see users purchasing a product to experience.

I note that users are very sensitive to artificial and fake-smelling scents. Great care is must be taken to attempt to produce an effect that works with other stimuli, rather than overwhelm them.

As such I propose a set of key problems that I feel must be addressed in exploring the role of smell as a medium. The problems that the New York Times identified in their review of the 1960 Smell-O-Vision premiere *Behind the Great Wall* [29] remains relevant and applicable to those addressing smell as media today. I reiterate:

'To begin with, most of the production's 31 odors will probably seem phoney, even to the average uneducated nose. A beautiful old pine grove in Peking, for instance, smells rather like a subway rest room on disinfectant day. Besides, the odors are strong enough to give a bloodhound a headache. What is more, the smells are not always removed as rapidly a the scene requires: at one point, the audience distinctly smells grass in the middle of the Gobi desert.'

These three problems of smell accuracy, intensity and duration are the key areas that must be addressed for automatic smell devices to become an accepted and viable technology.

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