Symbolic Olfactory Display

by

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1. Abstract

We are used to smell informing us about the state of things in our immediate vicinity; the aroma of bread baking or coffee brewing, or the odors of damp or burning. Emerging technologies will make possible computer-mediated scent. Computers will be able to control the output of smells as easily as they currently control video or audio. Computer control gives us the freedom to separate source from scent in an entirely new way. Scents can be used in a symbolic way, released as cues to signify an event or condition.

My work here explores the development of these smell icons, or "smicons." I will trace the history of smell science, focusing on the past, present and future of smell synthesis machinery. My thesis is that smells can be used as symbols to convey information, as a unique and powerful enhancement to communication systems.

I will attempt to characterize the circumstances under which smell is a desirable or preferred means of conveying information. I will demonstrate a system that uses scent to signal reminders for upcoming appointments, and I will determine a mixture of scents to convey two or more bits of information for this purpose. I also hope to design and build a more accurate smell output device, or aromatron, than exists today, with the ability to mix two smells and vary the concentration over time.

The primary changes to this revised thesis proposal are the above paragraph and Sections 6.3, 6.4, and Section 7.

2. Table of Contents

3. Reader Biography

In 1984, Marc Canter founded MacroMind, the company that went on to become Macromedia. As such, he was involved in the invention of Director, the world's first multimedia authoring tool.

After leaving Macromedia, Marc started Canter Technology in 1992, which focused on developing interactive, scalable and networked multimedia products. Under Marc's leadership, Canter Technology created MediaBand, the world's first interactive music video (1992-1994), the Marc Canter Show, a scalable talk show delivered over the Internet (1995-1996) and the MediaBar, a cyber restaurant and club that explored the potential of location-based entertainment as a stepping stone to interactive TV (1996-1997).

In 1998, Marc helped develop and deploy the ChoiceSeat system for Super Bowl XXXII. This closed-net interactive system of 600 built-in, flat-panel, touch-screen displays enabled stadium attendees to switch between real-time camera feeds, watch replays from multiple angles, view game statistics, shop for souvenirs, play computer games and access the rules of the game. Later in the year, Marc was instrumental in building a prototype of a digital city for Trieste, Italy. He has worked extensively Digiscents, the current leader in computer-controlled smell emission, on their early demonstrations.

He continues to be an innovator and leader in the field of multimedia technologies.

Peter Brown is a Technology Principal at Kraft Foods. He is at the forefront of Kraft’s work with Digiscents and TriSENX.

4. Introduction

William Buxton speculated about what conclusions a future anthropologist would draw about our physical make-up, on the basis of the tools (computers) used by our society. (Buxton, 1984) He pointed out that modern computing fails to take advantage of certain aspects of our physical abilities, and reflects a very distorted view of our senses. For example, our standard input devices almost completely fail to take advantage of our highly developed sense of touch and control over pressure. We have evolved to make sense of our environment through hearing, and have auditory abilities far more sensitive than registering a simple beep. And needless to say, our future anthropologist would conclude that we had no olfactory ability at all.

Smells inherently inform us about the state of things in our immediate vicinity, be they burning cookies, damp walls or merely fragrant flowers. Much like sounds, a smell may be strongly tied to a specific source (like the crackle, and the smell, of a pine-wood fire burning); or smells may form more ambient scenic mixtures in the background (like the sensations of a misty autumn walk through the woods.) And, socially, we are accustomed to using smells to scent our bodies and rooms as decorations and masks for less acceptable odors.

But suppose we had the ability to synthesize smells: to describe and release any smell we chose under computer control. This freedom of separating source and scent immediately begs a question: how and when can smells be used in a **symbolic** way, released as cues to signal some arbitrary information? This is analogous to, say, using a sound cue like a distinctive ring to signal caller identity. What would such signals best be used to signify, and under what circumstances would they be most valuable?

I intend to define and map the field of symbolic display of information by olfaction. Specifically, my thesis is that symbolic smells, or smicons, will be enabled by new computer technology, and that they can and will become an essential element of the language of computer-mediated interaction. In this thesis, I'll present an extensive survey of the literature and history of smell, and explore the past, current and future state of the art of smell synthesis machinery. I will enumerate olfactory user interface guidelines, and demonstrate my hypotheses through implementing and testing a system that uses scent to warn the user of approaching appointments, in a manner demonstrably superior to the current audio-based system in use by devices such as the PalmPilot. In addition, I will design and hopefully build a smell production device with far great accuracy than the current state of the art, using inkjet technology to provide picoliter accuracy.

5. Background

5.1. Smell

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)

I have spent the fall semester extensively researching smell, and have read some four hundred articles, papers and books. My sorted and annotated bibliography is at www.media.mit.edu/~jofish/thesis/reflist.html. I present a selection of this work here.

5.2. How we smell: a brief primer

A brief understanding of the sensory perception 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 odours. Any given molecule will combine with some number of receptors to varying degrees and produce a characteristic response. An entirely different smell will combine with a 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. The nature of smell C can only really be determined by experimentation. (Pybus & Sele, 1999)

Compare this to vision, in which we have only four different kinds of receptors - red, green, and blue cones plus rods. Any colour can thus be mapped in three dimensions with another value for transparency. Mapping a smell would require a 1000-dimensional space. This is the fundamental problem of computerized smell production.

5.3. Aroma Emission Technologies

Currently, the company that is most notably exploring aroma emission technologies is Digiscents, a California-based startup who received extensive press coverage for their iSmell device. (Platt, 1999), etc. However, they are yet to actually market a commercial product, although they have demonstrated prototype systems at a number of trade fairs. Their design, the iSmell, is a serial device that uses pots of oils that are selectively heated and wafted out to the user by means of a small fan. They claim they will combine 128 ‘scent primaries’; in practice, it appears that they have used a selection of pre-picked individual scents.

TriSENX, another startup, has actually produced a scent-emission device that sits next to the computer: a small, hockey-puck shaped object that plugs into the serial port and produces a single scent, reminiscent of perfumed hotel soap. They have multiple-scent-producing devices in design. Their system design seems to be similar to Digiscents.

The absence of any commercial product has made it necessary for me to build my own aroma-output devices. I feel I have gained a valuable understanding of the problems and

challenges inherent in the design of such devices. I have recently had a number of discussions with Hewlett-Packard about the possibility of using ink-jet technology to build a smell production device with far greater accuracy than the above designs; discussions with Kraft have confirmed the necessity for greater accuracy in aroma portion control if the device able to generate new scent combinations.

I am assuming such devices will become readily available, thus facilitating the widespread implementation of the ideas I present in this thesis. Throughout history, adoption of new uses of scents have started with expensive and specialized applications and trickled down to everyday life. I see an analogy in 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, often integrated into the motherboard. I anticipate a similar path will occur for computerized smell.

5.4. Smell in Media & Computing

Several moviemakers have attempted to couple synthetic aromas with projected narratives, notably *Behind the Great Wall* (1959), filmed in AromaRama, *Scent of a Mystery* (1960), in Smell-O-Vision, and *Polyester* (1981) filmed in Odorama. The first two involved a scentrack, piped into the auditorium in conjunction with the film; the latter involved a scratch-and-sniff card. Many authors have explored the sense of smell in literature, including, notably, *The Remembrance of Things Past* (1891), *Brave New World* (1932), and *Perfume* (1971). One of the more interesting and relatively recent developments is the use of scent in museums, such as the Jarvik Viking Museum in York, England (Agelton & Wasket 1990), and the Old Bushmills Distillery in Dublin, Ireland.

There is some prior work in the conjunction of scent with computing: most notably *Sensorama*, (Heilig, 1962) an immersive virtual reality experience that took the user on a motorcycle ride through Brooklyn, complete with the smell of an Italian pizza shop as you drove by. *Sensorama* never received the funding it need to scale up beyond prototype levels, and the technology quietly passed away. There has been work on uses of smell in virtual reality (Barfield & Danas, 1995) – notably in firefighter training – but these have been surprisingly limited in scope.

All of these are concerned with smell adding an extra dimension of reality, with the aim of increasing the immersive nature of the medium. This is fundamentally different from the aim of this thesis, which is concerned with symbolic and iconic use of smell.

5.5.Information Display

We use smell daily to sense information about our environment. Burning, disease diagnosis, food freshness and cooking status can all be conveyed using smell. Invariably, this is information directly and concretely related to the immediate environment; the event or condition about which information is being conveyed through olfaction is in physical proximity to the person doing the sensing.

Abstract uses of smell, where the particular scent is not directly correlated to the data conveyed, are more rare. Historically, temples in Japan and China have a history of using incense clocks. A line of incense was prepared of a certain length such that it would burn

for an hour; a second incense would then burn for another hour, and so on. In such a way, one could tell time to the hour with a sniff. (Bendini 1964) Gaver & Strong use scent emission to let the user know a loved one is thinking of them in their short paper. (Gaver & Strong, 1996) Tillotson, of Charmed Technologies, has been researching clothes that emit scent, primarily for health and wellness applications; however, no fully working devices have been built. (Tillotson 1997)

6. Completed Work

To date, I have built two systems to date: *inStink*, and *Dollars & Scents*, have spent three days in extensive discussions with Kraft Foods, and have taught a week-long class on all aspects of smell. In addition, I have had a number of meetings and conversations with Hewlett Packard.

6.1. inStink: A first look at the symbolic nature of scent

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

inStink is a system that explores the use of scent to convey ambient presence and activity awareness. The input device is a spicerack, which looks and feels like a regular spicerack, sitting in a kitchen. At internet distance away, perhaps in an office, sits the output device: a system of airbrushes, each of which has a diluted essential oil corresponding to the spices in the rack.

The relationship between the spices output and the food cooked is a synecdoche of smell: representative parts stand for the whole. There is a direct relationship between the spice and the smell emitted. However, the scents of cinnamon and ginger and nutmeg imply gingerbread – but perhaps apple pie, or spice cake. There is a fundamental difference between the foods implied by those scents, and those suggested by turmeric, cumin, and cardamom. In this way, *inStink* begins to explore questions of abstraction.

6.2. Dollars & Scents: Abstract relationship between data and scent

Dollars & Scents is an attempt to reproduce previous ambient media research using different medium. Wisneski explored ambient display of stock market changes through a personal device held in the pocket that would heat up or cool down depending on the state of the market. (Wisneski, 1999) *Dollars & Scents* takes an identical input, but releases scents into the air: roses if the stock is going up, and lemons if it's going down. At the time of writing, *Dollars & Scents* is not fully implemented: the smell output device has been built, but the interface to stock market prices is not yet finished.

6.3. Kraft Foods

I spent three days meeting with various people from Kraft's Flavor and New Technologies groups. Out of this came a greater understanding of the requirements of fragrance and flavour chemistry, some very indepth conversations about the current state

of the art of flavor producing devices, with which they are extremely familiar, and a great deal of discussion of the future of such devices.

6.4.IAP Class: Experimental Aspects

I taught a four-day class over IAP, briefly covering all aspects of smell. In addition to being a useful review, a number of relevant issues were raised in the process of discussion, and I had an interested group of volunteers with whom I could conduct some preliminary testing. I started to explore my first goal, to determine an appropriate combination of scents to convey more than two bits of information.

In my first preliminary experiment, I asked subjects to distinguish between three bottles, one of which contained scent A, one of which contained scent B, and one that contained both. Twelve of the fourteen subjects correctly identified the mixed combination. Most of the class listed A as mint, spearmint, or peppermint, and most of the class identified B as anise, fennel or black liquorice.

In the preliminary second experiment, I tried expanding my field from three data points (all A, all B, and a 50/50 mixture of A and B) to five data points: 4A:0B, 3A:1B, 2A:2B, 1A:3B, 0A:4B. Before handing the bottles out, I confirmed that smell A was peppermint and B was anise, and asked them to put the five bottles in order from 100% mint to 100% anise. Nobody got the sequence correct; however, there does seem to be some correlation with the expected results. I intend to explore this further as a fundamental part of my research.

7. Research Plan

I intend to:

- ?? Determine an appropriate combination of scents to convey more than two bits of information, and demonstrate that such a combination is reliable.
- ?? Use that combination to implement an augmentation an existing scheduler program that uses scent to convey information about upcoming events, and perform appropriate user studies to demonstrate that it is superior to the existing audio-based system.
- ?? Determine a set of guidelines for the use of scent as a user interface.
- ?? Hopefully, design and build a better smell-producing device in collaboration with Hewlett Packard.

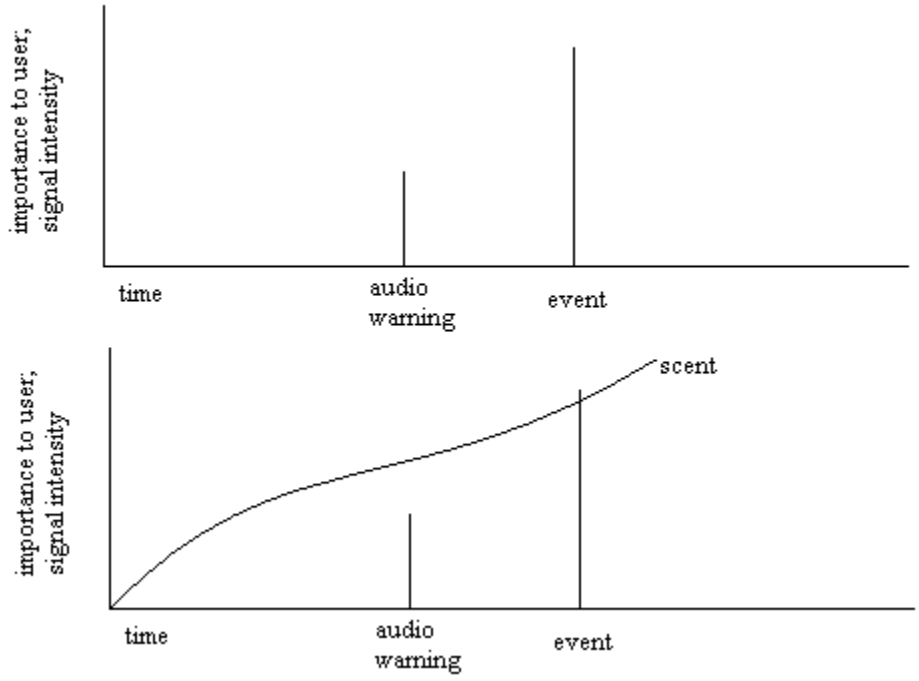
7.1.Conveying Information Using Scent

In my preliminary experiments, anise and peppermint were chosen arbitrarily, and the solutions were formed by dropping the relevant number of drops into water. I expect to perform several iterations of this experiment to determine a combination of scents and intensities that users can clearly identify in the above relative combinations, which will be of great use in conveying more than the two bits that the first experient suggests is possible. Determining the appropriate combination of scents is a non-trivial question, as

we are sensitive at different levels to different chemicals, and combinations of scents have again different responses.

7.2. Using Scent To Warn of Approaching Appointments

One of the most interesting ideas that came out of my Kraft visit was the possibility of using smell to convey information about upcoming appointments, much in the way the PalmPilot uses sound.



The upper graph demonstrates the current system as used by the Palm, and many other schedule organiser programs: at a fixed interval before the appointment, the user is given a single audio cue. The graph beneath demonstrates the advantage of scent as a warning: it can change over time to reflect the increasing need to attend to the event as it approaches. I intend to implement this idea as a proof-of-concept, and perform appropriate user testing to determine its effectiveness.

7.3. User Interface Guidelines

Over the last six months, I have built a library of possible situations under which smell may be used to convey information. Based of this research and my findings from Section 7.2, I intend to assemble a set of user interface guidelines for the use of scent to convey information. These will serve as guidelines for producing the tools that will be necessary to use smicons as part of the language of human-computer interaction.

7.4.Hewlett-Packard: More Accurate Smell Production

I have had a number of conversations with Hewlett-Packard about the possibilities of collaborating with them to build a more accurate smell producing device. As far as I understand both Digiscents' and TriSENX's devices, the degree of accuracy by which they can mix scents is very limited: a given scent can be turned on or off for a duration of time; the actual parameter controlled is the duration that the heater under the scent is turned on. By contrast, current inkjet technologies provide picolitre accuracy, and it is our hope that they will be adaptable to the task of spraying scent at a user rather than ink at a page.

I hope to collaborate with Hewlett Packard to build a prototype scent production device; however, since this will require extensive work with them, I am including it as a possibility rather than a certainty.

8. Timeline

- 8-12 January: Week at Kraft
- 16-19 January: Teach four-day course on smell
- 31 January: Background research chapter written
- 7 February: Background research chapter & thesis outline to readers
- 21 February: Appropriate combination(s) of scents determined
- 1 March: Second draft partial thesis to readers.
- 15 March: Software extension to scheduling software written
- 15 March: Hardware to output scent in relevant ratios designed and built
- 26 March: Hardware & Software integrated and working; user testing starts
- 1 April: Third draft: complete thesis to readers & external experts.
- 1-5 April: CHI. First complete working draft of thesis ready.
- 5-15 April: Incorporate feedback from CHI, readers into demos, thesis.
- 15 April Fourth draft thesis to readers.
- 16-18 April: CI. Second draft thesis ready.
- 18-30 Finish final draft.
- 25 April: Final draft thesis to readers
- 1-4 May: Layout and format thesis
- 4 May: Formatted final thesis to readers
- 11 May: Thesis Final Date.

9. Resources

9.1. Sponsors

I have been in close contact with a number of people at Kraft, including Bill Croasmun, Peter Brown and Gregory James. I expect to continue to develop this relationship. Kraft has extensive experience in the chemistry and practicalities of aroma and flavor, and a great deal of interest in the field of computerized scent.

I hope to continue collaborating with Hewlett-Packard to design and build a better scent-producing device. I have had a meeting with Grant Kinsman and conversations with others at HP. I believe their interest and experience with inkjet technologies will be very relevant to the possibilities of a droplet based scent emitor.

9.2. UROPs

I would like to have two dedicated urops. One will need experience in writing Windows extensions, and will be responsible for implementing an extension to an existing scheduling program; this is something beyond my programming skills. The other will assist me in building hardware devices. Both will aid me in user testing.

9.3. Space

I will require the shared use of the 068 kitchen as a laboratory for work with scents and use of the 468 electronics areas to build necessary prototypes. I will also need a quiet desk space in an office to enable me to concentrate and write with the necessary resources at hand.

9.4. Hardware

I will need to purchase some amount of chemistry paraphenalia – beakers, solvents, burettes, droppers, bottles and the like – to prepare the necessary scent combinations. I anticipate this will be a relatively small amount of equipment.

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