Olfaction Displays in Virtual Reality

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Abstract

The incorporation of olfactory stimulus in multimedia displays has been the dream of visionaries like Aldous Huxley and avant-garde filmmakers like Woody Allen. Recent development efforts have spawned many olfaction display devices, which can be adapted for use in virtual reality training scenarios. This discussion will begin with a primer on the physiology of olfaction, attempted classification scheme for odorants, and a historical review of the design and use of olfaction display technology. We will conclude with a list of prospective uses for olfaction displays in virtual reality training applications.

Introduction

“The scent organ was playing a delightedly refreshing Herbal Capriccio-rippling arpeggios of thyme and lavender, of rosemary, basil, myrtle, tarragon; a series of daring modulations through the spice keys into ambergris; and a slow return through sandalwood, camphor, cedar and newmown hay (with occasional subtle touches of discord – a whiff of kidney pudding, the faintest suspicion of pig’s dung) back to the simple aromatics with which the piece began. The final blast of thyme died away; there was a round of applause; the lights went up” (Huxley, 1932).

Aldous Huxley’s scent organ was designed to entertain audiences at the “feelies,” a projection of the future state of entertainment in his Brave New World. Although his prediction of the future has yet to materialize, recent developments in computer controlled olfaction display devices are bringing virtual reality closer to his vision. We will review the challenges of developing olfaction displays and present areas for near term research.

Physiology

The human smell and taste senses depend on complex, interconnected, chemical detectors that sample and analyze molecules from the environment. In the case of smell, these chemical detectors lie in two small patches of cells called the olfactory epithelium located at the very top of the nasal cavity. Each half of the olfactory epithelium contains on the order of five million olfactory neurons. Each neuron has at least ten hair-like cilia attached to it. These cilia protrude into a thin layer of mucus on the cell surface. It is in this mucus layer that odorant molecules are initially trapped and analyzed by proteins on the cilia. Each olfactory neuron is connected through a hole in the bone above it, called the criiform plate, to a part of the brain called the olfactory bulb. The size of the olfactory bulb is proportional to the degree of olfactory acuity in the species. The olfactory bulb in turn connects to the smell and taste sensory cortex. The workings of the olfactory bulb still remain a mystery as do the workings of another olfactory sensor called the vomeronasal organs (VNOs). If the VNOs in humans work the same way they do in rats, they would connect to an auxiliary olfactory bulb that connects to a part of the brain controlling maternal behaviour and reproduction, bypassing the cerebral cortex. If this alternative olfactory system exists in humans, we would have no conscious awareness of it (Pines, 1995).

Comparison to Other Senses

Our visual senses respond to electromagnetic energy that can be measured and reproduced on a convenient linear scale. So too can the pressure waves of sound be measured and reproduced in linear fashion. However, the first challenge faced in the design of olfaction displays is the
lack of a convenient linear scale on which to place the odor producing chemical substances which we will refer to as odorants. The number of individual odorants detectable by humans is estimated at about 10,000. As with the other senses olfaction acuity can be measured and classified: macrosmia (a good sense of smell), microsmia (a poor sense of smell), anosmia (a loss of the sense of smell), and parosmia (a perverted sense of smell) (Eisenberg, 2002).

Classification of Odorants
Since the time of Linnaeus, countless attempts have been made to classify odorants. All of the classifications reflect more about the cultural and social bias of the classifiers than the qualities of the odorants themselves. The two latest classifications are based on biochemistry and reflect more about the possible mechanisms of olfaction. The stereochemical theory classifies odorants by their molecular shape, dividing the population into seven categories (Amoore, 1964):

- Ethereal (dry-cleaning fluid)
- Camphoraceous (camphor)
- Musky (angelica root oil)
- Floral (roses)
- Pepperminty (peppermint candy)
- Pungent (vinegar)
- Putrid (rotten egg)

Most scents can be explained using Amoore’s theory, but many cannot. A more recent classification is based on vibrational theory which reflects the molecular structure of the odorants and explains the exceptions to Amoore’s theory (Turin, 1996).

Display Design and Use
A review of prior attempts to use olfaction displays in the entertainment industry reveals possible implementation pitfalls for VR. The first serious attempts were made in the late 1950s when cinema owners experimented with 3-D glasses, vibrating seats, and olfaction devices to lure theatregoers away from the rising popularity of television (Kaye, 2001).

AromaRama and Smell-O-Vision
The first such device, AromaRama, used freon gas to disburse odorants through the cinema’s air conditioning system, attempting to immerse the audience in a travelogue through China. The odorants were not realistic, the system provided little control over their intensity or removal, and the film was critically panned. The second device, Smell-O-Vision, was a more advanced system, which delivered odorants to the individual seats. This system also suffered from the use of unrealistic odorants, which were easily detected and critically rejected after only one attempted film, a murder mystery. The story writers must be credited with some creativity, though, for using an olfactory clue, the smell of pipe smoke at the crime scene, to engage the audience in the storyline.

Sensorama
The best early attempt at a multi-sensory virtual reality simulation was designed in the early 1960s by Morton Heilig (Heilig, 1962 in Kaye, 2001). About the size of a large video game, Sensorama was a motorcycle riding simulator that incorporated vibration sensing in the seat, fans to produce wind, and odorants released when passing pizza parlours and roadside flower gardens. The system was never commercially funded, however, despite years of development.

Scratch-n-Sniff
The next few decades saw few serious advances in olfaction displays with the notable exception of scratch ‘n sniff technology developed by the 3M Corporation. 3M encapsulated fragrances in a polymer coating that can be printed on paper and released by scratching the coating. Scratch-n-sniff cards played a frivolous role in the 1981 film, Polyester, but are used mostly for the advertisement of perfume samples. They do demonstrate the ability to store small amounts of odorants in a safe, compact package, which can be easily released when needed. An interesting use of Scratch-n-sniff came from Switzerland which issued a chocolate scented postage stamp in September 2001.

D.I.V.E.
The record of recent attempts begins with John Cater at the Deep Immersion Virtual Environment Laboratory of the Southwest Research Institute who designed an odorant delivery system for fire fighter training. Cater describes the early version of the system as a backpack mounted automatic scratch-n-sniff player that can deliver variable intensity odorants to the participants mask with a ¼ second response time. “Odors range from burning wood, grease and rubber to sulphur, oil and diesel exhaust. Lifetime of the odor cartridges is 6 months to a year without refilling. Olfactory output is…completely proportional from a hint
of odor to a stench that makes you want to rip the mask off...adds about $5000 to the cost of a VR system (Cater, 1992 in Kaye, 2001)."

**Recently Patented Devices**

A list of recent advances shows the level of interest and state of olfaction display development and integration:

- De Sousa describes a personal use olfactory dispenser similar in form to a compact disk player which uses a CD like disk containing embedded fragrance capsules (de Sousa, 1999 in Kaye, 2001).

- Prendergrass adds computer control to his device and claims it is “especially useful for providing a realistic sensory experience in an interactive or non-interactive use, and may be used in...the entertainment industry, the educational training field or a medical arena” and includes a virtual reality helmet and a neck-mounted individual smell output device (Prendergrass, 1996 in Kaye, 2001).

- Martin and Barbier further refine their devices incorporating breath sensors to time the odorant release and pressurized oxygen to speed delivery. At this point we should mention the chemical safety considerations for these devices. As Barbier states, “an over oxygenation of a zone or of a medium may indeed cause an activation of combustion phenomena, resulting in a degradation of some materials such as electric motors,” not to mention the wearer (Martin 1997, and Barbier, 1998 in Kaye, 2001).

- Corporate America enters the field led by IBM’s “Computer Controlled Olfactory Mixer and Dispenser for Use in Multimedia Applications” and “Aroma Sensory Stimulation in Multimedia.” Motorola holds the rights to a smell output device in a PCMCIA or PC adapter card and an Israeli company, Aromix, holds “Methods and Apparatus for Odor Transmission” and “Methods and Apparatus for Odor Reproduction” (Kaye, 2001). Can a wireless odornet be far away?

- Trisenx becomes a dominate player in the current olfaction device market, selling a software controlled 60 aroma Scent Dome for $269 and a single scent sampler device for $1.32 in bulk from their web site: www.trisenx.com.

- IST issues the Virtual Environment Software SandBox (VESS) 3.0.0 User’s Guide supporting olfaction devices and describing the hardware interface and software API for placing odors in a virtual environment (vess.ist.ucf.edu).

**Research Applications**

The previous discussion of olfaction devices points to the availability of cost effective olfaction displays for use in virtual reality training applications. The following discussion suggests uses for olfaction displays in virtual reality training applications.

**Memory and Recall**

The most promising application of olfaction displays may be the enhancement of memory and recall of skills learned in a simulation environment. The now classic description by Marcel Proust of long forgotten childhood memories evoked by the aroma and taste of tea soaked madeleine highlights the relationship between olfaction and recall (Proust, 1913). Improvements in recall may be accomplished by producing an ambient smell in the simulator training environment that will be present in the real world environment, thereby triggering recall. Several studies have found that improvement in memory resulted when the same ambient odor was present at both learning and recall (Schad 1990, Cann and Ross (1989), and Smith et al 1992 in Kaye 2001). A special case of memory recall training exists in the nursing and medical fields. Odors given off by the patient’s body can provide diagnostic clues to medical professionals.

**Presence and Immersion**

The attempts to introduce olfaction in the entertainment field, described previously, were intended to immerse the audience in the film experience. One reason they may have failed is due to the diminishing returns associated with combining input from multiple senses. When additional sensory input is added to existing sensory input without providing additional information, the more dominant sense will take over and the weaker sense can be ignored. The weaker sense can then be criticized for any discrepancies with the information provided by the more dominant sense. Olfaction displays may prove useful in increasing the sense of presence by simply masking any ambient odors in the simulator environment.

**Mood and Emotion**

As discussed in the physiology section, olfaction is a powerful, subliminal sense that operates in part at the subconscious level. Intentional or not, the addition of olfactory displays to a simulation has the potential to bring emotion, mood changes, and subconscious reactions to the participant. A careful study should be made in the selection of odorants and their predicted effects in a simulation.

**Abstract Information Display – Smell Icons**

As mentioned in the discussion of odorant classification, associating smells with information is learned and reinforced with each whiff. So, associating or
reassociating a smell with an abstract piece of information is easy to do. This is not a new idea. Incense clocks have been part of Chinese and Japanese temple rituals for a thousand years (Bendini 1964). The clocks, designed to burn a different incense each hour, allowed temple priests to tell the time to within one hour (the message: jasmine smell = it’s after noon). Smells are also used for alarm applications when no better indication is available. Since its inception, the natural gas industry in the United States has included small amounts of hydrogen sulfide gas in the odorless natural gas pumped into home communities to trigger alarm reactions in people who encounter leaking gas (the message: sulphur smell = move away!). North Sea mine networks are prepared to pump the scent of wintergreen into their extensive ventilation systems in the event of a catastrophe (the message: wintergreen smell = evacuate the mines!). Joseph Kaye at the MIT Media Lab has experimented with a two- aroma indicator device to notify lab visitors about the current status of the stock market. Dubbed Dollars & Scents, the computer controlled device emits the smell of mint when a selected market indicator is rising and the smell of lemons when it is declining (the message: mint smell = we’re making money) (Kaye, 2001). Kaye’s thesis work also proposes the use of smells as icons indicating the state or condition of a system in the same way that a computer’s icons indicate its battery charge level or network connection status.

Conclusion

If the recent flurry of interest in olfaction display design is any indication, these devices will soon become more readily available in the general population as well as virtual reality. Huxley’s scent organ will likely remain a fantasy, but the new devices will undoubtedly provide interesting research in the near future.

References


