Chapter 3
Basics for Olfactory Display

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ABSTRACT
An olfactory display, which is the olfactory counterpart to a visual display, is controlled by a computer or information equipment and provides smells to a human user. Because we sense smells through the air, the role of an olfactory display is to make scented air from odor materials in a stocked form with the desired components and concentration and to deliver the scented air to the human olfactory organ. This chapter provides a survey of various technologies, categorized by scent generation methods and scent delivery methods, used to construct an olfactory display. For scent generation methods, vaporization/atomization techniques, scent switching techniques, and formulation techniques are discussed. For scent delivery methods, several approaches to convey odor material from the scent generator to the nose are discussed. In addition, a brief description of evaluation methods of olfactory displays is provided.

INTRODUCTION
An olfactory display is a computer-controlled device that generates scented air with the intended component and concentration of odor material and provides it to the human olfactory organ. In general, the term “display” has implicitly referred to a visual display, which provides information through visual stimuli including texts and images. As its counterpart, an olfactory display provides olfactory stimuli instead of visual stimuli.

Although the technical field of olfactory display might seem to be relatively new, it has a long history comparable to that of audio and visual displays. The first example of using scent in conjunction with cinema can be found in 1906 (Gilbert, 2008). Surprisingly, this example precedes the use of sound. A famous example of a system incorporating smells with other kinds of sensory displays is Heilig’s “Sensorama,” developed in the early 1960s (Heilig, 1962). Users could enjoy multimodal movies incorporating breezes and smells. However, compared with the use of sounds or stereoscopic images, the use of smells in media technology has not become widespread. Only recently have smells been presented interactively in cooperation with computers.
Besides traditional ways of enjoying scents, such as aroma therapy and incense, several attempts have been made to apply computer-controlled olfactory displays in our life. Some entertainment attractions use scent; for example, McCarthy (1986) developed a scent emitting system that could emit a selected scent and produce a sequence of various smells. Toyota Motor Corporation, in the theater in their Amlux showroom, provided an aroma system that enhanced the experience of the audience. In 2005, the scent generator “Aromatrix” was used at a premium screening of the movie Charlie and the Chocolate Factory. The audiences were presented the aroma of chocolate, synchronous to the scene of being in the chocolate factory. NTT Communications conducted a social experiment to examine the effect of providing scents in an advertisement (Sakaino, 2008). On the academic side, an aroma blender was used as a part of a system that provided an interactive multimedia content showing a cooking procedure with the smell of foods (Nakamoto, et al., 2008). In 2011, Seems Inc. won the Ig Nobel Chemical prize (Improbable Research, 2011) with their alarm system to awaken sleeping people in case of a fire or other emergency by using the smell of wasabi (pungent horseradish) (Goto, Sakairi, Mizoguchi, Tajima, & Imai, 2011).

In this way, computer-controlled scent presentation has been gradually spreading in our life. In this chapter, the technical basics for recent olfactory displays are described.

TECHNOLOGICAL ASPECTS OF OLFACTORY DISPLAYS

Unlike sensory channels for which display technologies are already highly developed, such as visual and auditory senses, olfaction is a chemical sense. This fact makes it difficult to introduce olfactory displays in a similar manner to sensory channels based on physical stimuli. One of the characteristics specific to a chemical sense is its nonlinearity. The change of intensity of the stimuli (i.e., concentration of the odor material) can result in a qualitative change in subjective sensation. For example, a chemical compound that is recognized as having a good smell when its concentration is low can turn into a bad smell if the concentration is increased.

From the perspective of human-computer interaction, it would be interesting to examine how many kinds of smells are required to synthesize arbitrary smells. In addition, it would be helpful to compose a completely general olfactory display, if it was found that humans have a mechanism in olfaction comparable to the “three primary colors” in human vision. However, such a mechanism has not been found, or may not even exist. Previously, Amoore (1970), in his theory of stereochemistry, sophisticatedly categorized various odors into seven major groups of smells. Some researchers considered that these seven groups corresponded to the three primary colors, but recent progress in olfaction research shows that this does not sufficiently explain human olfaction. A breakthrough in olfactory research occurred in 1991. Using an approach from the field of genetics, Buck and Axel (1991) estimated the number of receptor proteins in mice to be approximately 1,000. Since then, physiological study on odorant receptors has made remarkable progress (Touhara, et al., 1999), and according to recent human genome analysis, 388 olfactory receptor genes have been found in humans (Niimura & Nei, 2003). Each receptor protein responds to multiple molecules, and a single chemical compound activates multiple receptors, resulting in very complex functions of human olfaction. The number of olfactory receptors can be an index that shows the order of required odor components for obtaining arbitrary smells, but researchers are still trying to find the minimum number of odor components required for achieving an acceptable quality of expressing arbitrary smells.

Nevertheless, from a practical point of view, we can proceed to develop olfactory displays without
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