Chapter 16
Bio–Inspired Background Suppression Technique and its Implementation into Digital Circuit

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ABSTRACT
Gas sensors have been widely used for various applications, such as gas leak detection, fire alarm systems, and odor-sensing systems. A problem of the gas sensors has been the selectivity to a target gas: background gases interfere with the measurement of the target gas. In the human olfaction, sensitivity to background odors is decreased by adaptation to the odors. Recently, several bio-inspired signal-processing methods mimicking the adaptation mechanism have been proposed for improving the selectivity of the gas sensors. In this chapter, the studies on the bio-inspired background suppression methods are reviewed. Furthermore, a case study of the bio-inspired background suppression is introduced. In the case study, a perceptron neural network with anti-Hebbian learning was used for realizing the adaptation to the background gas, and was implemented into a digital circuit for real-time gas sensing.

INTRODUCTION
Odor sensing systems have been developed in recent years (Nagle, Gutierrez-Osuna, & Schiffman, 1998), and are expected to be applied to practical applications such as gas leak detection, quality control in food industry, and environmental monitoring (Pearce, Schiffman, Nagle, & Gardner, 2003). The odor sensing systems can identify odors and quantify the concentration of the odors using odor sensors. The target odor samples are usually prepared in a small bottle and are measured under well-controlled temperature and humidity conditions.
In practical applications, however, it is sometimes necessary to measure an odor in an open air, where the target odor is drifted with other background odors. These background odors can be interferences in the measurement of the target odor. The odor sensing systems have to compensate the influence of the interferences for realizing accurate identification and quantification of the target odor.

A simple compensation method would be to subtract the baseline response of the odor sensor (the response to the background odors) from the measured sensor response (the response to the mixture of the background and target odors). This method would be satisfactory when the concentration of the background odors is constant. However, since odors in an open air fluctuate due to a turbulent flow (Yamanaka, Ishida, Nakamoto, & Morizumi, 1998), the simple compensation method will not work well. Therefore, a more sophisticated compensation method is required for the practical applications.

A method of the compensation (background suppression) has been proposed by mimicking the adaptation to an odor in biological olfaction (Gutierrez-Galvez & Gutierrez-Osuna, 2006; Gutierrez-Galvez, 2005). The method uses a neural model of biological olfaction (KIII model [Yao & Freeman, 1990]) with anti-hebbian learning (Principe, Euliano, & Lefebvre, 2000), and has been successfully applied to the background suppression (Gutierrez-Galvez, 2005). However, the KIII model, which has been developed for modeling the neural activity in the biological olfaction, is too complex to be used for the engineering purposes. In this chapter, a simplified bio-inspired method for the background suppression is introduced as a case study of bio-inspired background suppression methods (Ohba & Yamanaka, 2008). This algorithm was enough simple for the implementation into a digital circuit, which will lead to real-time gas sensing.

BACKGROUND

The adaptation is a common biological function in a sensory system, which allows the sensory system to reduce the sensitivity to previously detected stimuli, and then to improve the selectivity to a novel and interesting stimuli. In this chapter, we focus on the adaptation in the olfaction for developing bio-inspired signal processing methods for gas/odor sensing.

Neural computation models for olfactory adaptation or mixture segmentation have been proposed in various researchers (Figure 1). For example, Wang, Buhmann, and Malsburg (1990) proposed a neural model of pattern segmentation based on a neural network of associative memory, as shown in Figure 1 (a). They employed a neural network of oscillatory units linked with Hebbian connections to perform temporal segmentation of the stored patterns. Alternating bursts of activity induced by self-inhibition creates a spatio-temporal pattern that sequentially extracts the components of mixture.

Hendin, Horn, and Hopfield (1994) proposed models for the olfactory bulb which perform separation and decomposition of mixed odor inputs from different sources. Since the odors are unknown to the system, their model is considered as a blind-source separation problem. One of their models has hierarchical layers of neural network in Figure 1 (b), where each layer is inhibited by all previous layers. This network produces the different temporal fluctuations of the input odors.

Hoshino et al. have also proposed hierarchical models of odor-mixture recognition based on spatio-temporal encoding, shown in Figure 1 (c) (Hoshino, Kashimori, & Kambara, 1998; Oyamada, Kashimori, Hoshino, & Kambara, 2000). It models a neural mechanism for discrimination of different complex odors in the olfactory cortex based on the dynamical encoding scheme. Feedback signals from the bottom internuron layer
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