Neurocomputing 172 (2016) 394–398

Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

E-nose system by using neural networks

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ARTICLE INFO

Article history:
Received 15 September 2014
Received in revised form
3 February 2015
Accepted 18 March 2015
Available online 5 August 2015

Keywords:
E-nose
Learning vector quantization
Metal oxide gas sensor
Odor classification
Neural networks

ABSTRACT

This paper considers a new construction of an electronic nose (E-nose) system based on a neural network. The neural network used here is a competitive neural network by the learning vector quantisation (LVQ). Various odors are measured with an array of many metal oxide gas sensors. After reducing noises from the odor data which are measured under different concentrations, we take the maximum values among the time series data of odors. As they are affected by concentration levels, we use a normalization method to reduce the fluctuation of the data and reorder the measurement data according to the concentration levels to make the features invariant with the concentration levels. Those data are used to classify the various odors of teas and coffees. The classification results are about 96% in case of four kinds of teas and about 89% for five kinds of coffees.

1. Introduction

Recently, odor-sensing systems (the so-called electronic nose (E-nose) systems) have become important from technical and commercial viewpoints. The E-nose refers to a device of reproducing human sense of odor based on sensor arrays of odor using pattern recognition methods. There are several commercial E-nose instruments currently in use in the world such as quality control of food industry [1], public safety [6], and space applications [7]. In this paper we propose a new E-nose system which is independent of concentration levels based on a learning vector quantization algorithm.

Historically, James A. Milke [5] proved that two kinds of metal-oxide semiconductor gas sensor (MOGS) could have the ability to classify several sources of fire more precisely compared with a conventional smoke detector. However, his results achieved only 85% of correct classification by using a conventional statistical pattern classification.

An E-nose has been developed for odor classification of various sources of fire such as household burning materials, cooking odors, the leakage from the liquid petroleum gas (LPG) in Charumporn et al. [2,3] and Fujinaka et al. [4] by using neural networks of layered type. The E-nose has been successfully applied to the classification of similar odors from different kinds and the same kind of odors at different concentration levels. The time series signals of the MOGS from the beginning to the time until the MOGS fully adsorbs the odor from each source of fire are recorded and analyzed by the error back-propagation (BP) neural network. The average classification rate of 99.6% could be achieved by the BP method with only a single training data set from each source of fire. The accuracy with *k*-means algorithm is 98.3%. These results confirm the reliability of this new device in detecting various sources of fire in the early stage.

This paper proposes a new E-nose system to classify the various odors under the different concentration levels of teas or coffees using a competitive neural network based on the learning vector quantization (LVQ) method. The sensors used here are MOGSs, which are attached on the seal of the sampling box at grid points in an array. We have used 14 MOGSs of FIGARO Technology Ltd in Japan. We consider two types of data for classification in the experiment. The first type is four kinds of teas and the second one is five kinds of coffees of similar properties. The classification results of teas and coffees are about 96% and about 89%, respectively, which is much better than the results in Charumporn et al. [2,3] and Fujinaka et al. [4].

2. Principle of MOGS

MOGSs used in this paper are the most widely used sensors for making an array of artificial olfactory receptors in the E-nose system. These sensors are commercially available as the chemical sensors for detecting some specific odors. Generally, MOGSs are applied in many kinds of electrical appliances such as a microwave oven to detect the food burning, an alcohol breath checker to check the drunkenness, and an air purifier to check the air quality.

Various kinds of metal oxide, such as SnO_2, ZnO_2, WO_2, and TiO_2 are coated on the surface of semi-conductor, but the most widely applied metal oxide element is SnO_2. These metal oxides have a chemical reaction with the oxygen in the air and the

http://dx.doi.org/10.1016/j.neucom.2015.03.101
0925-2312/

chemical reaction changes when the adsorbing gas is detected. The scheme of chemical reaction of an MOGS when adsorbing with the CO gas is shown as follows:

$$\frac{1}{2}O_2+(SnO_{2-x})^*\rightarrow O^-\,ad(SnO_{2-x}) \quad (1)$$

$$CO+O^-\,ad(SnO_{2-x})\rightarrow CO_2+(SnO_{2-x})^*. \quad (2)$$

Here, $x=1$ or zero. The relationship between sensor resistance and the concentration of deoxidizing gas can be expressed by the following equation over a certain range of gas concentration:

$$R_s=A[C]^{-\alpha} \quad (3)$$

where R_s is the electrical resistance of the sensor, A is the constant, $[C]$ is the gas concentration, and α is the slope of R_s curve.

When the metal oxide element on the surface of the sensor is heated at a certain high temperature, the oxygen is adsorbed on the crystal surface with the negative charge as shown in (1). In this stage the grain boundary area of the metal oxide element forms a high barrier. Then the electrons cannot flow over the boundary and this makes the resistance of the sensor become higher. When the deoxidizing gas, e.g., CO gas, is presented to the sensor, there is a chemical reaction between negative charge of oxygen at the surface of the metal oxide element and the deoxidizing gas as shown in (2). The chemical reaction between adsorbing gas and the negative charge of the oxygen on the surface of MOGS reduces the grain boundary barrier of the metal oxide element. Thus, the electron can flow from one cell to another cell easier. This makes the resistance of MOGS lower by the change of oxygen pressure according to the rule of (3).

Generally, it is designed to detect some specific odor in electrical appliances such as an air purifier and a breath alcohol checker. Each type of MOGS has its own characteristics in the response to different gases. When combining many MOGSs together, the ability to detect the odor is increased. An E-nose system shown in Fig. 1 has been developed, based on the concept of human olfactory system. The combination of MOGSs, listed in Table 1, is used as the olfactory receptors in the human nose.

3. Experimental data and its pre-processing

We have checked the performance for two odor data as shown Tables 2 and 3, which are called Experiment I and Experiment II, respectively. Those data have measured by the E-nose system explained in the previous section and used in the later classification. Note that in Table 3 Mocha coffees of the labels A, B, and C are selected from different companies.

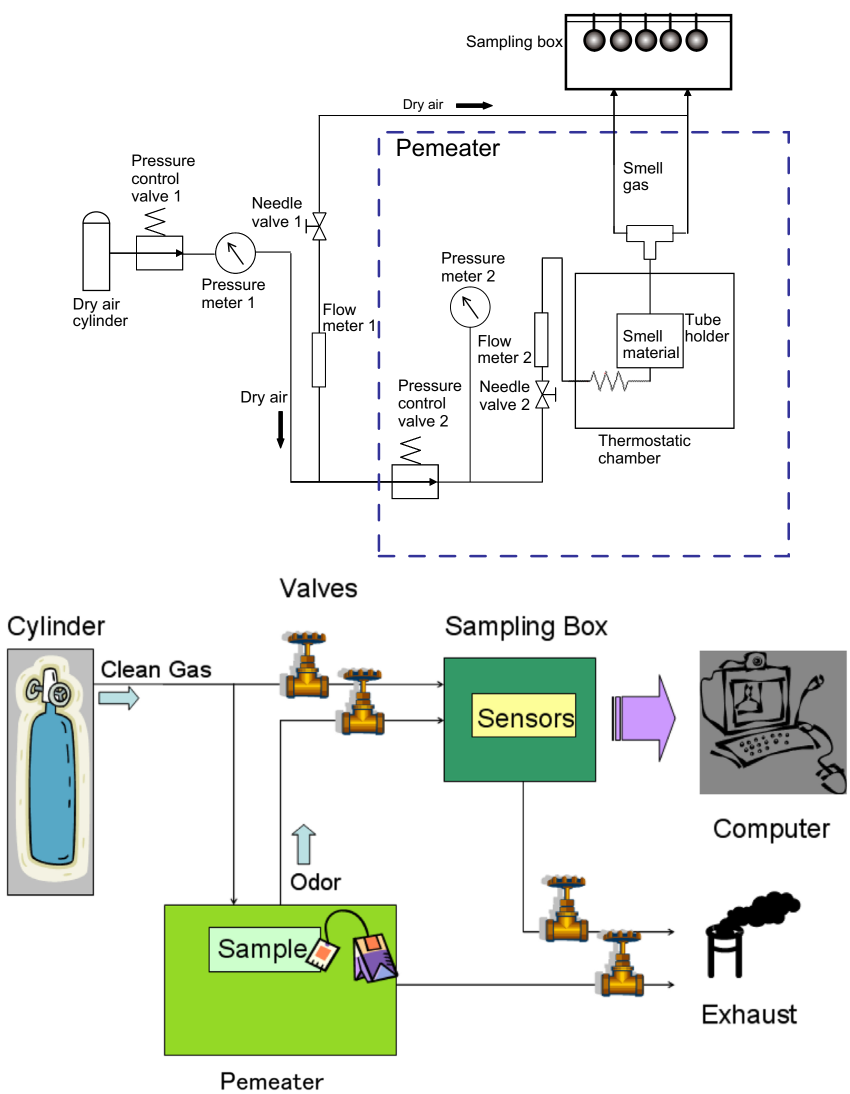

Fig. 1. Structure of the E-nose system.