CHAPTER 1

INTRODUCTION

1.1 Background

The importance of sensing and flavor detection can be seen in food industry which has shown devoted interest to food and flavor analysis using traditionally trained sensory panels and chemical analysis to specify and characterize raw materials to end products. As we know that food analysis is the biggest application field of smell sensing and analysis but other requirements like using dogs for detecting drugs and explosives at airports and customs also shown their need and interest in analysis of smells. All our traditional methods of smell sensing and analysis have series of drawbacks like human test panels and dogs are unreliable, costly and prone to fatigue, similarly chemical analysis is labor sensitive, time consuming and required trained specialists even if it is unbiased, accurate, and quantitative. So to get rid of all these drawbacks concept of artificial olfaction came into existence.

In 1982 Persaud and Dodd [1] had reported the design of the "electronic nose" for the first time in the history of smell sensors, they have shown that electronic nose can reproducibly discriminate between a wide variety of odors, and discrimination in an olfactory system could be achieved without the use of highly specific receptors. From then very fast developments have been seen in the concepts of e-nose and thier applications in many fields from food industry, medicine, public safety, environmental, cosmetics, robotics etc. Due to their potential, to help in a variety of applications, in the past few years, e-noses have generated much interest in food and beverage production [2], wine brand discrimination [3], fragrance and cosmetics manufacturing [4], environmental monitoring [5], medical diagnostics [6] and industrial robotics [7] etc.

The olfaction is the main sensory system used by humans to sense smell or flavor; so if we want to characterize the flavor of a particular substance, the use of smell sensor can provide us suitable information. First we should analyze things involved in “smelling” or what makes a “smell”, i.e., an odor. The molecules of odorant have some basic characteristics, they are light (relative molecular masses up to approximately 300 Da), small and polar and are often hydrophobic. A simple odor like alcohol contains only one chemical component. A complex odor like coffee may be a mixture of many different odorant molecules each in different concentrations. The term "electronic nose" is associated with an array of chemical gas sensors having properties of wide and overlapping selectivity for measuring the volatile compounds (VOCs), combined with computerized data analysis tools.

An electronic nose, mimicking a human nose is an intelligent and smart instrument that is designed using array of sensors to identify the chemical odors or to detect and discriminate the complex odors. The sensors are treated with a variety of odor-sensitive biological or chemical materials for detection of different smells. The most popular gas sensor or transducer is Metal Oxide Semiconductor (MOS) due to its high sensitivity and low price (typically, under 12$ each). It has some shortcomings also like need of pre-heating at temperatures up to 200–500 °C in order to facilitate the interaction with the target gas and have very long acquisition cycle because of their slow response, especially when recovering the baseline level after the exposure a particular gas ends [8]. This baseline level shows the sensor output in absence of target gases and varies with temperature, humidity and with variety of sensors.

MOS has a particular semiconductor behavior when exchanging oxygen molecules between the volatile and the MOS film so because of the chemical mechanism underlying MOS sensors the two limitations of temperature and long recovery time exist [9, 10]. To solve first problem of temperature limitation, pre-heating process carried out by built-in heaters which are powered up several minutes before operation. To solve second problem of long recovery time, we have to take repetitive samples in a short period of time. This is a more serious limitation in different applications.

Modeling of sensor response has been reported and exploited by different authors [11-13] as a double first-order low-pass filter, with a much higher time constant for the decaying phase.

Electronic noses are being integrated with other sensors on complex, intelligent platform especially in robotics that offers exciting application possibilities and considerable development challenges. The sensing system and the automated pattern recognition system are the two main parts of an electronic nose. The sensing system can be an array of different sensing elements (e.g. gas sensors), where sometimes each element measures a different property of the sensed odor or, mostly, the sensors respond to a complex odor with overlapped sensitivity that produce a characteristic signature or pattern [14]. This database of patterns used to train the pattern recognition system for classification purpose. This training process is done to configure the recognition system to produce unique classifications of each sample, to implement an automated identification. The pattern recognition system has two steps first is feature extraction to extracts useful information from the sensor signals and the second is pattern recognition algorithm. There are two types of pattern recognition techniques, supervised and unsupervised. In supervised pattern recognition, input patterns are learned and associated with a class of odor. In an unsupervised pattern recognition technique, feature space is made from the multidimensional configuration space given by pre-processor. The unknown sample is recognized by comparison to a knowledge base, from a previous learning scheme. The pattern recognition algorithms have a very critical role in the successful implementation of sensor arrays and electronic nose systems. Among many pattern recognition techniques, artificial neural networks (ANN) are very promising. The ANN is composed of neurons and the massive interconnection among them, regarded as the processing units similar to the brain of mammals. It has unique ability to produce reasonable outputs for new inputs not encountered during a learning process [15].

1.2 Objectives of Thesis

The main objective of the thesis is to develop a sensor system using MATLAB to show how an electronic smell system or e-nose system based on an array of MOS gas sensors, works. The sub-objectives are as follows-

To study the basic components of an electronic nose systems.

To study the research and development works that has been carried out on each part of electronic nose system from its origin till now.

To simulate and develop a sensor system that can be used in different applications.

To use a suitable model for modeling the response characteristics of the electronic nose sensors.

To use the suitable features of the sensor signals to apply on the neural network techniques specially RBFN and ANFIS for classification purpose.

To compare the results from the two classification techniques used for each of the applications.

1.3 Thesis Outline

The thesis at hand is made up of 5 chapters described as follows:

The first chapter presented introduction of the work in which the background of the thesis with a short description of the smell system is given. To end up this section, the objectives of the thesis are enumerated and explained.

Chapter 2 presents literature review in which human and artificial sensor systems are given with history of development. The first half describes the importance of smell and monitoring certain volatiles in human life, and then continues with a short exposition of various chemical sensor-based electronic noses detection technologies.

Chapter 3 presents description of the sensors used in the simulation work, modeling of data obtained from the dataset for the smells of 14 household items, and 10 toxic chemical that are dangerous for us and present in the environment. Then explained the RBFN and ANFIS the classification techniques used to recognize the smells.

Chapter 4 presents the results obtained from sensor array systems for the two applications and then analysis of the results has been done.

And chapter 5 draws the conclusions from the work done in these two applications and states future prospects of the work done.

List of References

[1] Persaud, Krishna; Dodd George (1982) **"Analysis of discrimination mechanisms in the mammalian olfactory system using a model nose"** *Nature* 299, pp. 352 – 355 Warwick Olfaction Research Group, Department of Chemistry and Molecular Sciences, University of Warwick

[2] Ampuero, S.; Bosset, J.O. (2003) **"The electronic nose applied to dairy products: A review"** *Sens. Actuat. B*, *94*, pp.1-12.

[3] Garcia, A.; Aleixandre, A.; Gutierrez, J.; Horrillo, M.C. (2006) **"Electronic nose for wine discrimination"** *Sens. Actuat. B*, *113*, pp.911-916.

[4] Nakamoto, T.; Fukuda, A.; Moriizumi, T. (1993) **"Perfume and flavor identification by odor-sensing system using quartz-resonator sensor array and neural-network pattern-recognition"** *Sens. Actuat. B 10*, pp.85-90.

[5] Baby, R.E.; Cabezas, M.; De Reca, E.N.W.(2000) **"Electronic nose: A useful tool for monitoring environmental contamination"** *Sens. Actuat. B, 69*, pp.214-218.

[6] Trincavelli, M.; Coradeschi, S.; Loutfi, A.; Soderquist, B.; Thunberg, P.(2010) **"Direct Identification of Bacteria in Blood Culture Samples Using an Electronic Nose"** *IEEE Trans. Biomed. Eng.*, *57*, pp.2884-2890.

[7] Distante, C.;Indiveri, G.; Reina, G.(2009) **"An application of mobile robotics for olfactory monitoring of hazardous industrial sites"** *Ind. Robot* , *36*, pp.51-59.

[8] Moseley, P.T.(1997) **"Solid state gas sensors"** *Meas. Sci. Technol., 8*, pp.223-237.

[9] Albert, K.J.; Lewis, N.S.; Schauer, C.L.; Sotzing, G.A.; Stitzel, S.E.; Vaid, T.P.; Walt, D.R.(2000) **"Cross-reactive chemical sensor arrays"** *Chem. Rev., 100*, pp.2595-2626.

[10] Sberveglieri, G.(1992) **"Classical and novel techniques for the preparation of SnO_2 thin-film gas sensors"** *Sens. Actuat. B, 6*, pp.239-247.

[11] Samitier, J.; Lopezvillegas, J.M.; Marco, S.; Camara, L.; Pardo, A.; Ruiz, O.; Morante, J.R.(1994) **"A new method to analyze signal transients in chemical sensors"** *Sens. Actuat. B, 18*, pp.308-312.

[12] Nakamoto, T.; Ishida, H.; Moriizumi, T.(1996) **"An odor compass for localizing an odor source"** *Sens. Actuat. B, 35*, pp.32-36.

[13] Yamanaka, T.; Ishida, H.; Nakamoto, T.; Moriizumi, T.(1998) **"Analysis of gas sensor transient response by visualizing instantaneous gas concentration using smoke"** *Sens. Actuat. A, 69*, pp.77-81.

[14] Martin, Y.G.; Oliveros, M.C.C.; Pavon, J.L.P.; Pinto, C.G.; Cordero, B.M. (2001) **"Electronic nose based on metal oxide semiconductor sensors and pattern recognition techniques: characterisation of vegetable oils"** *Anal. Chim. Acta*, 449, pp.69–80.

[15] Olafsson, R.; Martinsdottir, E.; Olafsdottir, G.; Sigfusson, T.I.; Gardner, J.W. (1992) **"Monitoring of fish freshness using tin dioxide sensors"** In *Sensors and Sensory Systems for an Electronic Nose*; pp. 257–272.