UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF E-NOSE HERB RECOGNITION SYSTEM BASED ON ARTIFICIAL INTELLIGENCE TECHNIQUES

UMI KALSOM BINTI MOHAMAD YUSOF

DEVELOPMENT OF E-NOSE HERB RECOGNITION SYSTEM BASED ON ARTIFICIAL INTELLIGENCE TECHNIQUES

By

UMI KALSOM BINTI MOHAMAD YUSOF

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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UMI KALSOM BINTI MOHAMAD YUSOF

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Chairman : Azura bt Che Soh, PhD
Faculty : Engineering

Herbs are useful for various applications especially in nutraceutical products and botanical medicine. In normal practice, the herbs identification is done mainly by botanists. However, it is difficult for botanists to recognize herbs based on aroma for the species under the same family. Thereupon, the herbs odors under the same family which is the physical appearance may look almost the same characteristic and also may be having the almost same aromas. Moreover, many factors might influence the accuracy of the human olfactory system as a panel sensory such as physical, mental and fatigue body conditions. Other factors, it requires various experimental exercises, very time-consuming, less efficient and costly. Electronic nose (E-nose) instruments, derived from numerous types of aroma sensor technologies have been developed for a diverse of applications in a broad field of agriculture including for herbs. The intervention of electronic nose was capable to reproduced human senses using sensor arrays and pattern recognition systems. E-nose in this project was developed as portable type, small size and easy to operate. The ability of the developed E-nose was emphasized to distinctive herbs leaves odor from *Lauraceae, Myrtaceae* and *Zingiberaceae* families. Multiple metal oxide semiconductor (MOS) gas sensors were assembled in the E-nose system to detect a broad range of chemical compound that released from the sample. The selected MOS gas sensors were TGS 2610, TGS 2611, TGS 2620, TGS 823 and TGS 832 from Figaro Inc. which was installed in the E-nose system as detection array. Meanwhile, the blended herb leaves prepared in sample preparation was found as a preeminent procedure that gives the advantage to secure the long-lasting function of a gas sensor compared to the existing sample preparation in another E-nose system. Finally, data captured by the gas sensors was classified by using two methods which are Artificial Neural Network (ANN) and Adaptive Neuro-Fuzzy Inference System (ANFIS). The percentage of accuracy to classify the herbs species by using ANFIS and ANN was compare to evaluate the effectiveness accordingly. From the result, ANFIS gives as higher as 94.8% percentage of accuracy compare than ANN for 91.7% of accuracy.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENCIPTAAN SISTEM PENGESANAN HERBA E-HIDUNG BERDASARKAN TEKNIK KEPINTARAN BUATAN

Oleh

UMI KALSOM BINTI MOHAMAD YUSOF

Januari 2016

Pengerusi : Azura bt Che Soh, PhD
Fakulti : Kejuruteraan

Herba mempunyai banyak kegunaan terutamanya bagi produk nutraseutikal dan perubatan berasaskan tumbuh-tumbuhan. Kebiasaannya, ahli botani yang akan mengenalpasti herba. Walaubagaimanapun, ahli botani mengalami kesukaran untuk mengenalpasti herba melalui bau bagi spesis herba dalam keluarga yang sama. Ini kerana bau herba dalam keluarga yang sama berkemungkinan mempunya bau yang hampir serupa. Tambahan juga, terdapat banyak faktor yang boleh mempengaruhi ketepatan sistem deria bau manusia sebagai panel penilai seperti aspek fizikal, mental dan keadaan badan yang letih. Selain itu, panel penilai bau juga memerlukan banyak latihan eksperimen, memakan masa, kurang berkesan dan memerlukan kos yang tinggi. Hidung elektronik terhasil dari teknologi sensor berasaskan bau yang dicipta untuk pelbagai aplikasi dalam bidang pertanian termasuk herba. Penemuan hidung elektronik ini mampu menghasilkan deria bau menyerupai manusia menggunakan kepelbagaian sensor dan sistem pengiktirafan corak. Hidung elektronik ini dicipta sebagai mudah alih, saiz yang kecil dan mudah untuk dikendalikan. Kelebihan hidung elektronik yang ingin ditekankan dalam projek ini ialah kebolehan untuk membezakan corak bau dua belas spesis herba dari empat jenis keluarga. Daun herba yang dikisar sebagai prosedur penyediaan sampel sebelum eksperimen telah ditemui sebagai prosedur yang dapat menambahbaik sistem sedia ada. Data yang terhasil dari sensor kemudian dikelaskan menggunakan Rangkaian Neural Tiruan dan Adaptasi Neuro-Fuzzy Sistem. Keputusan menunjukkan Adaptasi Neuro-Fuzzy Sistem memberikan peratusan ketepatan yang tinggi sehingga 94.8% berbanding Rangkaian Neural Tiruan sebanyak 91.7% ketepatan. Sebagai tambahan, validasi sistem yang dilakukan telah berjaya membuktikan keupayaan hidung elektronik dalam mencapai objektif penciptaannya.

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I certify that a Thesis Examination Committee has met on 28 January 2016 to conduct the final examination of Umi Kalsom bt Mohamad Yusof on her thesis entitled "Development of E-Nose Herb Recognition System Based on Artificial Intelligence Techniques" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Nurul Amziah binti Md Yunus, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Syamsiah binti Mashohor, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Zuwaire Ibrahim, PhD
Associate Professor
Universiti Malaysia Pahang
Malaysia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 25 May 2016

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Azura Bt. Che Soh, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Asnor Juraiza Bt. Ishak, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mohd. Khair b. Hassan, PhD
Senior Lecturer, Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: _____
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Signature: _____
Name of Member of Supervisory Committee: Dr. Asnor Juraiza Bt. Ishak

Signature: _____
Name of Member of Supervisory Committee: Dr. Mohd. Khair b. Hassan

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

E-NOSE	Electronic nose
ANN	Artificial Neural Network
ANFIS	Adaptive Neuro-Fuzzy Inference System
MSE	Mean Square Error
MOS	Metal Oxide Semiconductor
VOC	Volatile Organic Compound
PIC	Programmable Interface Controllers

CHAPTER 1

INTRODUCTION

1.1 General Overview

Herbs refer to the leafy green parts of a plant that does not develop persistent woody tissue [1]. Herbs are valued for their flavor, fragrance, medicinal and healthful qualities, economic and industrial uses, pesticidal properties, and coloring materials [2]–[6]. Most of the herbs have their own characteristic odor due to the presence of phytochemical in the form of volatile compound. Common herbal constituents such as terpenes, steroids, phenolic compounds, amino acids, lipids, and alkaloids give beneficial properties in herbs [7].

The ability to classify distinctive odor pattern for aromatic plants species, especially for herbs, provides significant impact for those in the field that uses herbs such as in food industry, medicine, culinary, healthcare product and pharmaceutical. Recently a lot of researchers use chemical gas and liquid to differentiate herbs odor with very complex experiment and need a huge budget for appropriate odor equipment [8]. Consequently, the invention of electronic nose sensor for diverse disciplines within the plant sciences was developed based on different electronic aroma detection principles and mechanisms [9]. It can be seen electronic nose devices have been used frequently especially in herbs industry due to the advantage of acquiring real-time information on chemical and physical characteristics of plants [6], [9]–[14].

1.2 Problem Statement and Motivation

The development of electronic nose technology nowadays gives many advantages in diversified field. Unfortunately, the existence electronic nose mostly designed with bulky and unsuitable for portable usage [10], [15], [16]. The sample preparations are also complicated and time-consuming. In addition, the experimental procedure by using heating and boiling process, addition of chemical gas and liquid is harm and expose the user to a hazardous situation. The portable device with appropriate size and adequate procedure of handling process need to be developed to enhance and boost the advancement of electronic nose technology. In normal practice, the herbs identification was done by organoleptic methods and heavily dependent on botanists [17]. Regardless of the expertise, human have disadvantages of being fatigue and inconsistencies due to overwhelming flavors and aromas in the samples [18], [19]. Thus, an artificial technology which capable to perform the identical task with high tolerance and precise is required.

Herbs species has unique leave characteristics such as the shape, color, texture and the nature of odors [20]. However, many researchers have investigated the methods of plant species recognition based on physical or texture of leaves [21]–[24]. The research involves in plant species recognition based on the odors is still rare. Therefore, the intention to explore, analyze and identify the difference between herbs leaves based on nature of odors become the purpose of this study.

On the other hand, the main problem of herbs odors with the same family which is the physical appearance may look almost the same characteristic and also may be having the almost same aromas. An equal characterization of herbs may cause difficulty to botanists in order to recognize herbs based on aroma measurement for the species under the same family.

1.3 Objectives

The main objective of this project is to develop an electronic nose herbs recognition system based on an artificial intelligent technique to recognize herbs species under the same family based on aroma measurement. The specific objectives are:

1. To design and develop a prototype of portable e-nose system.
2. To identify features selection of e-nose system.
3. To classify herbs species under the same family based on aroma measurement using ANFIS technique.

1.4 Scope of Research

The scope of this research includes the following:

- The metal oxide semiconductor gas sensors were used as the most commercially available, high sensitivity and long life features type of the gas sensor in electronic nose field.
- Various types of odor signal herbs can be captured by the system as long as in the range of gas sensor detection. In this study, three families from aromatic types of herbs were used to validate the system.

1.5 Thesis Outline

This thesis is organized into five chapters.

Chapter 2 is a literature review about human olfactory perceptron and the biomimicry of electronic nose system. The descriptions on the past researchers work on electronic nose remarkably in agriculture and herbs area was

described. Besides, gas sensors commonly employed in electronic nose systems was reviewed. The mechanism of sample preparation in equivalent e-nose function was presented. The data pre-processing method was explained in this chapter as well as the classification process using artificial intelligent technique.

Methodology transcripts in comprehensive steps and procedures have been conducted in the study as in Chapter 3. Architecture for both hardware and software part throughout the development of electronic nose was illustrated in details. Selection of gas sensor array was justified. The procedure of data collection and further process of odor signal was explained. A statistical test of data was executed. Feature analysis was performed and the structure of the output implicate in classification process was described.

In Chapter 4, the pattern of the output signal from the gas sensor array was studied. The processed data in the preprocessing stage was evaluated. The significance result of statistical test was interpreted. The features analysis validated by using Euclidean distance formula was clarified. The desired electronic nose system was conferred by the ability to classify the herbs using Artificial Neural Network (ANN) and Adaptive Neuro-Fuzzy Inference System (ANFIS).

Chapter 5 consists of summarized outcomes, contribution of the research and emphasized on a recommendation to improve the innovation in future.

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