Identification of spices by Electronic Nose using pattern recognition technique

M. V. Kukade, N. M. Kulkarni
Department of Computer Science, Electronic Science
Fergusson College,
Pune, India 411 004
mkukade@gmail.com, nmkulkarni123@yahoo.com

D. S. Kumbhar
Department of Electronic Science
Modern College of Arts, Science & Commerce
Pune, India 411 016
deep.s.kumbhar@gmail.com

D. C. Gharpure
Department of Electronic Science
Savitribai Phule Pune University
Pune, India 411 007
dcg@electronics.unipune.ac.in

Abstract **—** In the past decades, odor discrimination with electronic noses has received a growing attention and much study has been done on how to classify odors using an array of gas sensors and a pattern recognition algorithm. By using the same concept, identification of different spices like Cinnamon, Clove, Nutmeg etc. can be done for good food quality and health benefits. Keeping this view in mind this research paper is focusing on the design of an Electronic nose by using an array of eight MOS sensors (TGS 800, TGS 813, TGS 823, TGS 2602, TGS 2610, TGS 2611, TGS 2620 & MQ 135) to detect an odor, PIC Microcontroller to acquire a data of the evolved gases from the respective spice and spice odor identification by pattern recognition using neural network tool of MATLAB software. In order to check the quality of the spice its identification is the basic requirement. Electronic nose is designed with three major parts: i) Spice odor delivery system, ii) Detection system and iii) Analyzing system. In the spice odor delivery system, the spice was kept in a plastic container on which array of the sensors was kept in such a way that the sensors can detect the evolved gases from spice container. The data generated after detection was acquired by PIC microcontroller and saved in the excel files. Using Pattern recognition tool box of the MATLAB, analysis of the acquired data was done, The designed Electronic-Nose was used to identify Cinnamon, Clove and Nutmeg. The gas sensor array was exposed to these spices alternatively. The data was acquired for one minute for each spice and was repeated fifteen times for each of the said spice and was saved in the separate excel files. A feed forward neural network of 8 input neurons, 10 hidden neurons and 3 output neurons was implemented using 15 training samples and 30 test samples with 1000 epochs in MATLAB software. This MATLAB tool leads through solving a pattern recognition classification problem with sigmoid function. The confusion matrix showed 100 % correct trained network with the best validation performance at 24th epoch. With such a trained network 100 % correct identification was done for Clove & Cinnamon and 40 % for Nutmeg.

Keywords-Electronic Nose, Feed forward, Neural Network, Pattern recognition, Confusion Matrix, Epochs

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I. INTRODUCTION

The human nose has been used as an analytical tool in many industries to measure the quality of food, drinks and other chemical products. It is commonly used for assessing quality through an odor. In spices evaluation, detection of smell by a human nose from the respective spice is traditional way. An odor (commonly referred as a smell) is caused by one or more volatile chemical compounds, generally at a very low concentration that humans or other animals perceive by the sense of olfaction. The product's quality testing by human nose is not very accurate and has various limitations, it is laborious and time-consuming job. It suffers due to problems like adaptation fatigue, infection and irritating state of mind if a person keeps on testing for long time. Basically, to overcome these limitations a concept of Electronic Nose (E-Nose) is applied. Once an Electronic nose has been 'trained', it does not require any skilled operator and can potentially obtain the results within few tens of seconds. In the Electronic nose system, a pattern recognition engine enables the system to perform complex aroma analysis of the sensor signals. Artificial neural

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networks (ANNs) have been extensively used to perform pattern recognition, and good results have been reported previously in the classification of foodstuffs, such as tea[3], wine[4], fish[8], beverages[12], eggs[20], meat[23]etc. The back propagation trained multilayer perceptron (MLP) paradigm is the most popular pattern recognition method in aroma analysis. Other promising techniques include LVQ, PNN and RBF [3].
Gardner and Bartlett defined an 'Electronic Nose' as an instrument, which comprises an array of electronic chemical sensors with partial specificity and an appropriate pattern recognition system, capable of recognizing simple or complex odor[1]. Like the human sensory system, these electronic odor-detection systems incorporate sensors, (which are conceptually analogous to human olfactory receptors) and a data-processing system (which conceptually simulates the brain). Most of the Electronic noses operate by recognizing the pattern of responses.

The aroma and flavor are two quality factors of food products, which depend upon the number of volatile compounds present and their ratios. Quality analysis by a panel of experts is a costly process since it requires trained people who can work for only relatively short periods of time, additional problems such as the subjectivity of human response to odors and the variability between individuals are also to be considered. Hence, the need of an instrument such as the Electronic Nose, whose strengths include high sensitivity and correlation with data from human sensory panels for several specific applications in food product is essential. Electronic Noses are becoming more and more popular because they require a short time for analysis, automated and uses non-destructive techniques to characterize food aroma[1,9].
Aim of this paper is to identify an odor of Cinnamon, Clove and Nutmeg by using an Electronic Nose. The Enose consists of an array of eight MOS based gas sensors exposed to evolved gases, PIC Microcontroller to acquire data from the array in response to specific spices and a Neural Network for identification of spices.

II. Methodology

A. Components of Electronic Nose

In the past decade, odor discrimination with Electronic Nose has received growing attention. Studies have been done on odor classification using an array of gas sensors, Artificial Neural Network(ANN) and pattern recognition algorithm for various applications like classification of Wine[7], Beer[13], fish[8] etc. This paper deals with the identification of different spices like Cinnamon, Clove, and Nutmeg using an E nose system developed.

The Electronic Nose includes five blocks as shown in fig. 2.

i) Odor sample holder
ii) Gas sensor array
iii) Signal conditioning
iv) Data acquisition
v) Pattern recognition.

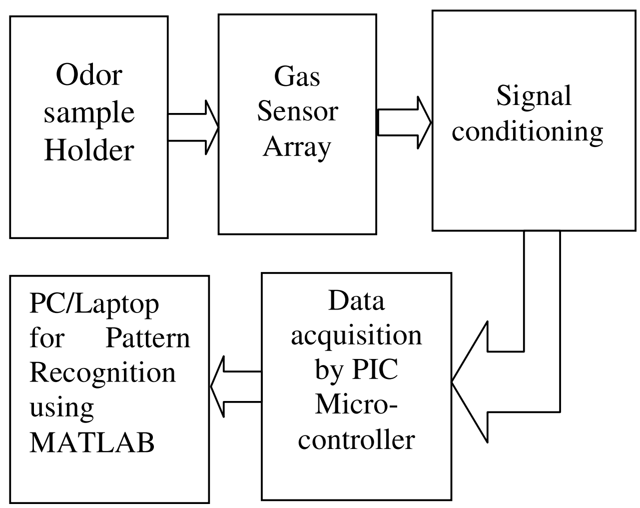
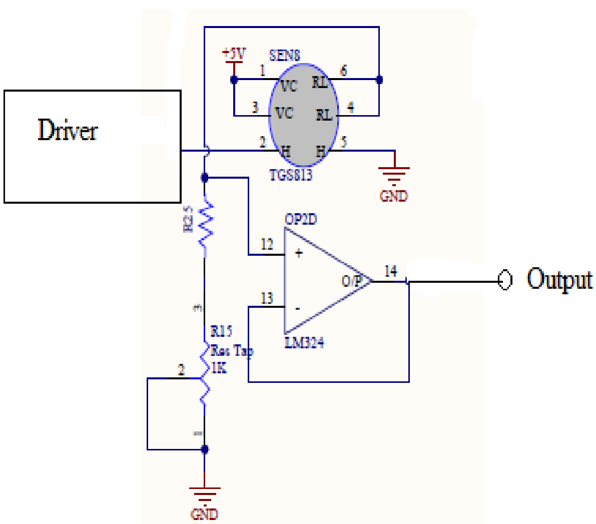


Fig. 2 Block diagram of Electronic Nose

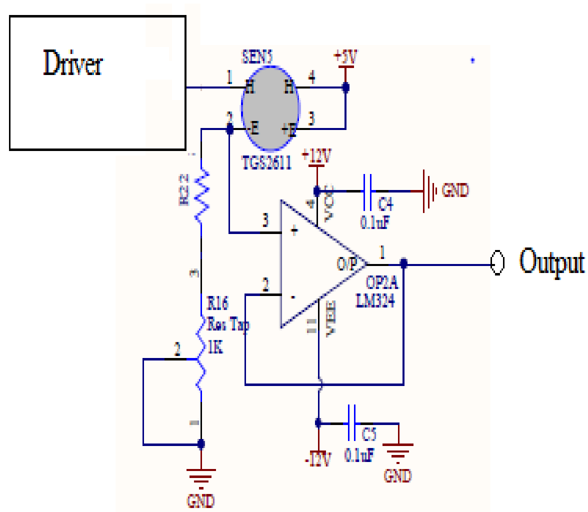
In Electronic Nose odor sample holder holds the spice to be identified. In this research work a small plastic rectangular box of size 10 cm. X 9 cm. X 2.5 cm was used as sample holder as shown in the fig. 3.

Fig. 3 Spice Sample Holders

Each spice has its own odor (smell) which is the mixture of gases. To detect the spice odor, MOS sensor array circuit using TGS 800, TGS 813, TGS 823, TGS 2602, TGS 2610, TGS 2611, TGS 2620 & MQ 135 sensors was designed based on their sensitivity to the odors. The interface circuit for the sensors is as shown in figure 4. The sensors have a built-in heater driven by the driver IC 2808 and the output response was obtained by using a potential divider arrangement followed by Operational Amplifier used as buffer as shown in the Fig. 4 a & 4b.



(a)



(b)

Fig. 4. Circuit connections for (a) six terminal sensor and (b) four terminal sensor

The output of operational amplifier is in the analog form. To acquire a data using PIC Microcontroller these analog outputs were converted in to digital by using inbuilt ADCs in the PIC Microcontroller. Ten in built ADCs are available in the PIC Microcontroller, out of which eight ADCs were interfaced to 8 different sensor outputs. Such digitally converted spice odor data was passed serially to the computer software as shown in the Fig. 5.and is saved in the form of excel sheet.

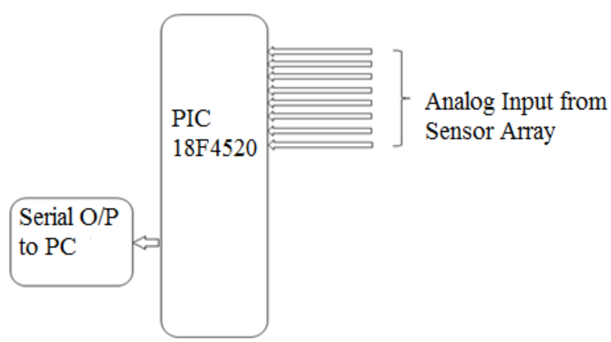


Fig.5. Interfacing of PIC Microcontroller to sensor Array output

B. Experimental Setup

The experimental setup was as shown in Fig. 6. It includes, Computer System, Sample spice holder, Electronic Nose circuit boards (Sensor array and

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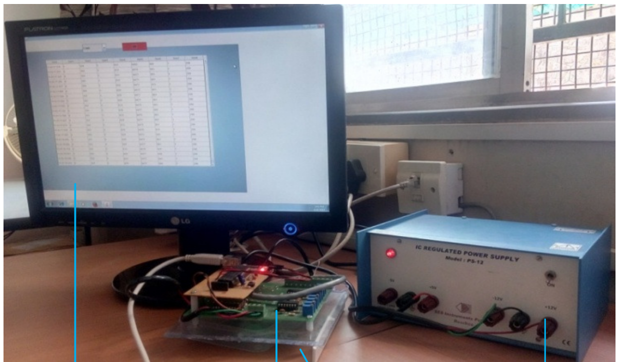
Data acquisition circuit boards, Mounted on each other) and Power Supply.



Computer System

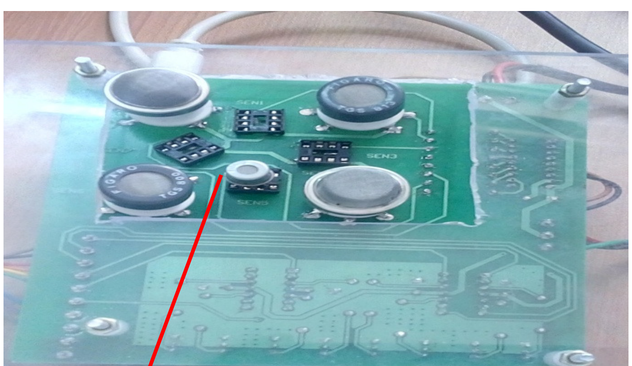
Sensor array & DAQ Circuits

Sample spice holder

Power Supply

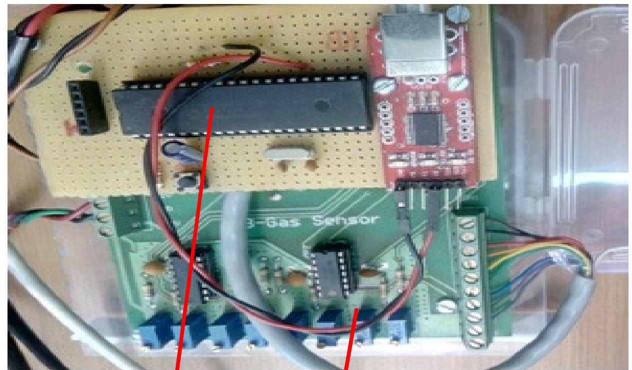
Fig. 6 Experimental Setup

Computer system used in this project was 200 GHz Intel i-3 processor, 4GB RAM and 500 GB Hard disk with windows XP software. Three different sample spice holders (Plastic boxes of size 10cm X 9cm X 2.5cm) were used in this setup. Electronic Nose consisted of two circuit boards a) Sensor array circuit board and b) Data Acquisition (DAQ) circuit board as shown in Fig.7.



Sensor array circuit board

(a)



PIC Microcontroller

Signal Conditioning Circuit

(b)

Fig. 7. (a) Sensor array Circuit Board
(b) DAQ Circuit Boards

As shown in the Fig. 7 (a) an array of eight sensors with signal conditioning circuit was obtained using double sided PCB (Printed Circuit Board). On one side of PCB eight sensors were connected in such a way that they can be kept properly on the sample holder for data acquisition. On its back side, signal conditioning circuit was designed. Fig. 7(b) shows Data Acquisition (DAQ) Circuit in which PIC Microcontroller was connected on general purpose circuit board with its allied circuit and connector, mounted on the back side of the gas sensor array PCB.

The data acquisition system was designed by interfacing PIC Microcontroller to the Computer. Analog output voltage of eight sensor's array circuit was applied to inputs of the eight inbuilt ADCs of PIC Microcontroller. These ten bit ADCs (of resolution 1024) convert analog spice data into its digital equivalent output. This digitally converted 10 bit parallel data was then converted in the serial bit form and was connected to computer through USB. To acquire data at regular interval with proper indication of acquired time and to save it in the excel file, a separate software was prepared in JAVA. Using this software the data from each sensor was saved sensor wise (from sensor 1 to senor 8) in the form of decimal values in eight different columns of Excel sheet.

An electronic power supply is an essential requirement for an electronic circuit. In this project

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the requirement of +12V, -12V, +5V & -5V with 1A current is fulfilled by the shown power supply in the experimental setup.

C. Experimental

Initially to remove earlier spice odor molecules on the sensing material of the sensor, sensors were refreshed by air using air dryer for two minutes than the air data was collected for two minutes. In this two minutes around 1100 data samples were acquired and saved in the excel file. After that Cinnamon was put in the sample holder and an array of sensors was kept on the container in such a way that the odor released from the sample (Cinnamon) got exposed to the sensor array as shown in Fig. 8. After detection of the evolved gases the sensor resistance changed. Using voltage divider arrangement the change in the resistance was converted into the change in voltage by applying constant current to flow through it. Such obtained voltage was then applied to the operational amplifier connected in the non-inverting mode, which act as signal conditioning circuit.

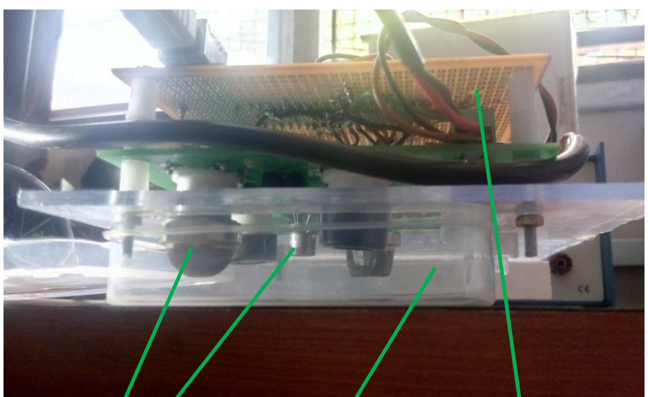

Fig. 8. Data acquisition of Electronic Nose

Thus the change in output voltage due to change in resistance is obtained after exposing the Cinnamon odor to the sensors. Since there were 8 sensors used in the Electronic Nose, 8 output voltages were obtained through 8 operational amplifiers. These output voltages were applied to the 8 inbuilt Analog to Digital Converters (ADCs) of PIC Microcontroller. Using Embedded C language the appropriate ADCs were initialized. Using single UART module of PIC, data was communicated to PC over Serial PORT with DB9 connector. Serial Port baud rate was configured to 115200 bps. The serially sent data was saved in the Excel sheet (with acquisition time and 8 sensor's output) using software written in JAVA.

This process of cinnamon data acquisition continued for two minutes and around 1100 data samples were acquired. After this, sensors were refreshed by exposing air using air dryer for two minutes and air data was acquired for two minutes. Thus the data of air and cinnamon was acquired alternately and saved in the excel files. This process was repeated a number of times and such data sets were obtained. Using same process alternate reading of air & Clove and air & Nutmeg was recorded. Thus 1100 readings of Cinnamon, 1100 readings of Clove and 1100 readings of Nutmeg were obtained. From these 1100 data samples appropriate 50 data samples (after removing garbage values) were used to prepare training data set and testing data sets for neural network.

Analyses of a data was done in two stages i) By training neural network and ii) By testing neural network for pattern recognition. This was done using neural network tool of MATLAB software. The Neural network was designed using 8 input nodes (for 8 sensors), 10 hidden nodes and 3 output nodes(for three spices) as shown in Fig. 9 . To train neural network MATLAB program was written using trainlm function. It was trained for epoch value 1000. The network was tested using test matrix vector prepared from the test sample values.

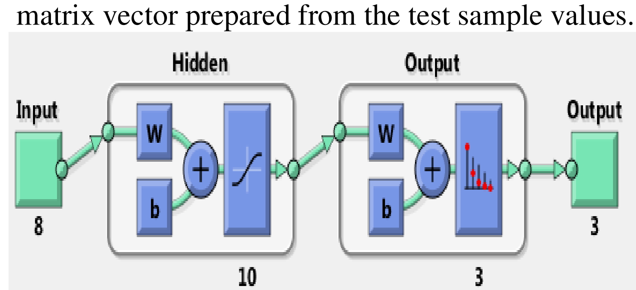

Fig. 9 Neural Network design

III. Result and Discussion

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As stated earlier, fifteen sets of data were obtained in this experiment by repeating the experiment. Each set was acquired by placing the three spices in the sample holder and each spice odor data included the analog data from eight sensors converted into its digital equivalent count as shown below.

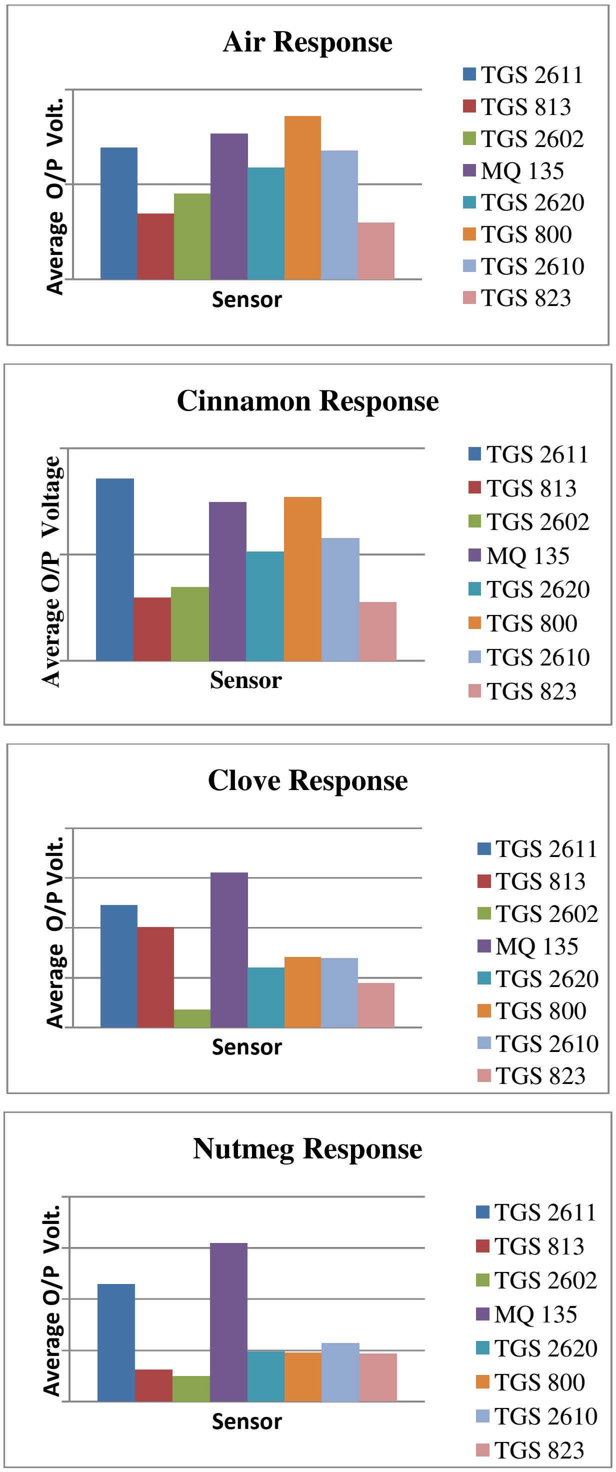

Fig. 10 Average Output Voltage for each sensor

A typical response of these sensor output with respect to sensor number is as shown in Fig.10. The graphs show that as the spice in the spice container (sample) changes, the Electronic Nose response i.e. the output voltage of each sensor in the array, response also changes. The pattern of the sensors response is different and can be used for identification of spices.

In this experiment three-layer (Input, hidden and output) feed-forward neural network, with sigmoid function (patternnet), was used for exact identification of spice odor. The neural network was designed with eight input neurons, ten hidden neurons and three output neurons and trained with fifteen training samples (five samples per spice), and tested with ten test samples per spice with 1000 epochs in MATLAB software. There were eight input neurons used in the neural network because eight sensors were used for spice data acquisition, three output neurons were used because three spices were to be identified and proper identification can be done using ten hidden neurons. To train neural network, one training set and to test the appropriate spice, three test sets were prepared. The training set used was of the matrix size 15 X 8. In which fifteen rows were of fifteen set's average (rounded up to next digit) values of three spices (5 values per spice) data and eight columns were of eight sensors output digital count. The test sets were of matrix size 10 X 8. In which ten rows were average values (rounded up to next digit) of ten set's individual spice data and eight columns were of eight sensors output value.

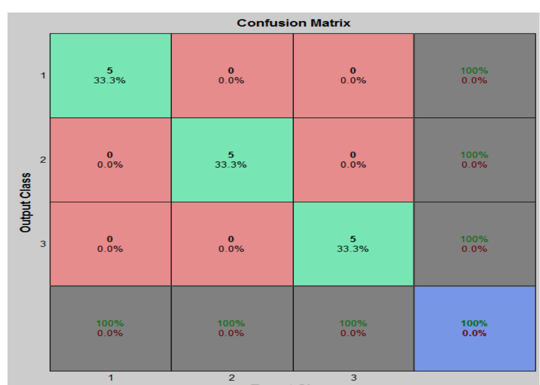

Fig. 11. Confusion Matrix after Neural Network training

The confusion matrix showed 100 % training as shown in Fig.11. The best validation performance obtained was at 24th epoch, which is shown in the Fig. 12. This trained network identified the applied spice odor while testing and the results are shown in Table I.

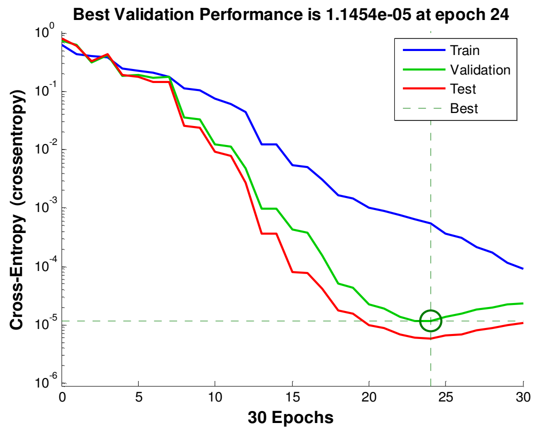

Fig. 12 Best Validation Performance after training Neural Network

TABLE-I. Spice identification in percent

Spice Name	*Cinnamon*	*Clove*	*Nutmeg*
Identification	100 %	100 %	40 %

IV. CONCLUSION

The objective of this paper was to identify Cinnamon, Clove and Nutmeg using pattern recognition technique.

The Electronic Nose was built using eight Figaro metal oxide sensors to evaluate three different types of spices (Cinnamon, Clove and Nutmeg). Selected sensor's array showed different response with the different spice odor.

In this study, the Bar chart plot of data signal output voltage from the sensors array against the sample time is obtained. The purpose of getting this Bar chart as shown in fig.10 was to observe the capability of the Electronic Nose to differentiate odors of different spices for identification and to check whether the sensors are suitable to used in this system or not. The Artificial Neural Network can successfully evaluate the spices. Result shown in TABLE-I indicate that the used Electronic Nose system has the capability to identify spice odor sample.

As the Bar chart showed different responses for three different spices, the selection of sensors was appropriate. The Neural network training was 100% with prepared training set and identification of Clove and Cinnamon was also 100% whereas identification of Nutmeg was of 40%. This shows that the used Electronic Nose is good for Clove and Cinnamon but some improvement is required for Nutmeg identification.

The Electronic-nose designed is a simple, low cost system which can find applications in areas related to food processing, Aurvedic medicine preparation etc. There is scope for identification of other spices and odors so work on training the Electronic Nose for the same will be done in future.

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