Electronic-nose (E-nose) for recognition of Cardamom, Nutmeg and Clove oil odor

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ABSTRACT

The human nose is the primary instrument used to assess the smell or flavor of various natural and industrial products. The use of human nose has various limitations. Basically to overcome these limitations a concept of Electronic-nose is applied. It comprises an array of chemical sensors with partial specificity and an appropriate pattern recognition system, capable of recognizing simple or complex odor. Electronic nose has been used in a number of applications ranging from quality control of cosmetics, beverages freshness of food, detection of hazardous chemicals.

This paper presents development of E-nose to identify Cardamom, Nutmeg or Clove oil using TGS 2610, TGS 2611 and TGS 2620 gas sensors. The gas sensor array was exposed to the Cardamom / Nutmeg / Clove oil alternatively. The data was acquired for two minutes for each spice oil using National Instruments Data Acquisition card, which was interfaced to the PCI slot of computer. The data acquisition was repeated sixteen times for each of the said spice oils and was saved in the separate excel files. A feed forward neural network of 3 input neurons, 5 hidden neurons and 3 output neurons was implemented using nprtool (Pattern Recognition Tool) with 34 training samples, 7 validation samples and 7 test samples with 1000 epochs in MATLAB software. This MATLAB tool leads through solving a pattern recognition classification problem with sigmoid function. The graphs showed different responses to the different spice oils and more than ninety seven percent correct classification was done by the neural network.

I. INTRODUCTION

Since its emergence the electronic nose technology has been advancing tremendously. From a simple system that was capable to solve simple odor based classification problem, it is now equipped with sophisticated accessories and has been used to solve many problems involving odor analysis in various industries.

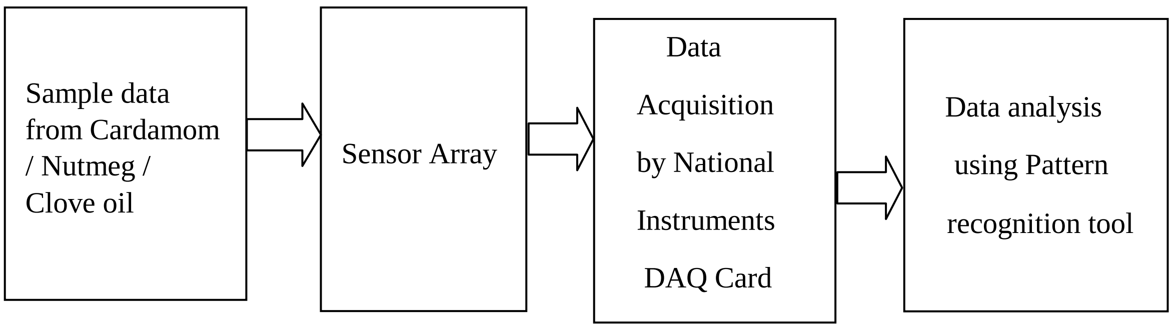
Many research papers have reported the application of electronic nose in the food industry, where it was used for quality control of spice mixtures and to find out product adulteration[1], to evaluate the quality of dairy product[5], characterization of beer aging[6], freshness of food, to determine storage stability of food product like bread, to determine the fruit ripeness level, to determine food shelf life, to distinguish different types of beverages. The extensive applications of electronic nose in food industry was due to the complicated nature of odor emitted by food and difficulty in analyzing it by other techniques like GC. Enose detect the volatiles emitted by the food sample by using the gas sensor array, obtain the valuable information from each of the sensor response, and finally identify the food sample. To execute the above operation, the electronic nose has a gas sensor array, a data acquisition and controller system and data analysis software. The gas sensor array consists of several chemical gas sensors with different selectivity and sensitivity. Multiple sensors are used normally in the electronic nose system. Each sensor in the array interacts with the volatiles emitted by the food sample. When the volatile molecules come in contact with the sensing material in the sensor, change in the resistance across the sensor terminals takes place.

By passing appropriate current through sensing material with the external source, change in the voltage is obtained. This change in the voltage is acquired by the data acquisition system. Thus, the information contained in the sensor response is extracted. The combination of such information obtained from every sensor response will form a pattern that represents the food sample. Based on this pattern, the data analysis software can analyze the food product [4].

This paper presents the classification of Nutmeg oil, Cardamom oil and Clove oil by using enose with an array of three gas sensors TGS 2610, TGS 2611 and TGS 2620. The electronic nose detects the volatiles emitted by the spice oil sample. This detected volatile is produced in the form of change in the voltage which is then acquired by national Instruments Data acquisition Card and saved in different excel files. By observing graphs of the said responses some sample data points, which will help to classify the odor is selected. Such selected data points are used for training, validation, and testing of neural network for spice odor classification.

II. METHODOLOGY

Experimental Setup

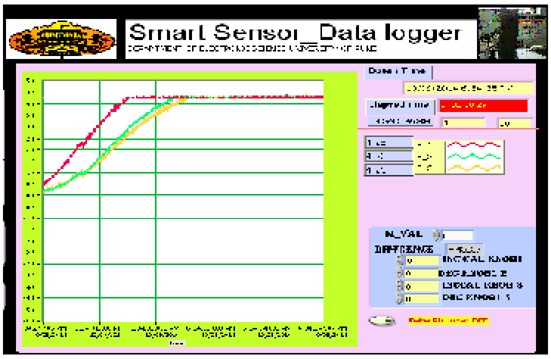


In this study, the Cardamom and Clove oil manufactured by DEV herbals Pvt. Ltd. and Nutmeg oil manufactured by FAME Drugs in India is used. 20-ml. spice oil of each type was used as sample. It was kept in the closed plastic container with cap at the top. By opening cap, the collected odor inside the container of the spice oil was detected. Three MOS sensors TGS 2610, TGS 2611, and TGS 2620 were used to sense these odors. The sensing element in the sensors is comprised of a metal oxide semiconductor layer formed on an alumina substrate of a sensing chip together with an integrated heater. In the presence of a detectable gas, the sensors conductivity increases depending on the exposed gas concentration. A simple electronic circuit with voltage divider arrangement at inverting input of a unity gain operational amplifier (IC 324) converted the change in conductivity to an appropriate output signal. Such outputs of three sensors were connected to the multi-Channel National Instruments Data Acquisition Card (18750B-02) through 68-pin DAQ connector. Three channels for three sensors of the said card were used for Data Acquisition. Pin no. 28 of the connector was connected to TGS 2611, pin no. 30 was connected to TGS 2620 and pin no. 60 was connected to TGS 2610. Such connected DAQ card was then interfaced to the PCI slot of a computer. Using LAB-View software, air and spice oil data was collected with sampling rate of 500 samples per second and was saved in different excel files.

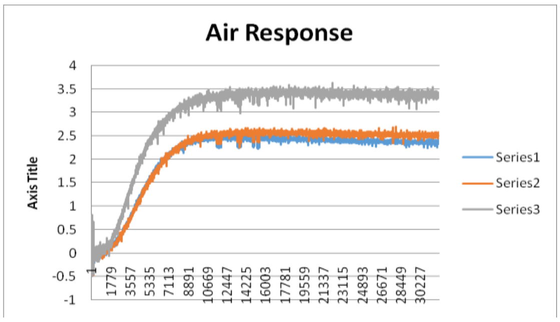
Initially the sensor card was kept in the air for fifteen minutes and later on air data was acquired for two minutes which generated around 60,000 samples of data and saved in separate excel file. This was done to make sure that no other odor molecules remain on the sensing surface before the spice oil data was collected. After that by opening Cardamom container's cap, sensors were exposed to the Cardamom oil odor.

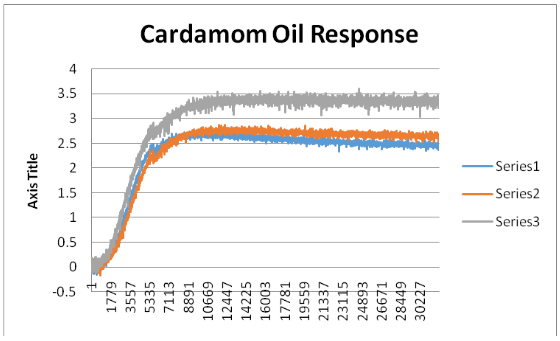
After switching ON this system, data was acquired for two minutes, which also generated around 60,000 samples of data and saved in another excel file.The process was continued for Nutmeg and Clove oil as well and was repeated sixteen times alternatively between air and corresponding spice oil odor.
Thus, sixteen sets of air data samples and sixteen sets of each spice oil data were obtained.
Before collecting spice oil data each time, sensors were refreshed by keeping it in the air and switching ON the system for five minutes to remove earlier spice oil molecules.

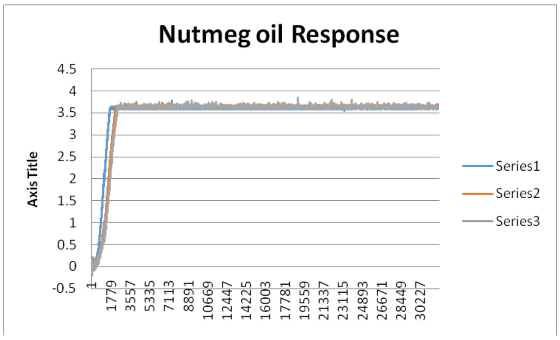
V I in LabVIEW Data acquisition

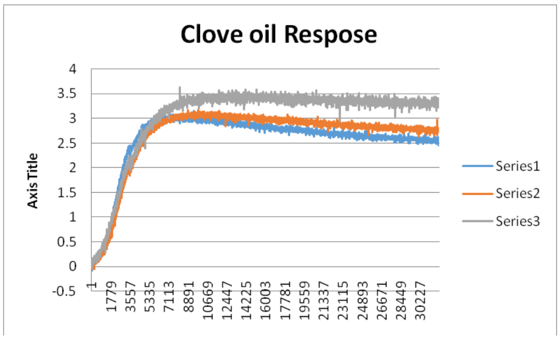


Graphical representation of Data







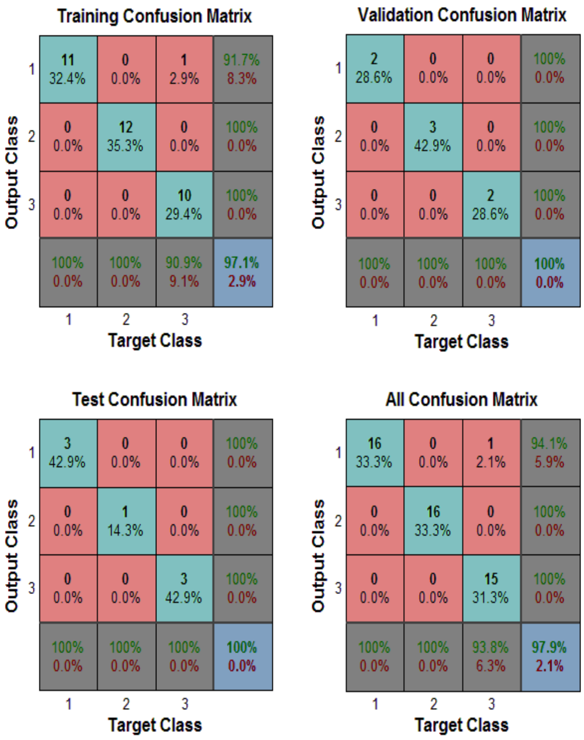


In the above graph series 1 is the response of TGS 2611 sensor. Series 2 is the response TGS 2610 sensor and Series 3 is the response of TGS 2620 sensor. These graphs show that, as the number of samples increases the initial sensor output response of air, cardamom oil and Clove oil increases almost linearly and later on (from sample number 8891 to 30227) decreases slightly. Whereas the response of Nutmeg oil shows sharp rise at beginning and then remains constant. The variations in the slop of the linear portion of graph and variations in the final output helped to classify the spice oil properly.

III IMPLEMENTATION OF NEURAL NETWORK FOR CLASSIFICATION

Classification of the spice oil is obtained by using MATLAB pattern recognition tool nprtool. Using this tool feed forward neural network of 3 input neurons, 5 hidden neurons and 3 output neurons was prepared with 34 training samples, 7 validation samples and 7 test samples with 1000 epochs. These total 48 samples were chosen from the data acquired at 20,000th sample out of 60,000 samples of each spice oil data saved in the earlier excel files of 16 different sets. Using train option of nprtool the prepared neural network was trained. This MATLAB tool leads through solving a pattern recognition classification problem with sigmoid function. The graphs showed different responses to the different spice oils and more than ninety-seven percent correct classification was done by the said neural network.

The confusion matrix, for each output class of the data obtained from MATLAB nprtool is as follows.



In training confusion matrix, the amount of classification done successfully is shown in the bottom right blue colored cell. The green colored figure in the same cell shows 97.1 % of classification is correct, where as red colored figure in the same cell shows that 2.99 % data is mismatching. In the validation confusion matrix bottom right blue colored cell shows the amount of validation of the data done. The green figure in that cell shows that 100 % data is validated. Similarly Test confusion matrix and All confusion matrix shows test data in percentage and overall target achieved after the training of neural network.

IV CONCLUSION

The classification of 3 spice oils i.e. Cardamom, Nutmeg and Clove oil by using this electronic nose were presented in this paper. Based on the graphs and confusion matrix, the results showed that the classification done is with 97.1 % accuracy.

To conclude, this study shows that the designed electronic nose has the ability to identify spice odor namely Cardamom, Nutmeg and Clove oil.

Using this concept, few more spice oils can be detected. The study of pattern recognition of the same spice oil with different qualities can also be tried out to test the quality of the spice oil in future.

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