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Classification of Grapes Using Electronic Nose

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ABSTRACT

Automatic classification of foods and beverages has a potential to increase the productivity of food and beverage industries. In this paper, an electronic nose (E-nose) system was developed using an array of sensors which was successfully used for classification of three different types of grapes (i.e. green grapes, red grapes and black grapes). The system was developed using metal oxide gas sensors. The classification of the data acquired by the E-nose was done by principal component analysis (PCA) and support vector Machine (SVM) as the classifier. SVM has the advantage of relying on a well-developed theory and has already proved to be successful in a number of practical applications. This study demonstrates that the E-nose based on odour sensor array has a high potential in the classification of grapes according to different fermentation degrees.

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INTRODUCTION

Currently, the biggest market for electronic noses is the food industry. There are various methods and tools that are being used for classification of food products. Classification using Support Vector Machine (SVM) is proven to be effective and globally optimum (Mamat, 2012).

Support vector machine (SVM) is a learning algorithm for maximizing a particular mathematical function with respect to a given collection of data (Noble, 2006). SVM is a balance between the closeness to the data and complexity of the solution. In the case of two-class classification problems, SVM establishes the best possible separating surface by maximizing the distance between the closest points in the training set and the separating surface, thus creating a margin between the two class. Moreover, the optimal separating surface is expressed as a linear combination of kernel functions centred on a small set of the data points called support vectors (Distante, 2003).

Classification using supervised SVM has been proven to give the best results for the data attained from electronic nose in (Mamat, 2012). In this study, we used an array of 8 metal oxide sensors to classify three different types of grapes (black grape, green grape and red grape).

Experimental procedure:

A. Sample preparation

Fresh sample of grapes were initially stored in a refrigerator and kept at constant temperature of 4 ^{o}C. Two grapes of each sample (green, red and black) were then placed in glass tube (sample chamber) for extraction of data using the electronic nose.

B. E- nose System:

The developed E-nose was composed of mainly of 5 parts: sample chamber, sensor chamber, power supply, data acquisition system and control unit and computer as shown in Figure 1.

The sample chamber is a 100 ml glass tube. A rubber stopper with two holes was used to close the chamber. Two plastic tubes that are connected to the air pump in the sensor chamber were inserted into the two holes of the rubber stopper making the chamber air tight. The air pump draws the odour coming from the sample chamber to the sensor chamber. The sensor camber is constructed with 8 metal oxide sensors and 1 temperature sensor. The types of sensors used are listed in Table 1.

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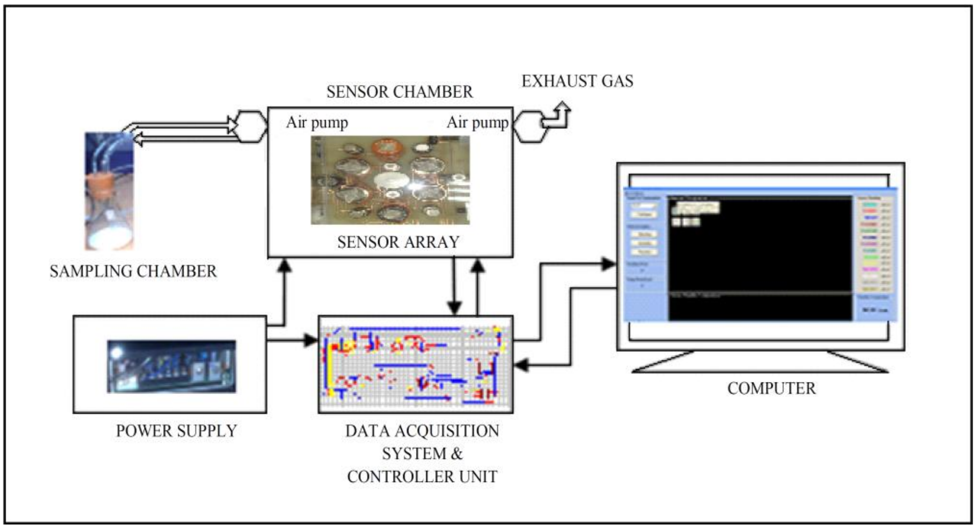

Fig. 1: Electronic Nose System.

The data acquisition and controller (DAC) unit consists of AD708JN amplifiers, DG406DJ analogue multiplexer, PIC16F877A microcontroller and MAX232 for serial interfacing. A program to read, perform analogue to digital conversion, receive and transmit data was implemented in the microcontroller (Mamat, 2011). The computer provides the software that communicates with the microcontroller and displays the gas conductance, temperature and humidity.

Table 1: The eight gas sensors used in the E-nose system.

Sensors	Targeted odour
LM35DZ	Temperature sensor
TGS822	Organic Solvent Vapours (ethanol)
TGS826	Ammonia
TGS813	Combustible Gases (methane, propane, butane)
TGS825	Hydrogen Sulfide
TGS821	Hydrogen
TGS830	Chlorofluorocarbons
TGS2620	Alcohol and Solvent Vapours
TGS2600	Air Contaminants (hydrogen, carbon monoxide)

RESULT AND DISCUSSIONS

A. Sensor responses:

The E-nose was activated for 400 seconds altogether. The first 200 seconds were used to clean the system of any ambient air so that the sensor chamber is free from any volatile gas providing a stable baseline. After the baseline is established the sample chamber is connected with the samples inside while the system runs for another 200 seconds. Figure 2 shows the voltage response curve of the gas sensors of green grapes on the first day of analysis. Similar curve were acquired for the other samples.

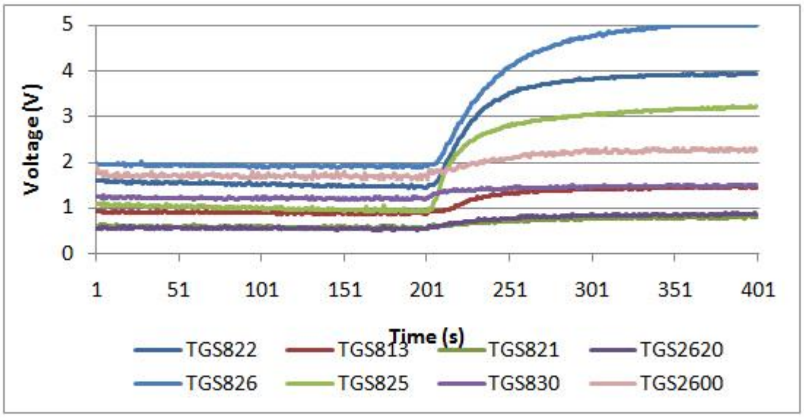

Fig. 2: Voltage response of an array of 8 sensors.

B. Features Extraction:

Data were acquired from 18 samples of each red, green and black grapes, giving a total of 54 samples. Each sample has 8 sensor readings and from these reading relative voltage responses (Vr) was obtained using equation 1 (Mamat, 2011).

$$Vr = \frac{Vmax - Vmin}{Vmin} \quad (1)$$

whereVmax is the maximum voltage reading and Vmin is the minimum voltage reading. Figure 3 shows the features that were extracted from the sensor response to be used for data analysis. The Vr values obtained from the 8 sensors were the features of that sample.

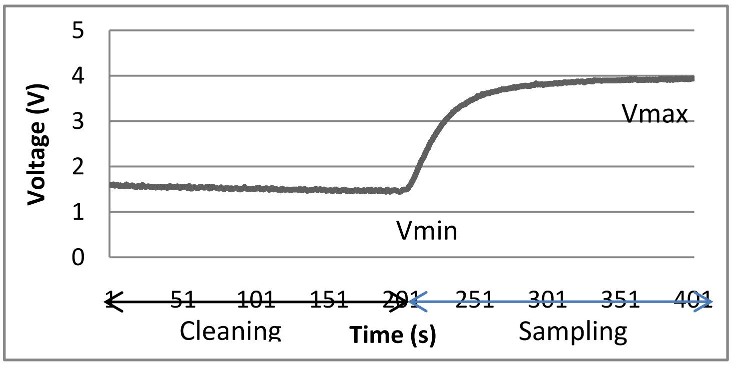

Fig. 3: Typical voltage response of gas sensor.

C. PCA Analysis:

Figure 4 shows the PCA results on the analysis of black, red and green grapes. The first two principal components allow us to present 75.25% of the information in the database.

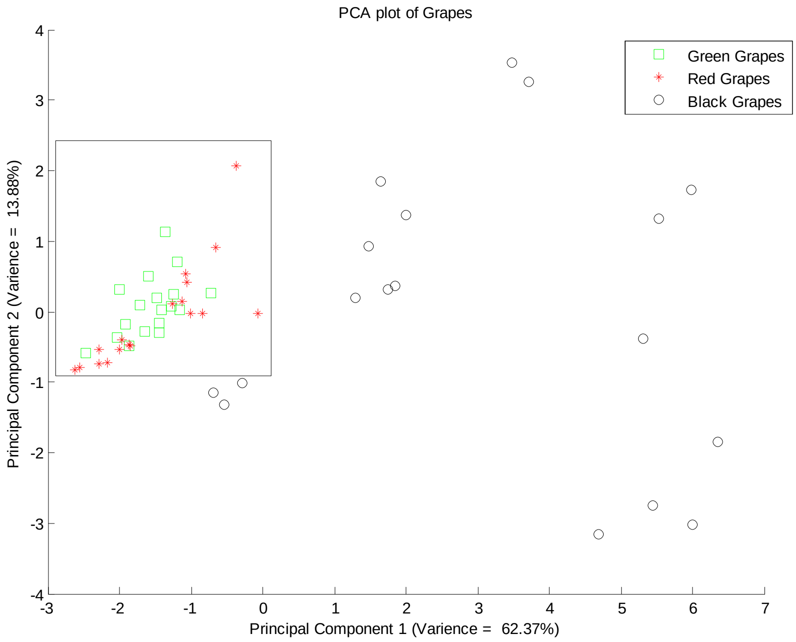

Fig. 4: PCA plot of green (□), red (+) and black (o) grapes.

Green and red grapes were clustered in a group separating them from the black grapes. The result above shows that green and red grapes have similar aroma compared to black grapes.

D. SVM Analysis:

Table 2 shows the success rate of SVM classification between Black Grapes (BG) and the rest and between Green Grapes (GG) and Red Grapes (RG). Different kernel functions were applied to determine the best performance of the SVM classifier.

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Table 2: Success Rates of different SVM methods.

Kernel	Success Rate (%)	
	BG vs Rest	GG vs RG
Linear	96.30	55.56
Polynomial	100.00	66.67
Quadratic	100.00	83.33
Gaussian Radial Basis Function	92.59	66.67
Multilayer Perceptron	100.00	77.78

Due to its different odour property and its cluster in the PCA plot the classification success rate of black grapes verses the rest is more the 92%. However quadratic SVM classification gives the best performance between green grapes and red grapes with a success rate of 83.33%

Conclusion:

In this paper, we presented that the classification of the three different grapes can be done by using electronic nose system. The PCA analysis shows us the similarities and differences between the grapes. The best performance for both classifications can be obtained using quadratic SVM.

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