Data Mining Techniques in Food Safety

Rajina R Mohamed[1], Razali Yaacob[2], Mohamad A Mohamed[3], Tengku Azahar Tengku Dir[4], F A Rahim[5], Abd Rasid Mamat[6]

[1]College of Computer Science and Information Technology, Universiti Tenaga Nasional, Malaysia
[2]Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, Malaysia
[3]Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Besut Campus,Terengganu, Malaysia
[4]Universiti Kuala Lumpur, MFI, Bangi, Malaysia
[5]College of Computer Science and Information Technology, Universiti Tenaga Nasional, Malaysia
[6]Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Besut Campus,Terengganu, Malaysia

ABSTRACT

Food safety is an important consideration because the reduced quality of freshness may result in food poisoning that can threaten our health. There are many methods used to test the freshness of food such as visual appearance as well using a variety of devices. One of the devices that can be used to test the freshness of food is the E-Nose. E-nose is an instrument that enables the discrimination of gas and odor in food industry for quality and safety purposes. It is a well-established instrument to detect odor and aroma not only in the food industry, but also in health-diagnosis, defense, and environmental industry. Generally, E-nose mimics human olfactory sense to detect and discriminate gasses or volatile organic compound from a few objects such as food, chemicals, explosive etc. Thus, E-nose can be used to measure gas emitted from food due to its ability to measure gas and odor. Principally, the E-nose operates by using a number of sensors to response to molecules from vaporous compound. Each sensor will respond to their specific gas respectively. These sensors are the major component in electronic nose to sense and obtain percentage of gases release by the compound samples. All gases detected by sensors will be recorded, that to be analyzed using classification method. Classification is a way to distinguish a mixture odor/aroma obtained from gas sensors using a method of machine learning. In this paper, we discussed briefly about electronic nose, it's principle of work and classification method and in order to classify food freshness.

Key words: Electronic Nose, Food Freshness, Food Classification, Food Quality.

1. INTRODUCTION

The main requirement for the food is fresh, unprocessed food, easily prepared and ready to eat, especially at room temperature [1]. For the past few years, food safety incidents often occur as a result of food poisoning from various food sources such as in schools, hospitals, night markets, street stalls and the like. According to [2], when the quality of food is reduced due to the low level of freshness, cleanliness factor, safety and nutrition, it can contribute to health risks. Hence the freshness of food should be given priority because of the lack of food hygiene quality and freshness will give a risk to health. Hence it is important to at least maintain the freshness of the food especially for area of school and hospital.

There are many methods used to test the freshness of food such as visual appearance, also classical olfaction including normal olfactory and Scentometer [3], which requires trained panels to taste or smell the food samples to ensure the quality or strength of the odor. However, this kind of method is rather subjective, because the human sense of smell and taste is different and may be influenced by the weather, and also sinus infection [4].

Electronic nose (e-nose) is one of the best choice of a sensible device that is used to identify and distinguish vaporous chemical compound [5, 6]. It is an electronic device that is intelligent of simulating human olfactory system [7] which contains an array of electrochemical sensors to detect and identify gases/odor and will classify through a kind of pattern recognition method. It is extensively used in the food industry – for example in assessing the freshness of food in the food production [8],quality estimation of ground meat [9] mainly for export, estimation of food fish freshness for grading [10], fresh vegetables [11], beer production [[12], also to predict the degree of musty odor in cereal [13] and many more. Besides widely used in food production E-nose also useful in diagnosing disease [5]; water quality [14]; air pollution [15-16] as well as liquid chemical concentration [6].

E-nose contains of two main components, i.e. the sensor part and classification part. The sensor part is using the gas sensor to detect an odor which can be used a market ready product such as MOS transistors, QMB, CP, piezoelectric crystal, QCM [17-19] and there are some of researchers developed their own gas sensors [20-22] for their research.. While

classification part is to identify and distinguish types of gas in order to determine the quality of food.

Food can be classified as bad or good from the activity of microorganism in food that eventually will produce gas [8,23]. The higher the contents of microorganism, the more the activity of them, the higher the chances of spoilage. As e-nose is widely used in the food industry, especially in terms of determination the quality and freshness of food, thus determination process is crucial in order to sustain the quality of nutrition, avoiding the problem of poisoning, food wastage and the like [24]. This de-termination method is implemented by classification using a few methods towards gases / odor that has been yielded by gas sensors in electronic nose.

2. ELECTRONIC NOSE

Electronic Nose is a sensor that was first developed in 1982 by Persaud and Dodd [25] followed by Ikegami et al. in 1985 and 1987 at Hitachi in Japan [26, 27]. It mimics human olfactory sense to detect and distinguish an odor or gases or volatile organic compound from a few objects such as food, chemicals, explosive etc. Conventionally, the resulting gas can only be identified by people based on past experience which is stored in their brain memory. Data stored in this memory will be reused if they are faced with a similar smell and it is subjective between individuals. Hence, this concept is transformed electronically using a device called E-Nose. Figure 1 shows a comparison of biological nose to the E-Nose. E-Nose will receive input from a gaseous sample then it will be converted into electric signal form to be processed through data processing i.e. data classification using certain algorithm in order to identify sample odor.
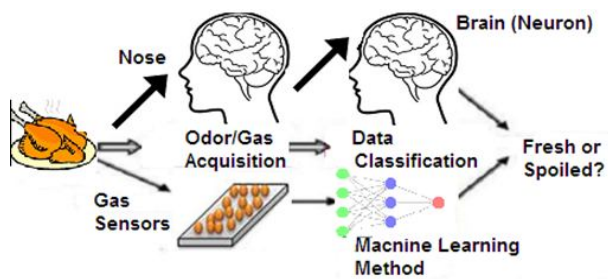

Figure 1: Comparison between biological nose and electronic nose

2.1 Principal of Electronic Nose

The e-nose operates a sensor to response to the odorant molecules (aroma). Figure 2 shows the general architecture of E-Nose to detect gas which later need to be analyzed. The basic important requirement of E-Nose is sampling chamber for gas sample, sensor chamber which contain a number of gas sensors, a software-based of gas acquisition and analyzer.

Sampling and sensor chamber will communicate to each other in order to produced output in a specific form (recorded through data acquisition system) and after that will be analyzed using classification method.
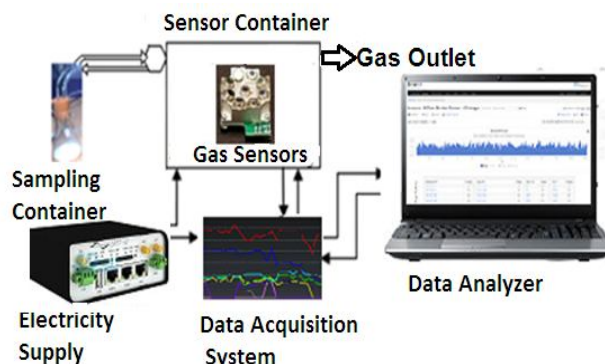

Figure 2: Electronic Nose System Architecture

2.2 Gas Sensor Array

The sensor array is a main component of the electronic nose to detect gas / odor contained in volatile component. Each sensors will respond to their specific gas respectively. Examples of gases that can be detected by E-nose are CO, CH4, H2, SO2, NOx, O3 (to name a few) while Table 1 summarized the involved gas and gas sensors used by commercial product gas sensors [28-29] for the specific purpose, in order to use E-Nose to detect food freshness, researchers need to know the specific gas that will be produced by food through some findings, i.e. information from literature or through experts. Researchers have to find the specific commercial E-Nose or specific gas sensors if they want to develop their own E-Nose.

Table 1: Electronic Nose and the related gases

Applications	Smells/gases involved	Examples of gas sensors	Ref.
Safety	H_2, CO, NO_2, NH_3	TGS-109-203-311-800-812	[22–26]
• Leak detection	CH_4, $CHCl_3$, H_2S,	TGS-813-815-823-832-842	[27–31]
• Poisonous gases	C_2H_5OH, C_4H_{10},	TGS-2600-2610-2611-2620	[32–36]
• Dangerous and	CH_3SH, $(CH_3)_3N$,	ZnO/Al_2O_3, SnO_2/Pd, ZnO	[37–41]
combustible gases	C_2H_4O, C_3H_8, C_6H_6	SnO_2-/ZnO-/CdS-Pt-/La_2O_3	[42–46]
	CF_3CH_2F, CH_4	WO_3/Au, MOS, MOSFET	[47–49]
Environmental control		Gradient sensor microarray	
• Air quality control	CO, NO_x, SO_2, CH_4	TGS, MOS, MOSFET	[2–4, 50, 51]
• Combustion atmosph.	C_6H_6, C_4H_{10}, C_3H_8	Tin oxide doped Pd/Al/Pt,	[52–54]
• Contaminated soils		and different film thickness	
Quality control	Coffee, vinegar,	TGS-813-880-822-825-812	[6–8, 55, 56]
• Food quality control	perfume, aroma,	SnO_2-/Sb_2O_3-/ZnO/NiO	[57–61]
• Perfume and aroma	diary products	Polymer, MOSFET, Quartz-res.	[62–66]
• Monitoring cultivation	wine, etc.	Thin-film WO_3/Pd-/-/Bi-/Sb	[67–70]
Medical		Quartz microbalance (QMB),	
• Infection detection	NA	Metal oxide semiconductor	[9–11]
• Bacterial detection		Electrochemical sensors	
Mobile robot navigation	CO, NO_x, SO_2, CH_4	TGS-2600, 2610, 2611, 2181	[12]
Space	NA	Polymers and quartz	[13]

There are several gas sensors available in the market such as metal-oxide semiconductor sensors (MOS) which can detect more than 20 odors [30], Metal Oxide Semiconductor Field Effect Transistors (MOSFETs), Piezoelectric sensors, Intrinsically Conducting Polymers (ICPs) Optical sensors

[31- 34], to name a few. Sensors to detect gas involved with this type of sensing material as well as way of detection can be summarized by Table 2.

Table 2: Electronic Nose – Sensing Type and detection methods

Sensor Type	Sensitive Material	Detection Principle
Acustic sensors: Quartz crystal microbalance (QMB); surface acoustic wave (SAW)	Organic or inorganic film layers	Mass change (frequency shift)
Calorimetric; catalytic bead	Pellistor	Temperature or heat change
Metal-oxide semiconductor field effect transistors (MOSFET)	Catalytic metals	Electric field change
Conducting polymer sensors	Modified conducting polymers	Resistance change
Electrochemical	Solid or liquid	Current or voltage

sensors	electrolytes	Change
Fluorescence sensors	Fluorescence-sensitive detector	Fluorescent-light emissions
Infrared sensors	IR-sensitive detector	Infrared-radiation absorption
Metal-oxide semiconductor (MOS)	Doped semi-conducting metal oxides (SnO2, GaO)	Resistance change
Optical sensors	photodiode, light-sensitive	Light modulation, 510 optical changes

The example of market ready of E-Nose were used in the previous research, i.e. Znose, Cyranose, FOX, however, the market ready E-Nose devices are expensive (between US $ 10,000 to US 33,000) with limited and specific sampling procedures, which some of that not meet the requirement of research target [22]. Weaknesses and advantages of the market ready E-Nose have been discussed in detail in [35 – 39]. Due to that, there are many research done previously has developed their own fabricated E-Nose to fulfill their own research requirement.
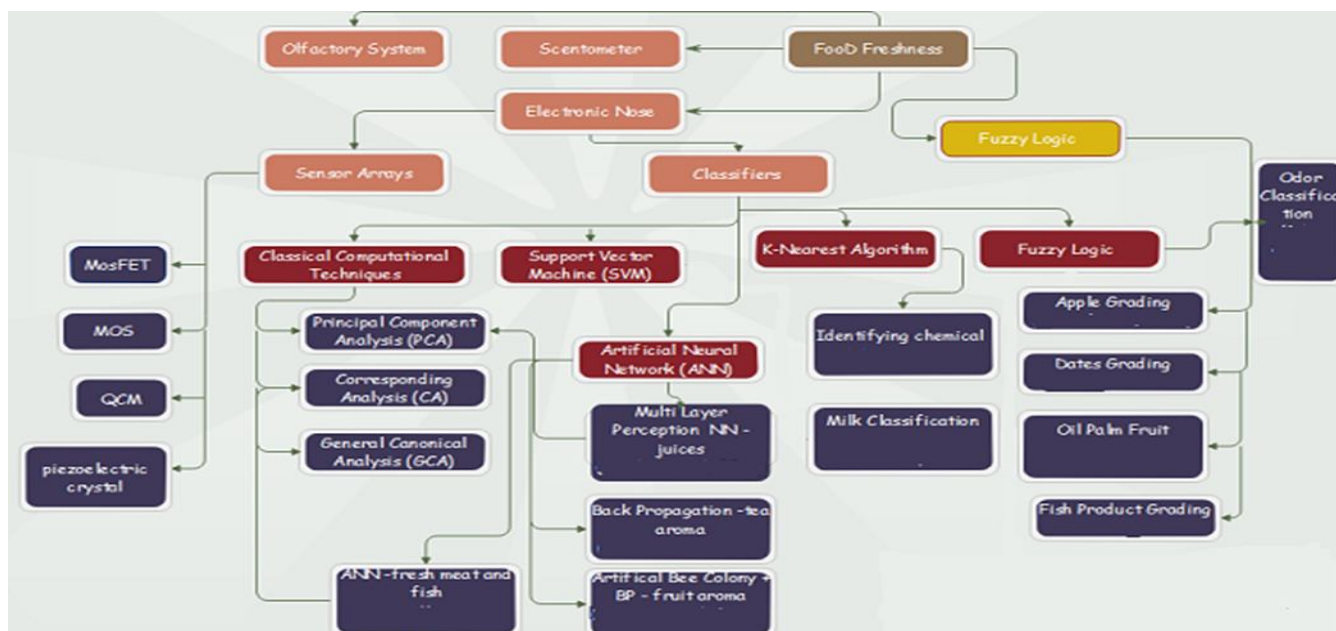

Figure 3: General Overview about food freshness and method for classification

3. DATA MINING TECHNIQUE

Data mining has been actively used in application such as networking and security [40, 41], it allows ones to analyze and thus classify the data into categorical class labels. In this study, we use classification as a way to analyze electrical signal obtained from gas sensors in order distinguish a mixture odor/aroma. This distinguishes are further can determine the level of food freshness. Most of them using machine learning algorithm as shown in Figure 3.

3.1 Statistical Analysis and Neural Network
There are several methods to classify data from E-nose as explained earlier, such as classical computational techniques based on statistical and factorial analysis such as Principal Component Analysis (PCA), Corresponding Analysis (CA), and Generalized Canonical Analysis (GCA) [17]. Another method is Artificial Neural Network (ANN) which was introduced in 1943, for food classification through learning process. It is an interconnected network of neurons that capable to classify a complex vaporous data. In e-nose, the ANN learns to identify the various chemicals or odors by example as well as can rapidly identify un-known chemical in vaporous object.

Both ANN and statistical based classification method contributed to the improvement of sensitivity and accuracy of food classification and air quality control. In [42] a fusion method of gas sensor array with neural network improve the sensor selectivity and accuracy. PCA and ANN also were used to evaluate the signals from multisensory as in [43-44] while in [45], GA was used to determine air pollution and air quality control. A reliable result obtained in [46-47] by applying ANN and PCA for detection and classification of apples ripeness. However, some weakness of non-probabilistic character in statistical analysis (PCA, CA, GA) is not efficient for uncertainty information especially for data obtained through olfactory based sensor as it contain a sampling biases [48].

A few other methods have been explored by researchers to improve performance parameters in food classification. For example, in [49], neural network is applied to analyze data from gas sensors in order to improve selectivity and accuracy. While [22] approached an integrated Multi-Layer Perception Neural Network to increase repeatability and reproducibility towards three kind of beverages i.e. blackcurrant juice, mango juice and orange juice. In this research, PCA was used in order to test the capability of E-Nose in extricating different substance. Another algorithm in ANN is back-propagation algorithm (BP) was used by [42] to classify tea aroma.

BP algorithm was also used in [23] to determine gas contained in a few samples of teas and coffees. ANN's ability to classify odor has been proved in [50] by combining ANN algorithm with General algorithm (GA) to improve the selectivity of the gas sensor arrays which has been tested on decay and fresh meat and fish. In [20] analyzed data using PCA and Artificial Neural Network (ANN) using Backpropagation algorithm. Based on result, honey classification using electronic nose with ANN and Back propagation algorithm had produced good classification.

Another hybrid method has been studied by [51] to improve performance in the training phase of the food classification by combining artificial bee colony algorithm (ABC) and BP algorithm. In their experiment, tests were carried out on four kinds of fruit aroma of strawberry, lemon, cherry and melon. Good result achieved in terms of performance after a comparative study between BP algorithm only and ABC algorithm with BP were done.

3.2 Fuzzy Logic

Fuzzy logic is one of the method that also can be used to identify food freshness. This is because food is considered as uncertainty object, where its attribute is complex to be specified as good, somewhat good, poor and so forth. While the most machine learning method can only specify a crisp data such as good or poor. As such, a fuzzy logic based classification can be applied in order to tackle the problem of uncertainty condition of food. Fuzzy sets were first introduced by Zadeh in [52] as a way to express degrees of membership to a set in imprecise, rather than crisp, terms. Generally, the theory of fuzzy logic allows machines deal with imprecise language used by human to describe data that may not be exact or crisp. Fuzzy logic has been found appropriate for various practical classification problems for food quality evaluation since most food quality attributes rather difficult to specify whether poor, worst, good, very good and so on. Using the fuzzy membership functions, a more realistic knowledge base can be created. Due to that, more studies were done by researchers to improve classification performance as well as for food quality determination since it has been studied has ability to identify the uncertainty in food classification.

In literatures, research done by [53], applied Sugeno-based fuzzy logic to increase an accuracy in identifying odor towards a few gases yielded by food i.e. butanol, acetic acid, acetone, benzene, chloroform, di-chloromethane, ethyl-acetate, and sulfuric acid. Fuzzy Inference System (FIS) method was proposed by [54] to evaluate a grading of dates based on water contents since dates can be graded as moist, dry, somewhat dry and solid dry. Another achievement has been proven by [55-59] which approached fuzzy logic for apple grading based on color defect and sizes.

4. CONCLUSION

In this paper, we present electronic nose and component involved and specific methods that can be used to perform the classification. Each gas sensor array has their own capability depends on the type of gas that would be detected. There are many classification algorithm that generates promising results to identify the freshness of food, have been discussed briefly in this paper.

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