

Electronic Noses that are used in Academic Studies

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Abstract

New trends in sensor technology provide many developments in various areas and also in olfactory systems. These systems which named as Electronic Noses provide doing intelligent techniques on odor data. But the important thing in these studies is choosing the best sensor array which means choosing the best electronic nose. Starting from this idea, we aim to investigate Electronic Noses which are used in academic studies and compare their performance and their features. We hope this study will shed light on, which they want to choose best Electronic Nose for their studies.

Key words: electronic noses, sensors, olfactory systems

1. Introduction

Electronic noses that mimic human olfactory system have sensors which can capture odor and convert it to digital signals. The history of electronic noses goes back to until 1970. Response of the sensors are transmitted parallel and it is combinatorial encoded [1], [2]. An electronic nose sample can be seen in figure 1.



Figure 1. An electronic nose [2]

Table 1 show very different kinds of sensors can be found on the market and can be used in academic studies.

Table 1. Most known electronic noses [3]

Firm	Sensor Type	System
Agilent Technologies	MS	4440
Alpha M.O.S.	MOS, CP, SAW MS and MS-EN electronic tongue	Fox, Centauri Kronos & Prometheus Astree
Applied Sensor	MOSFET, MOS, QCM 4 x MOS, 8 x QCM QCM	3320, 3310 VOCseries VOCcheck
Bloodhound Sensors	CP	BH114
Cyrano Sciences Inc.	CP (composite)	Cyranose 320
Daimler Chrysler Aerospace	QCM, SAW, MOS	SAM system
Electronic Sensor Technology	SAW	zNose
Element	MOS	FreshSense
EnviroNics Industry	IMCELL	MGD-1
Forschungszentrum Karlsruhe	MOS, SAW	Sagas
HKR Sensorsysteme	QCM, MS	QMB6
Lennartz Electronic	QCM, MOS, electrochemical	MosesII
Marconi Applied Technologies	CP, MOS, QCM	e-Nose 5000
Microsensor Systems	SAW	ProSat
Osmetech	CP	OMA and core sensor module
Quartz Technology	QCM	QTS-1
Smart Nose	MS	Smartnose-300
WMA Airsense Analysentechnik	MOS	PEN

Table 1 lists some of the electronic nose devices which are large and bulky and some that are hand terminals and can produce successful results. For example the company "Cyrano Sciences Inc." has designed an electronic nose which is a hand held device and has used in many academic studies [4]–[13]. The device can be seen in figure 2 as an example.

**Figure 2.** An hand held electronic nose

When an electronic nose used in an experiment, the sensors which are used in electronic nose must be rested for a while. Sensors used in electronic noses convert gases into digital signals by using ions, molecules, atoms or fluids [3]. Different sensors can be used in electronic noses. The electronic nose sensors which are investigated in this study are listed in Table 1. if an electronic nose is used for obtaining odor data in an academic study, three steps as shown in figure 3 must be followed. In the first step which is named as sampling the related odor is transferred to the electronic nose. When sensors come to saturation point they are left to rest for a while. Then they are cleaned by clean air. In the third step (analysis), classification and clustering methods are used to classify or cluster obtained the numerical data.

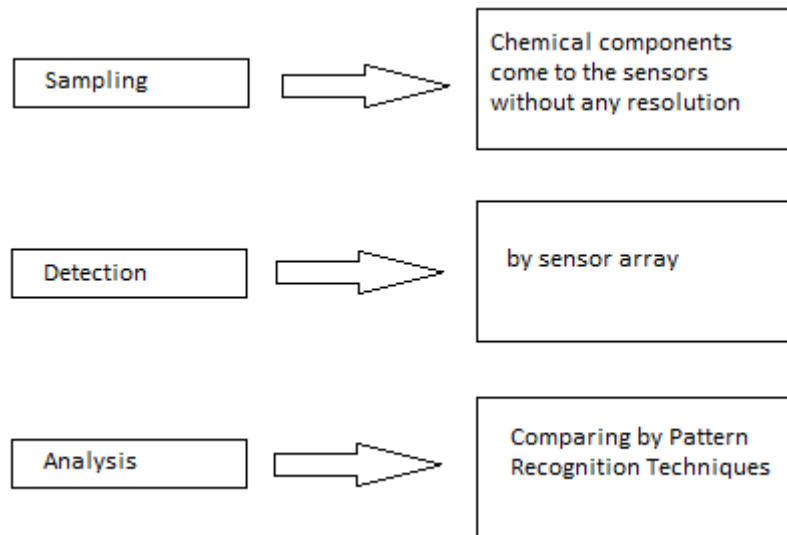


Figure 3. Steps of obtaining electronic nose data

2. Literature Review According to Electronic Noses

In this section 10 of electronic noses which are listed in Table 1 are investigated and studies which used these electronic noses are presented as a summary.

2.1. Alpha MOS (FOX-4000)

Generally there are 18 sensors in this electronic nose and can be found liquid part in it. Mostly it can be used in food quality and classification of cosmetics and it can be seen in many academic studies. For example, to make qualitative and quantitative analysis of perfume cleaners easily electronic nose is used. For example in this study they focus especially in two issues, perfume counterfeiting and determining amount of perfume in an unknown solution [14]. In another study the relationship of the chemical parameters can be predicted was used in to test suet. Successful results obtained by using electronic nose than other techniques [15]. In another study which olive oil is classified, Principle Component Analysis (PCA) and Artificial Neural Network are used. The data which is used in these techniques is electronic nose data [16]. Another method GC-MS which is usually compared with electronic nose is used in [17] with electronic nose data and obtained successful results . In a study that electronic nose and Support Vector Machine are used

together to determine amount of bacteria on pork which held on freezer [18]. In [19] authors made classifications according to unpleasant odor level in pharmaceutical tablets which contains unpleasant odor by using electronic nose.

2.2. Bloodhound Sensors (BH114)

This electronic nose first designed in a university. It has 14 sensors and the sensor technology is based on liquid crystals. This electronic nose is mostly used in medical field and also there are some studies in food quality that use this electronic nose [20]. Sample studies for medical use, such a study that Artificial neural networks and electronic nose is used and some micro-organisms is detected can be given as an example [21]. The gas which is released from urine has been sniffed to the electronic nose for classification bacteria in the urine and from 19 urinary tract infection patients, 18 patients were recognized [22]. In another study Artificial Neural Network and electronic nose data obtained from volatile compounds produced by sputum samples are used to diagnose tuberculosis. In this study 100% performance was obtained [23]. The analysis which is applied to electronic nose data can be combined into several groups. For example Linear Discriminant Analysis (LDA) [24] and Principle Component Analysis (PCA) [25].

2.3. Cyranose 320

As can be seen in Figure 2, electronic nose is capable of being used in many fields. Because of it is portable and has 32 sensors, provides to be used in many different academic studies. When looking examples that are used in medical field, electronic nose has been used in the diagnosis of sarcoidosis that affects the lung. Sarcoidosis disease that could be detected approximately rate of 83% by taking breath samples from patients [4]. In another study authors used electronic nose to rapidly assess grand lure content in boll weevil and they obtain 82% performance from classification of grand lure [5]. A study to be considered important in the health field, to recognize basal stem rot (BSR) caused by Ganoderma Boninense fungus that affecting palm oil farms, using electronic nose and intelligent techniques is proposed. In this study image processing techniques used beside C-320 electronic nose [6]. Again using C-320 electronic nose and sniffed human breath then analysis done on human breath, various lung and respiratory diseases were diagnosed and obtained successful results [4], [10], [11]. In the 21st century how determining food quality and control a review study was made on electronic noses and these studies were summarized successfully. Again from this study, C-320 the electronic nose can be seen how important it is and how often is used in food quality [13].

2.4. zNose

This electronic nose is mostly used in determining food quality. The sensor technology of this electronic nose is based on SAW technology. In a study which used this electronic nose, classification of pears was made and the quality was determined according to their collection dates. They applied regression algorithms on electronic nose data and obtained successful results [26]. Zhang also mentioned about zNose in a study that determine quality of food [27].

2.5. FreshSense

This electronic nose is usually used for determining food quality and has 5 sensors (CO, H₂S, NO, SO₂ and NH₃). When studies which used this electronic nose are investigated they will see that they studied more on fish quality. These studies can be summarized as follows; in a study authors mentioned about artificial quality index which this electronic nose used it. In this study both the odor and visual analysis were made and successful results were obtained [28]. Zhang's study was also in fish quality assessment [27]. Although the study area was fish quality, they looked from slightly different angles and they took measurements from two different electronic noses. They classified cod-fish fillet in a 17 day storage period [29]. The FreshSense electronic nose is used rarely in Environment area like in [30].

2.6. MGD-1

There are both large device and mobile versions of this electronic nose. It has 6 sensors. In a study that used this electronic nose they used ion mobility and determined spectrometry of gases compounds provides rapidity. Therefore ion motion based electronic nose MGD-1 was used in study. In this study the smell of hard and very hard cheese was taken and classification was made successfully [31].

2.7. Sagas

MOS and SAW sensor types can be used in this electronic nose. This electronic nose can be used in various fields to analyses odor. For example in a study that made in food quality, they investigate different types of pork by PCA and PNN (Probabilistic Neuronal Network) and they got good results [32]. In another study made in medical, this electronic nose is used for diagnosis and monitoring respiratory tract and systemic disease [33].

2.8. QMB6

It is possible to see this electronic nose which uses QCM sensors in food and environment fields. Ampuero and Bosset used this electronic nose for analyzing dairy products [34], Deventer and Mallikarjunan used for analyzing of ink that used in plastic packaging of food [35]. This is similar to former study but made in environment field, they determined the quality of plastic material by using this electronic nose [36].

2.9. MosesII

This electronic nose has advanced system and it can use various sensors (MOS, SAW, QMB). This device provides completely a laboratory field but it is very expensive. Some studies using this electronic nose; in a study which emphasized how gas mixture can be analyzed they developed an algorithm and they obtain successful results. As the number of gases increase the synthesis process is also becomes difficult [37]. In another study that uses multiple methods of trying to match between two electronic nose they obtained approximately 67% of successful results [38]. In another study an algorithm was developed to process electronic nose data when an

disorder or deficiency occurs. This type of data occurs when measuring gases that predominantly concentrated [39].

2.10. e-Nose 5000

It is possible to see this electronic nose in the environmental analysis. For example it is used in a study which they examined online drinking water and wastewater [40]. In another hybrid study for chemical analysis they used electronic nose besides the physical movement of gases given more successful results [41].

2.11. ProSat

This electronic nose is usually used in environment odor analysis. For example in a study of analysis of industrial wastes, detection of organic compounds in waste water are made according to responses of the sensors [42]. Again in another study of analysis of waste water, 12-month period the waste water was observed online by electronic nose [43]. Unlike other studies made by this electronic nose, in this study waste water and drinking water was analyzed separately. Online observations made both in land and in laboratory and successful results were obtained [44].

2.12. Smartnose-300

MS (mass spectrometry-based) sensors are used in this electronic nose is possible to see it in the medical field. For example they used this electronic nose for investigate the rats which exposed to hydrogen gas [45].

3. Graphical Representation of Results Obtained from Electronic Noses

Some specific techniques are used to realize data obtained from the electronic nose. These techniques are supported by a variety of intelligent ways like Artificial Neural Network (ANN), Support Vector Machines (SVM) etc. to cluster or classify odor. The most commonly used methods are fingerprint, radar plot and PCA (Principle Component Analysis).

3.1. Fingerprint

It is inspired from human fingerprints analysis and applied to other types of data. Therefore by using fingerprint it can be determined which data belong which class. When look at electronic nose data it will be seen responses of sensors are different for each odor. This situation shows that the fingerprint method can be used for electronic nose data to classify it. It can be seen in [6], [17], [33], [46]–[52] studies the fingerprint method was used.

3.2. Radar plot

The fingerprint method is generally applied to this type of graphical representation. Radar plot is represented as circular. It can be seen this type of usage in [6], [47], [50], [53]–[55] studies.

3.3. PCA

When using the electronic nose it would be too large data obtained so it would be very difficult to process this data. In this case size of data must be reduced. In this reduction process obtained data should represent whole data. Therefore, one of the commonly used analyses which are PCA (Principal Component Analysis) is applied to the data. These basic components include the greatest possible variance. This method is used almost all of the literature reviewed in this study.

Conclusions

In this study researches have shown the electronic noses, are used in many areas like determining the quality of food, disease diagnosis, environmental analyses and decomposition of gases. However it is easily seen from literature review, it is very important to select the most appropriate electronic nose for which area it is used. Number of sensors is as important as selection the type of sensor. The successful results obtained from hand held electronic noses shows that large-sized electronic noses wouldn't be preferred in the future.

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