International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

A Review on Automated Detection of Gases using Electronic Nose

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***Abstract*—** This paper describes an overview of electronic noses and its applications in the environmental, medical, space, military and food industries. Electronic noses are being developed as systems for the automated detection and classification of odors, vapours, and gases. An electronic nose is generally composed of a sample delivery system for fractional analysis of volatile compounds , detection system such as sensor array set and a computing system like artificial neural network.

***Keywords*—** Artificial nose; Automated odour detection; E-Nose; E-sensing; Human olfactory system; Volatile Organic Compounds (VOCs).

I. Introduction

The concept of the electronic nose appeared for the first time in a nature paper by Persuade and Dodd in 1982. The authors demonstrated with a few examples that the responses of gas sensor array could be analyzed with artificial neural networks thereby increasing sensitivity and precision in analysis significantly. This first publication was followed by several methodological papers evaluating different sensor types and combinations[1]. Last advances in the electronic means of seeing and hearing were observed by the scientists. Witnessing these fast advances they scent a marker for systems mimicking the human nose. Human panels along with gas chromatography (GC) or mass spectroscopy (MS) are helpful in quantifying smells. The human panels are subject to fatigue and inconsistencies while classical gas chromatography (GC)/ mass spectrograph (MS) technique separate ,quantify and identify individual volatile chemicals , but incapable of identifying the odor of the components. The E-nose is sensitive and as discriminating as the human nose and it also correlates extremely with GC/MS data[2]. The e-sensing technology is several steps ahead of the conventional gas sensors. The E-Nose detects and sense devices with pattern recognition sub system. The electronic nose is mainly useful in food analysis for rapid and reliable quality classification in manufacturing testing. Later, the electronic noses are also been applied for classification of micro organisms and bio-reactor monitoring. It is a device that can learn to recognize almost any compound or combination of compounds. Like a human nose, the E-Nose is versatile, yet it is much more sensitive. E-Nose can detect an electronic change of 1 part per million[3].

II. ELECTRONIC NOSE

An electronic nose, also called as E-Nose or Artificial Nose, is a device that identifies the specific components of an odour and analyzes its chemical makeup to identify it. An e-nose consists of a mechanism for chemical detection, such as an array of sensors, and a mechanism for pattern recognition and detection, such as Artificial Neural Network(ANN)[4].

A human nose uses over 100 million specialized receptors or sensors which act together in complex ways to identify and tell apart the molecules they encounter. Electronic noses use similar method but often have less than 50 sensors in an array.

An odour is composed of molecules, each of which has a specific and definite size and shape. Each of them has a correspondingly sized and shaped receptor in the human nose. When a specific receptor is activated by a molecule, it sends a signal to the brain and the brain identifies the smell associated with that particular molecule. Electronic noses work in a similar manner, albeit substituting sensors for the receptors, and transmitting the signal to a program for processing, rather than to the brain. Electronic noses are one example of a growing research area called biomimetics, or biomimicry, which involves human-made applications patterned on natural phenomena[5].

The two main components of an e-nose are the sensing system and automated pattern recognition and detection system. The sensing system can be an array of number of different sensing elements (e.g., chemical sensors), where each element measures a different property of the sensed chemical, or it can be a single sensing device that produces an array of measurements for each chemical, or it can be a combination. Each chemical vapour presented to the sensor array produces a signature characteristic of the vapour[6]. By using different chemicals to the sensor array, a database of different and unique signatures is built up. This database of labelled signatures is used to train the pattern recognition system for its detection. The goal of training process is to configure the recognition system to generate unique classifications of each chemical so that an automated identification can be implemented easily.

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III. SNIFFER DOGS VS E-NOSE

In 2017, the Mumbai police department has a force of fifty sniffer dogs and spends about Rs 7,000 on each dog per month on them, in addition to trainers' salaries. Costs rise when a dog gets sick[7]. The following table gives the comparison between sniffer dogs and electronic nose[8].

TABLE I. Comparison between sniffer dogs and e-nose

E-NOSE	SNIFFER DOGS
The sensors can be designed to detect particular compounds.	Sniffer dogs nose cannot be designed according to the needs.
It does not get tired or sick, it does not stop to eat or sleep, does not need any holiday and does not get distracted by other smell.	Sniffer dogs may get tired or sick, needs sleeps and food and may get distracted by other smell.
Its memory can be programmed to recognize thousands of combinations of chemicals.	Sniffer dogs that can only be trained to sniff a finite number of combinations.
The electronic nose can also provide the police more precise clues.	Sniffer dogs narrows down to the exact type of explosive used.
It can work longer, harder and cost less in the long run than real sniffers.	They have a definite life span since they have to sniff narcotics and explosives, which represent a health hazard.

IV. BIOLOGICAL NOSE

The mammalian olfactory system uses various chemical sensors, known as olfactory receptors, combined with automated pattern recognition present in the olfactory bulb and olfactory cortex in the human brain.

The olfaction process starts with sniffing process which brings odorant molecules from the outside world into the biological nose. Next, the odorant molecules dissolve in this thin mucus layer which then transports them to the cilia (hair like fibers) of the olfactory receptor neurons. The mucus layer functions as a filter to get rid of larger particles. Reception involves binding the odorant molecules to the olfactory receptors. These olfactory receptors respond chemically with the odorant molecules. This process involves temporarily binding of the odorant molecules to proteins that transport the molecules across the receptor membrane. Once the molecules are across the boundary, the odorant molecules chemically stimulate the receptors. Receptors with different binding proteins are arranged randomly throughout the olfactory epithelium.

The chemical reaction in the receptors produces an electrical stimulus. These electrical signals from the receptor neurons are then transported by the olfactory axons through the cribiform plate (a perforated bone that separates the cranial cavity from the nasal cavity within the skull) to the olfactory bulb (a structure in the brain located just above the nasal cavity).From the olfactory bulb, the receptor response information is transmitted to the olfactory cortex where odour recognition takes place. Then the information is transmitted to the limbic system and cerebral cortex.

It is the brain that connects the collection of olfactory signals with the odor. Finally, for the nose to respond to new odors, the olfactory receptors must be cleansed. This includes breathing fresh air and the removal of various odorant molecules from the olfactory receptors.

Each and every part of E-Nose is similar to the biological nose. The following table gives the comparison between the biological and electronic nose[9].

TABLE II. Comparison between biological and electronic nose[18]

BIOLOGICAL NOSE	E-NOSE
Inhaling	Pump
Mucus	Filters
Olfactory Epithelium	Sensors
Binding with proteins	Interaction
Enzymatic proteins	Reaction
Cell membrane depolarized	Signals
Nerve impulses	Circuitry and neural network

V. MAIN COMPONENTS

Electronic Noses include three major parts:

1. A Sample Delivery System
2. A Detection System
3. A Computing System

The sample delivery system enables the generation of the headspace (volatile compounds) of a sample, which is the fraction analyzed. The sample delivery system is necessary to assure constant operating conditions.

The detection system, which consists of a array of sensors, is the reactive part of the device. Most of the e-noses use sensor arrays that react to VOCs on contact i.e. the adsorption of VOCs on the sensor surface causes a physical change of the sensor properties. A unique and specific response is recorded by the electronic interface thereby transforming the signal into a digital value. Recorded data are then computed based on statistical models.

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The computing system combines the responses of all of the sensors, which act as the input for the data treatment. This part of the system performs global fingerprint analysis and provides outputs and representations that can be interpreted easily and can be correlated to those obtained from other techniques[10].

VI. WORKING

The sensor array sniffs the vapours from a sample and provides a set of measurements; the pattern-recognizer compares the pattern of the measurements to stored patterns for known materials. Gas sensors have broad selectivity thereby responding to many different substances. Although every sensor in an array may respond to a given chemical, these responses will usually be different.

This changes the way a sensor conducts electricity, and each sensor responds to the same compounds in different ways[11]. The combined response of the sensors can thus vary greatly with each individual smell. E-sensing technology of electronic nose has the ability to send a signal to an environmental control system where a central computer decides how to handle the problem, without any human efforts. The device also can be trained in one session to detect many specific contaminants.

VII. SENSORS FOR E-NOSE

At present, e-nose uses tiny sensors, which together are about the size of the human nose. The more commonly used sensors include:

1. Metal Oxide Semiconductors (MOS)
2. Conducting Polymers (CP)
3. Field Effect Transistors (MOSFET)

VIII. MOS SENSORS

The MOS sensor technology is a proprietary solid state metal oxide semiconductor. The MOS sensor consists of two thin films: a temperature sensitive heater film, and a gas sensitive sensor film. Both films are deposited on a silicon microchip by vacuum deposition. The heater film elevates the operating temperature of the sensor film to a level where an optimized sensitivity and response to the given sample is achieved. The sensor film consists of a proprietary metal oxide that shows a dynamic signal change to given sample.

Range of sensitivity is from PPB to % by volume. This rugged sensor is capable of maintaining its operating characteristics for periods of upto 10 years in most industrial environments[12].

IX. CONDUCTING POLYMERS SENSORS

E-nose uses a collection of different conducting polymer films. These films are typically designed to conduct electricity. All of the polymer films start out at a measured resistance called as their baseline resistance[13]. If there has been no change in the composition of the air, the films stay at the baseline resistance and the percent change in electricity is zero.

When the e-nose smells something each polymer changes its size, and therefore its resistance, by a different amount, making a pattern of the change.

X. MOSFET SENSORS

They are based on metal-insulator-semiconductor structures and are mainly two types, metal insulator semiconductor field-effect transistor (MISFET), called MOSFET and metal insulator-semiconductor capacitor (MISCAP). MOSFET gas sensors are field effect transistors covered with a thin catalytic metal layer. When the sensors come into contact with volatile compounds a reaction takes place in the catalytic metal, that diffuses through the gate and change the electrical properties of the device[15]. The sensitivity and selectivity of MOSFET devices can be changed by using different types, structures and thicknesses of metal catalyst coverings and also by varying the operating temperature of the sensor between 100°C and 180°C.

MOSFET sensors respond to a wide range of complex odors, consist of amines, aldehydes, esters, ketones, aromates and alcohols [16]. The sensors respond to ppm concentrations of compounds.

XI. COMPUTING SYSTEM

The quantity and complexity of the data collected by sensors array can make conventional chemical analysis of data in an automated fashion difficult. The statistical techniques used are based on commercial or specially designed software using feature extraction and pattern recognition routines like principal component analysis (PCA), partial least squares (PLS), functional discriminant analysis (FDA), cluster analysis, fuzzy logic or artificial neural network (ANN). Other newer techniques that seem to have an interesting potential are multiway decomposition and Independent Component Analysis (ICA). Artificial Neural Network System (ANNS) which have been used to analyze complex data and to recognize patterns are showing promising results in chemical vapour recognition. When an ANN is combined with a sensor array, the number of detectable chemicals is generally greater than the number of sensors.

An Artificial Neural Network (ANN) is an information processing paradigm that is influenced by the process by

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which biological nervous systems, such as the brain, operates information. The main element of this paradigm is the novel structure of the information processing system. It comprises of various highly interconnected processing elements i.e. neurons, working in unison to solve problems.

An ANN is designed for a particular application, such as pattern recognition or data classification, through a learning procedure. Learning in biological systems includes adjustments to the synaptic connections existing between the neurons. Pattern recognition process can be executed by using a feed-forward neural network that has been trained accordingly. During training, the network is trained to associate outputs with input patterns[17]. When the network is used, it identifies the input pattern and tries to output the output pattern associated with it. The power of neural networks comes to play when a pattern that has no associated output with it, is given as an input. In this case, the network gives the output that corresponds to a taught input pattern that is least different from the given pattern.

The objective of generalization is to yield a correct output response to an input stimulus to which it has not been trained before. The system must induce the salient feature of the input stimuli and detect the regularity. It enables the system to function competently throughout the entire space, even though it has been trained only by a limited body of exemplary patterns.

XII. EXPERIMENTAL SETUP FOR ANALYSIS

As a first step, an electronic nose needs to be trained with qualified samples so as to build a database of reference. Then the instrument recognize new samples by comparing the VOCs fingerprint to those present in its database.

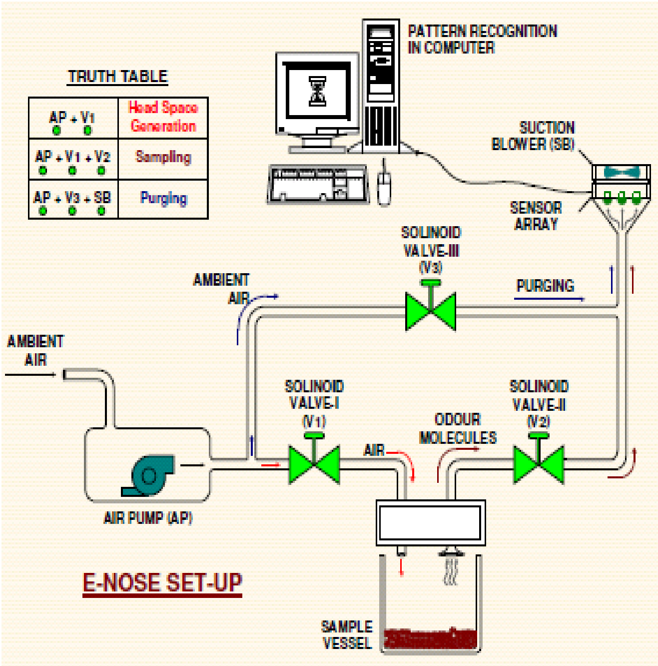

Fig.1. Experimental setup for E-Nose

XIII. APPLICATIONS

E-Nose has many uses on Earth. Some of its applications are:

A. E-NOSE FOR ENVIRONMENTAL MONITORING

The environmental applications of the electronic nose will include[6]:

i. Identification of toxic wastes.
ii. Analysis of fuel mixtures.
iii. Detection of oil leaks.
iv. Identification of household odours.
v. Monitoring air quality.
vi. Monitoring factory emission.

B. E-NOSE IN FOOD INDUSTRIES

Currently, the biggest market for electronic noses is the food industry. In some cases, e- nose can be used to augment or replace panels of human experts in food production especially when qualitative results will do. In other cases, electronic noses can be used to minimize the amount of analytical chemistry that is performed in food production especially when qualitative results will do[18].

The applications of electronic noses in food industry are numerous. They include:

i. Inspection of food by odour.
ii. Grading quality of food by odour.

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iii. Fish inspection.
iv. Fermentation control.
v. Checking mayonnaise for rancidity.
vi. Automated flavor control.
vii. Monitoring cheese ripening.
viii. Beverage container inspection.

C. MEDICAL DIAGNOSIS AND HEALTH MONITORING

Since the sense of smell is an important sense it the physician, an electronic nose has applicability as a diagnostic tool. An electronic nose can be used to analyze the odours from the body and identify the possible problems. Odour in the breath can indicate gastrointestinal, liver and sinus problems, infection, diabetes etc, infected wounds and tissues will release distinctive smell, which can be identified by the electronic nose [15].

It is found that the fruity, nail-varnish remover smell found of the breathe of a diabetic about to enter a sever coma. The tin traces of illness-related chemicals on breath could indicate diseases such as schizophrenia when detected by a new generation of electronic noses.

I. RESPIRATORY DISEASE DIAGNOSIS

Human breath contains thousands of volatile organic compounds (VOCs) in gas phase.

i. Electronic noses can detect respiratory infections such as pneumonia. It does so by comparing smell prints from the breath of sick patients with those having standardized readings.
ii. It is also being considered as a diagnostic tool for lung cancer.

II. URINARY TRACT INFECTIONS

The e-nose as a potential diagnostic tool for patients affected with kidney diseases, by distinguishing traces of blood in urine samples.

III. CANCER DETECTION

E-nose is capable of differentiate between the breath of a healthy person and a person with cancer. The device is especially promising because it is able to detect cancer before tumors become visible in X-rays.

D. SPACE APPLICATIONS: E-NOSE AND NASA

In Jet Propulsion Laboratory (JPL) NASA, it is a full-time, continuously operating event monitor used in the International Space Station. It is designed mainly for the purpose of detecting air contamination from spills and leaks in the crew habitat. It also provides rapid, early identification and quantification of atmospheric changes caused by chemical species to which it has been trained and can also be used to monitor cleanup processes after a leak or a spill[19].

XIV. FUTURE SCOPE OF E-NOSE

Research is being done on IC E-Noses to minimize the current technology. Also improvements are being made in sensitivity for lower levels of organisms or smaller samples. Scientists are working on the digital scent technology which includes:

i. Sensing, transmitting and receiving smell through internet.
ii. Detection and processing of scent using E-Nose.
iii. Scent to be indexed along two parameters, its chemical makeup and its place in the scent spectrum and then digitized into a small file.
iv. Broadcasting i.e. digital file can be sent or attached to enhance web content.
v. Smell Synthesizer, a device which can be used to generate the smells[20].

REFERENCES

[1] Irfan Inamdar ,"Electronic Nose",Author Stream, 2013.
[2] Diana Hodgins and Derek Simmonds,"The Electronic Nose and its application to the manufacture of food products",Journal of Automatic Chemistry,Vol.17,No.5,pp. 179-185,1995.
[3] Dr.S.S.Verma, "Electronic Nose Technology",Department of Physics,S.L.I.E.T.,Longowal,Distt.-Sangrun,Punjab-148106, 2017.
[4] Abdul Sayeed and Mohammed Suhail Shameem,"Electronic Nose",Advances in Medical Informatics,Vol.1,Issue 1,pp. 06-09,2011.
[5] Margaret Rouse,"Electronic Nose(e-Nose)",WhatsIt, 2016.
[6] Paul E.Keller and Sherif Hashem,"Electronic Noses and Their Applications",Pacific Northwest National Laboratory,Cairo University,1995.
[7] Express News Service,The Indian Express,Mumbai,2017.
[8] Tyler Berrigan,"Electronic noses might replace search and rescue dogs", Science News for Students,2018.
[9] Paul E.Keller,"Overview of Electronic Nose Algorithms",Battelle Pacific Northwest Division,USA,1999.
[10] Anonymous,"How does an ekectronic nose works", Elprocus, 2008.
[11] P.E. Keller, L.J. Kangas , L.H. Liden, S. Hashem, R.T. Kouzes, "Electronic Noses and Their Applications,"Proceedings of the World Congress on Neural NetworksP6,pp. 928-931, Lawrence Erlbaum Associates Inc., Mahwah,NJ,USA,1996.
[12] GardnerJ., Bartlett P.N, "Electronic Nose Principles and Applications", Oxford University Press,Oxford,UK,1999.
[13] D Hodgins,"The electronic nose using conducting polymer sensors",Sensor Review,Vol.14,Issue 4,pp. 28-31,1994.
[14] Bill Drafts,"Acoustic Wave Technology Sensors ", Sensors Online, 2000.
[15] Hasin Alam, "Overview of Smell Sensor System", Ph. D. Thesis, Development of a Sensor system and Its Applications, Integral Univrsity,2015.
[16] Lister T. & Renshaw J. ,"Understanding Chemistry for Advanced Level", Stanley Thornes Publishers, p.61,1990.
[17] Maria Jamal,M.R.Khan,S.A. Imam,Arif Jamal," Diagnosis of Diabetes Mellitus using Artificial Neural Network based E-nose for Telemedicine",Proceedings of the 2009 International Conference on Signals,System and Automation(ICSSA 2009),Universal Publishers,2010.

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[18] B. Lakshmi , K.Parish Venkata Kumar , Dr. K.Nageswara Rao, Shahnaz Banu," Simulation of Artificial Noses for the Automated Detection and Classification of Organic Compounds", International Journal of Computer Science and Information Technologies, Vol. 4 (2) , pp. 233 – 237,2013.
[19] Margaret A. Ryan,"JPL Electronic Nose",2017.
[20] B.Jebina Priscill, M.Anandhavalli, "Digital Smell Technology", International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) ISSN: 0976-1353 ,Vol. 25, Issue 5,2018.

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