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REVIEW OF ELECTRONIC NOSE AND APPLICATIONS

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ABSTRACT:

An electronic nose is a device that performs the electronic olfactory to substitute human experts. The development of these devices is growing faster due to higher demand. Electronic nose is the mimicking of human nose. Electronic-nose devices have received considerable attention in the field of sensor technology during the past twenty years, largely due to the discovery of numerous applications derived from research in diverse fields of applied sciences. The harnessing of electronics to measure odor is greatly to be desired. Recent applications of electronic nose technologies have come through advances in sensor design, material improvements, software innovations and progress in micro circuitry design and systems integration. There are numbers of applications of e-nose including the agricultural, biomedical, cosmetics, environmental, food, manufacturing, military, pharmaceutical, regulatory, and various scientific research fields. In this paper we have described the basic working of e-nose system, e-nose systems available today and their different applications.

Keywords: Fluorescent, Polypyrrole. Radial basis function

INTRODUCTION:

The human nose has been used as a judge for food and perfumes for years. The best way to know, how the fresh food gives a sniff. I f the food smells well, it is fresh but how do we smell. After a few hours of smelling, even the best inspector's nose can come up a bit short. Electronic noses automatically detect and recognize odors, vapors and gases. Electronic noses (e-nose) consist of an array of gas sensors with different selectivity patterns, a signal collecting unit and pattern recognition software applied to computer. E-nose systems utilize an array of sensors to give a fingerprint response to a given odor, and pattern recognition software then performs odor identification and discrimination.

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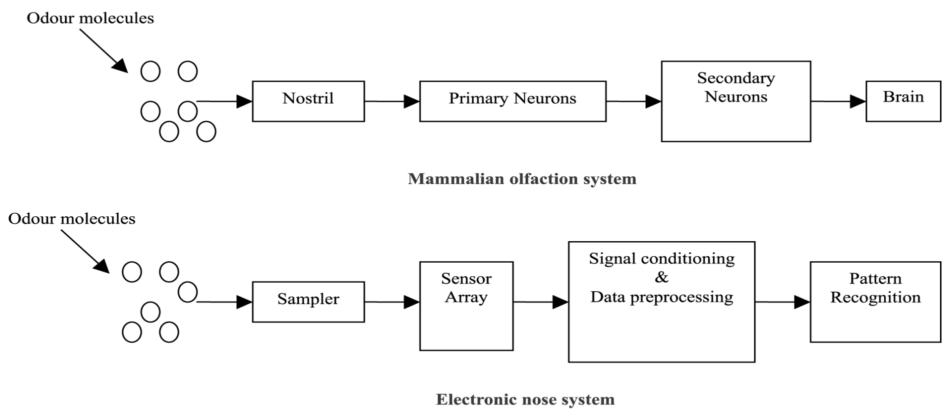

Fig 1 Comparison of the mammalian olfactory system and the e-nose system

The e-nose attempts to emulate the mammalian nose by using an array of sensors that can simulate mammalian olfactory responses to aromas. The odour molecules are drawn into the e-nose using sampling techniques such as headspace sampling, diffusion methods, bubblers or pre-concentrators [1]. The odor sample is drawn across the sensor array and induces a reversible physical and/or chemical change in the sensing material, which causes an associated change in electrical properties, such as conductivity [2]. Each "cell" in the array can behave like a receptor by responding to different odors to varying degrees [3]. These changes are transduced into electrical signals, which are preprocessed and conditioned before identification by a pattern recognition system as shown in Figure 1. The e-nose system is designed so that the overall response pattern from the array is unique for a given odor in a family of odors to be considered by the system.

ELECTRONIC NOSE PRINCIPLES

The e-nose attempts to emulate the mammalian nose by using an array of sensors that can simulate mammalian olfactory responses to aromas. The odour molecules are drawn into the e-nose using sampling techniques such as headspace sampling, diffusion methods, bubblers or pre-concentrators [1]. The odour sample is drawn across the sensor array and induces a reversible physical and/or chemical change in the sensing material, which causes an associated change in electrical properties, such as conductivity [2]. Each "cell" in the array can behave like a receptor by responding to different odours to varying degrees [3]. These changes are transduced into electrical signals, which are preprocessed and conditioned before identification by a pattern recognition system as shown in Figure 1. The e-nose system is designed so that the overall response pattern from the array is unique for a given odour in a family of odours to be considered by the system.

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In effect, the electronic nose can create odor-exposure profiles beyond the capabilities of the human panel or GC/MS measurement techniques. The electronic nose is a system consisting of three functional components that operate serially on an odorant sample--a sample handler, an array of gas sensors, and a signal-processing system. The output of the electronic nose can be the identity of the odorant, an estimate of the concentration of the odorant, or the characteristic properties of the odor as might be perceived by a human.

SENSING AN ODORANT

In a typical electronic nose, an air sample is pulled by a vacuum pump through a tube into a small chamber housing the electronic sensor array. The tube may be made of plastic or stainless steel. Next, the sample-handling unit exposes the sensors to the odorant, producing a transient response as the VOCs interact with the surface and bulk of the sensor's active material. (Earlier, each sensor has been driven to a known state by having clean, dry air or some other reference gas passed over its active elements.) A steady-state condition is reached in a few seconds to a few minutes, depending on the sensor type. During this interval, the sensor's response is recorded and delivered to the signal-processing unit. Then, a washing gas such as an alcohol vapor is applied to the array for a few seconds to a minute, so as to remove the odorant mixture from the surface and bulk of the sensor's active material. (Some designers choose to skip this washing step.) Finally, the reference gas is again applied to the array, to prepare it for a new measurement cycle. The period during which the odorant is applied is called the response time of the sensor array. The period during which the washing and reference gases are applied is termed the recovery time. The response of e-nose to an odorant.

OPTICAL FIBRES

Optical-fiber sensors, yet another type, utilize glass fibers with a thin chemically active material coating on their sides or ends [Fig. 7]. A light source at a single frequency (or at a narrow band of frequencies) is used to interrogate the active material, which in turn responds with a change in color to the presence of the VOCs to be detected and measured. Odorant optical-fiber sensors employ a glass fiber coated on its sides or ends with a thin, chemically active material containing fluorescent dyes immobilized in an organic polymer matrix. A pulse of light from an external source propagates along the fiber and interrogates the active material, with which VOCs can interact. The interaction alters the polarity of the dyes, which respond by shifting their fluorescent spectrum. For high-temperature applications, the over coating is a protective layer, while for in vivo uses it is a biocompatible material.
The active material contains chemically active fluorescent dyes immobilized in an organic polymer matrix. As VOCs interact with it, the polarity of the fluorescent dyes is altered and they respond by shifting their fluorescent emission spectrum. When a pulse of light from an external source interrogates the sensor, the fluorescent dye responds by emitting light at a different frequency. As the source intensity is much greater than the sensor response, great care must be taken to ensure that the response photo detectors are protected from the source emissions. Arrays of these devices with different dye mixtures can be used as sensors for an electronic nose. For example, researchers at Tufts University, in Medford, Mass., have constructed an optical system that interrogates the sensors at an (excitation) wavelength of 535 nm, and measures time and amplitude changes in fluorescence (emission) at 610 nm.

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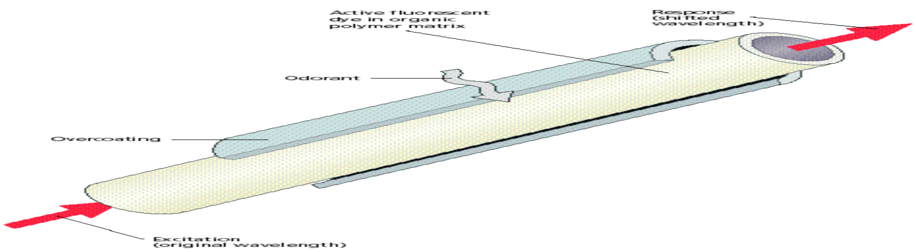

Fig 7 Odorant optical-fiber sensors

ELECTRONIC NOSES DATA ANALYSIS

The outputs generated by e-nose sensors are digital and have to be analyzed and interpreted in order to provide useful informations to the operator. Basic data analysis techniques [6] are Multiple regression analysis(MRA) and Principle component analysis(PCA)

Analysis techniques fall into three main categories as follows [7]:

1. Graphical analysis: bar chart, profile, polar and offset polar plots

2. Multivariate data analysis (MDA): principal component analysis (PCA), canonical discriminate analysis (CDA), featured within (FW) and cluster analysis (CA)

3. Network analysis: artificial neural network (ANN) and radial basis function (RBF)

The choice of method utilized depends on the type of available input data acquired from the sensors and the type of information that is available.

APPLICATIONS OF ELECTRONIC NOSES

Electronic-nose systems have been designed specifically to be used for numerous applications in many different industrial production processes. A wide variety of industries based on specific product types and categories, such as the automobile, food, packaging, cosmetic, drug, analytical chemistry and biomedical industries utilize e-noses for a broad and diverse range of applications including quality control of raw and manufactured products, process design, freshness and maturity (ripeness) monitoring, shelf-life investigations, authenticity assessments of premium products, classification of scents and perfumes, microbial pathogen detection and environmental assessment studies (Table 1). Some individual examples of electronic nose applications in each of these individual industries and product areas are discussed below

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Table.1 Examples of some industry-based applications of electronic noses

Industry sector	Application area	Specific use types and examples
Agriculture	a. crop protection b. harvest timing & storage c. meat, seafood, & fish products d. plant production e. pre- & post-harvest diseases	homeland security, safe food supply crop ripeness, preservation treatments freshness, contamination, spoilage cultivar selection, variety characteristics plant disease diagnoses, pest identification detect non-indigenous pests of food crops
Airline Transportation	a. public safety & welfare b. passenger & personnel security	explosive & flammable materials detection
Cosmetics	a. personal application products b. fragrance additives	perfume & cologne development product enhancement, consumer appeal
Environmental	a. air & water quality monitoring b. indoor air quality control c. pollution abatement regulations	pollution detection, effluents, toxic spills malodor emissions, toxic/hazardous gases control of point-source pollution releases
Food & Beverage	a. consumer fraud prevention b. quality control assessments c. ripeness, food contamination d. taste, smell characteristics	ingredient confirmation, content standards brand recognition, product consistency marketable condition, spoilage, shelf life off-flavors, product variety assessments
Manufacturing	a. processing controls b. product uniformity c. safety, security, work conditions	product characteristics & consistency aroma and flavor characteristics fire alarms, toxic gas leak detection
Medical & clinical	a. pathogen identification b. pathogen or disease detection c. physiological conditions	patient treatment selection, prognoses disease diagnoses, metabolic disorders nutritional status, organ failures

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Military	a. personnel & population security b. civilian & military	biological & chemical weapons safety explosive materials detection
Pharmaceutical	a. contamination, product purity b. variations in product mixtures	quality control of drug purity formulation consistency & uniformity
Regulatory	a. consumer protection b. environmental protection	product safety, hazardous characteristic air, water, and soil contamination tests
Scientific Research	a. botany, ecological studies b. engineering, material properties c. microbiology, pathology	chemotaxonomy, ecosystem functions machine design, chemical processes microbe and metabolite identifications

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Food Freshness, Quality, Ripeness and Shelf-Life

The age of fruits (ripeness or maturity level) determines the shelf life and future rate of quality loss due to changes in flavor, firmness and color. Harvesting fruits at an optimal physiological condition ensures good quality at a later stage (when evaluated by the consumer) by enhancing a number of quality characteristics that extend the shelf-life, slow the rate of decline in firmness or texture, and maintain a preferred level of flavor and overall appearance. Several studies have demonstrated that the aroma emitted by fruits can indicate the maturity level and thus quality and shelf-life of the marketed product. Pathange *et al.* [8] used maturity indices such as starch index and puncture strength to categorize fruit of the "Gala" apple variety into three maturity groups referred to as immature, mature and over-mature fruits. Gòmez *et al*. [9] studied volatile production of unripe, half-ripe, full-ripe and over-ripe tomatoes using the PEN 2 E-nose (10 different metal oxide sensors) with principal component analysis (PCA) and linear discriminant analysis (LDA). The results demonstrated that the electronic nose could differentiate among the ripeness states of tomatoes and classify them with 100% reliability in each ripeness group.

Medical Pathology

Modern medicine faces the problem and challenge of achieving effective disease diagnoses through early detections of pathogenesis or disease conditions in order to facilitate the application of rapid treatments, but at the same time dramatically reducing the invasiveness of diagnostic treatments. Chemical analysis of human biological samples, such as breath, blood, urine, sweat and skin, are the most common means of diagnosing most pathological conditions. As summarized in the "metabolic profile concept" described by Jellum *et al.* [30], current clinical chemistry is largely limited to investigations of the composition of human fluids [31]. It is well known that pathogenic microbial species produce a wide range of VOCs, and the diagnostic potential of pathogen recognition through analysis of secondary microbial metabolites was recognized and considered theoretically possible as early as the 1960s [32]. However, the use of VOC chemical analyzers, such as GC or GC/MS, is still very expensive, requires highly-skilled personnel and is time consuming to the extent of precluding early diagnoses. The connection

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between differences in the aroma of diseased vs. healthy human tissues and diagnostic detection of human pathogenesis is supported by studies using the extraordinarily keen olfactory abilities of well trained dogs whose sense of smell is one million times greater than human's in the ability to detect melanoma tissues [33], bladder cancer [34], as well as lung and breast cancers [35].

Conclusion

For future developments of more e-nose applications is enormous as in many fields of scientific investigation and industrial development researchers become more aware of the capabilities of the electronic nose. The present era is trending toward the development of electronic noses for particular purposes or a fairly narrow range of applications. The efficiency of electronic nose can be increased by minimizing the number of sensors needed for discriminations, reducing instrument costs, and allowing for greater portability through miniaturization. A proper selection of an appropriate e-nose system for a particular application must involve an evaluation of systems on a case by case basis. New potential discoveries in this relatively new sector of sensor technology will continue to expand as new products, machines, and industrial processes are developed. These development will lead to the recognition of new ways to exploit the electronic nose to solve many new problems for the benefit of mankind. New emerging technologies are continually providing means of improving e-noses and EAD capabilities through interfaces and combinations with classical analytical systems for rapid discrimination of individual chemical species within aroma mixtures.

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