E-Nose

CONTENTS

INTRODUCTION

- Volatile organic compounds (VOC) are basic to odours.

- The detection of chemicals such as industrial gases and chemical warfare agents is important to human health and safety and also for industrial purposes.

- But the human nose is not sensitive to all kind of VOC's.

- It is also important to have a detection system for VOC's which are hazardeous to human beings.

- Until now, online communication involved only two of our senses, sense of sight & sense of hearing. A system to transfer or for the digital representation of the odour is also a matter of concern.

- These all facts lead to the requirement of an electronic detection system for odours which is "Electronic Nose" .

What is the E-Nose?

- An electronic nose (e-nose) is a device that identifies the specific components of an odour and analyzes its chemical makeup to identify it.

- Can be regarded as a modular system comprising a set of active materials which detect the odour, associated sensors which transduce the chemical quantity into electrical signals, followed by appropriate signal conditioning and processing to classify known odours or identify unknown odours .

- Device intended to detect odours or flavors.

- Can be seen as arrays of sensors able to generate electrical signals in response to either simple or complex volatile compounds present in the gaseous sample.

Why do we need an E-Nose?

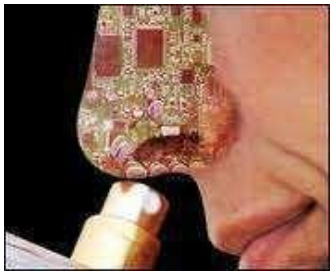
- E-nose can be sent to detect toxic and otherwise hazardous situations that humans may wish to avoid.
- Human olfactory system may be unstable with respect to mood or physical condition, but E-nose are not.
- Speedy and Accurate decision making capabilities because of pattern matching technology.
- The human sniffers are costly when compared to electronic nose.
- For the confirmation of the values obtained from a sniffer the result obtained from the sniffer has to be compared with some other sniffer's value.
- There lies a great chances of difference in the values got by each individual.

Sniffer Dogs Vs E-Nose

There are things a dog cannot smell because its 'sensors' are just not sensitive to it.

- One of the advantages of an electronic nose is that we can design sensors to detect particular compounds -- with a dog, it has whatever it has.
- Another advantage of an electronic nose is that it doesn't get tired or sick, it doesn't stop to eat or sleep, cannot have an 'off day' and it does not get distracted by more interesting smells.
- Its memory can be programmed to recognize thousands of combinations of chemicals, as against 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 since— unlike sniffer dogs—it narrows down the exact type of explosive used.
- It can work longer, harder and cost less in the long run than real sniffers.
- A trained dog cannot work for more than 40 minutes at a stretch.
- Dogs have a short lifespan since they have to sniff narcotics and explosives, which represent a health hazard.

Biological Nose



- Of all the five senses, olfaction uses the largest part of the brain and is an essential part of our daily lives.
- Human nose is very sensitive. Subject to fatigue, inconsistances, adaptation etc.
- Smelling toxic gases may involve risk .
- Each and every part of the electronic nose is similar to human nose.

Biological Nose	E-Nose
Inhaling	Pump
Mucus	Filter
Olfactory epithelium	Sensors
Binding with proteins	Interaction
Enzymatic proteins	Reaction
Cell membrane depolarized	Signal
Nerve impulses	Circuitry and Neural Network

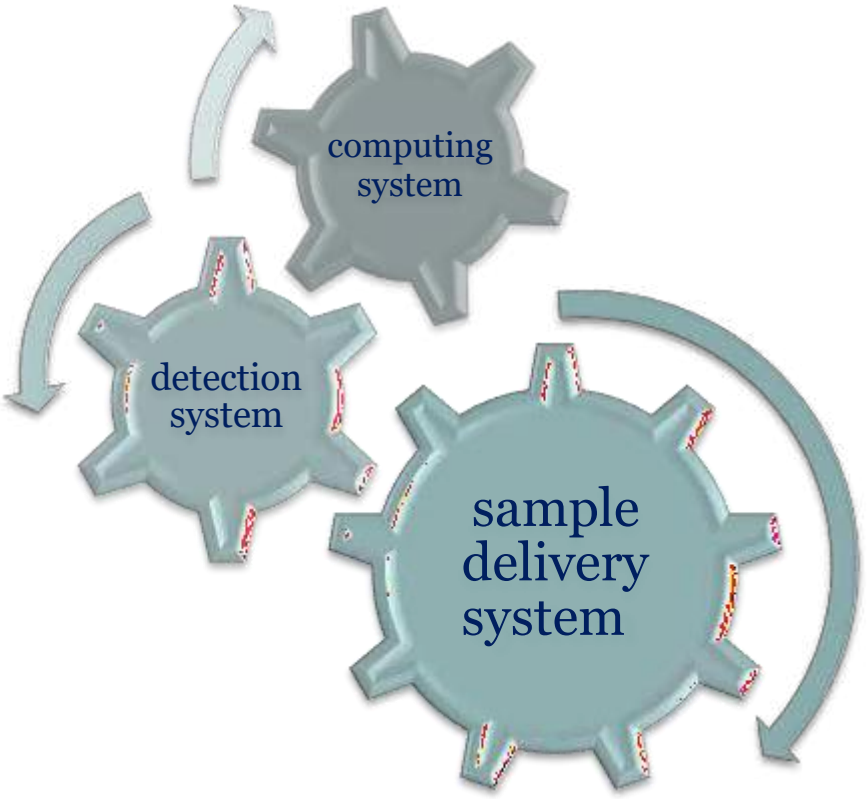
E-Nose: Main Components

Electronic noses include three major parts:

I. a sample delivery system

II. a detection system

III. a computing system



I. Sample delivery system

- Enables the generation of the headspace (volatile compounds) of a sample.
- The system then injects this headspace into the detection system of the e-nose.
- The sample delivery system is essential to guarantee constant operating conditions.

II. Detection system

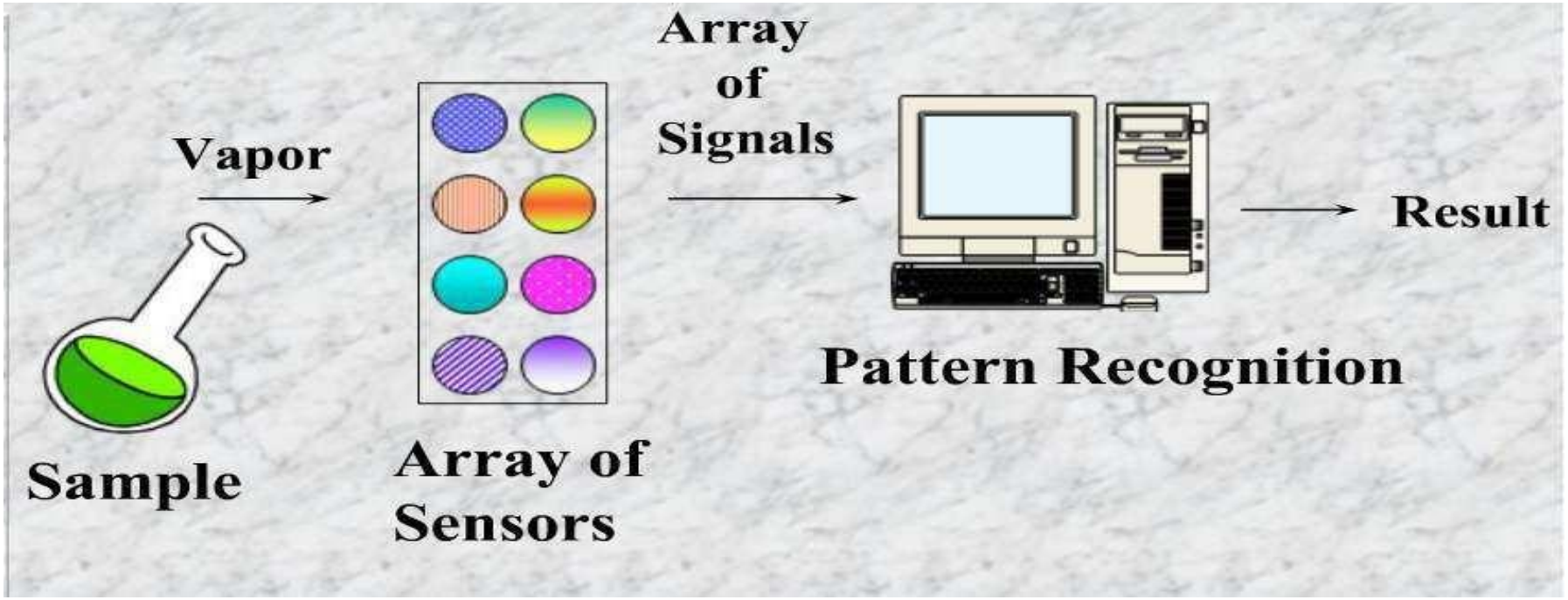
- Consists of a sensor set, is the "reactive" part of the instrument.
- **Adsorption of volatile compounds on the sensor surface causes a physical change of the sensor; they experience a change of electrical properties.**
- A specific response is recorded by the electronic interface transforming the signal into a digital value.
- Recorded data are then computed based on statistical models.

III. Computing system

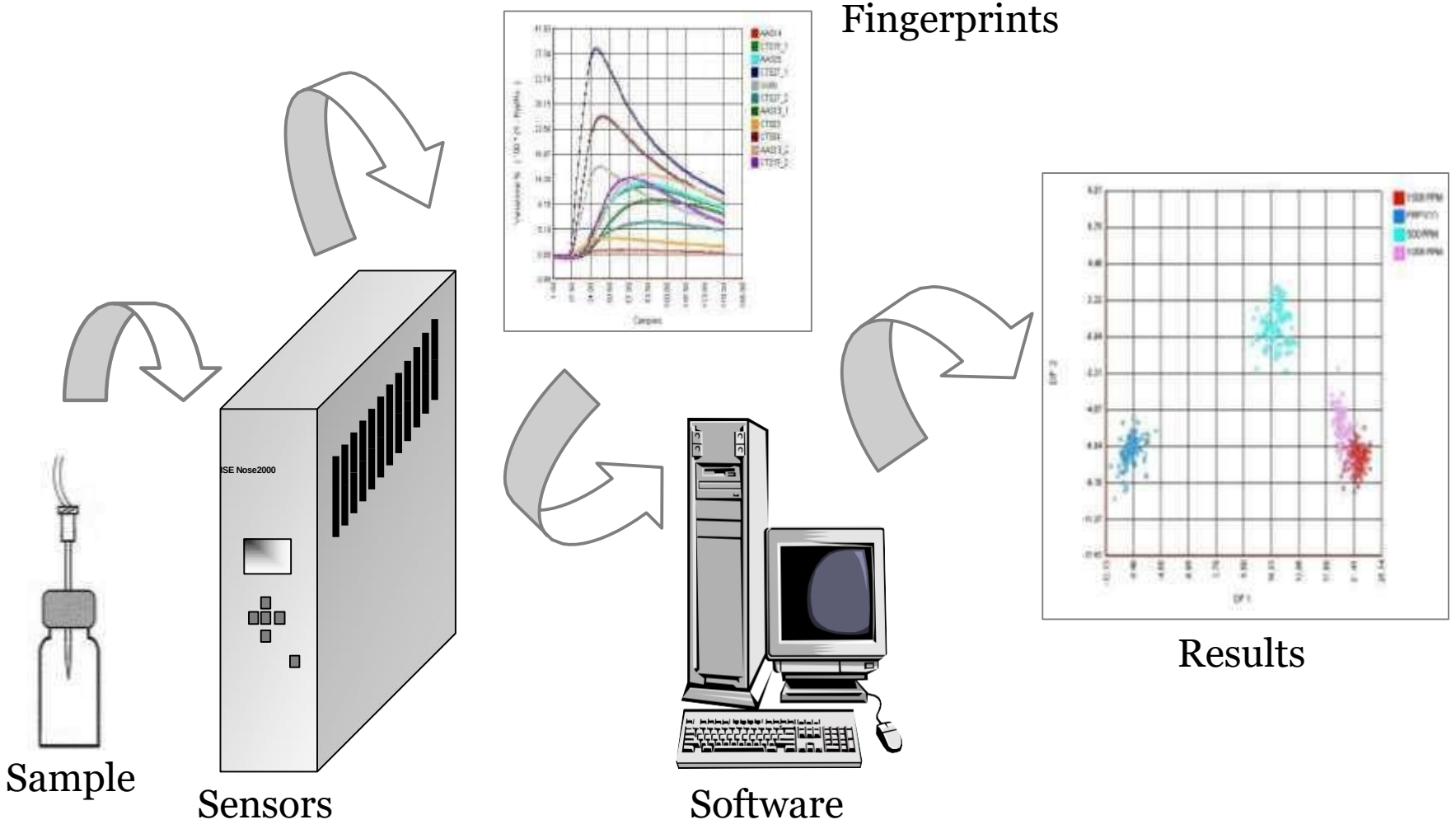
➢Works to combine the responses of all of the sensors, which represents the input for the data treatment.

➢ This part of the instrument performs global fingerprint analysis and provides results and representations that can be easily interpreted.

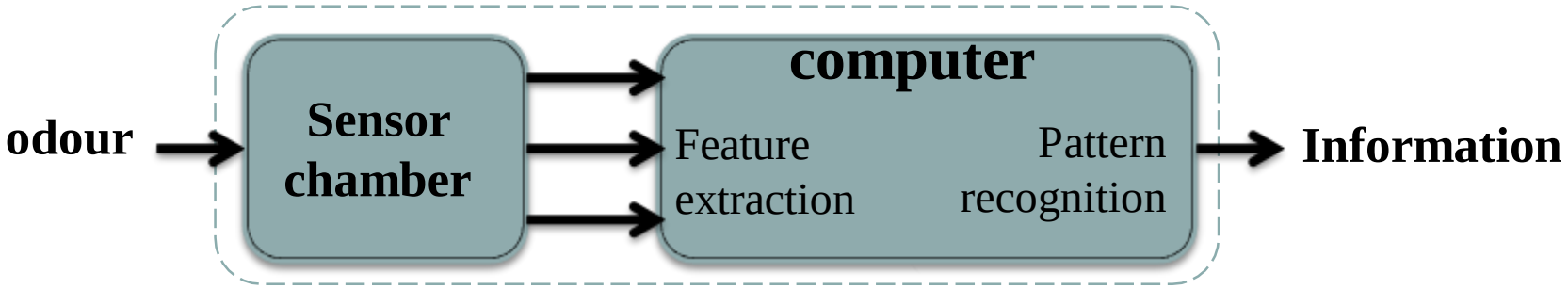
➢Moreover, the electronic nose results can be correlated to those obtained from other techniques.



E-Nose: Block Diagram



E-Nose: Working Principle



- An air sample is pulled by a vacuum pump.
- It is led through a tube into a small chamber consisting of electronic sensor array.
- A transient response is produced as the volatile organic compounds in the sample
interact with the surface of the sensor's active material.
- A steady state response is reached within few minutes.
- This response is then sent to a signal processing unit.

➢A washing gas such as an alcohol vapour is applied to the array for a few seconds to a minute.

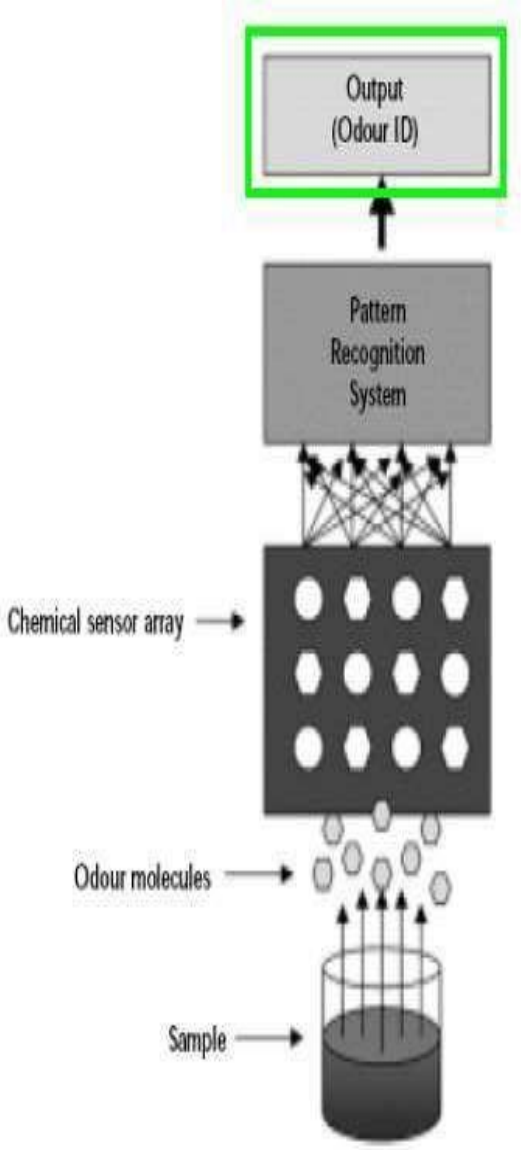
➢This is done to remove the odorant mixture from the surface and bulk of the sensor's active material.

➢ Finally, the reference gas is again applied to the array, to prepare it for a new measurement cycle.

➢A variety of basic sensors can be used according to the nose strategy chosen.

➢ Each sensor in the array has different characteristics.

➢The pattern of response across all the sensors in the array is used to identify and/or characterize the odour.



E-Nose: Sensing System

- Using array of sensors, each sensor designed to respond to a specific chemical .

- Number of unique sensors must be at least as great as the number of chemicals being monitored

- Each element measures a different property of the sensed chemical

- Each chemical vapour presented to the sensor array produces a signature or pattern characteristic of the vapour

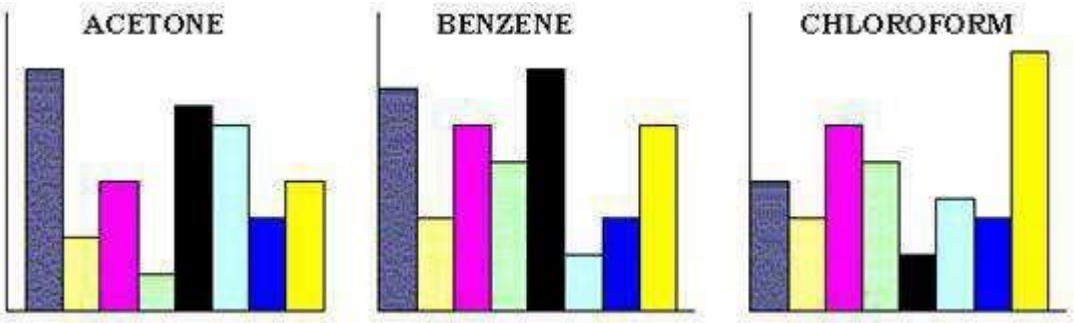


Fig. Response of sensor array to different pure chemicals

- Use of Artificial neural networks (ANN) along with array.

- Used to analyze complex data and to recognize patterns, are showing promising results in chemical vapour recognition.

- ANN combined with a sensor array

- Number of detectable chemicals is greater than that of sensors

- Less selective sensors can be used

- Less expensive too

- Electronic noses incorporating ANNs have been demonstrated in various applications.

E-Nose Sensors

The sensor array is clearly the key element. It forms the primary step in the detection or identification of an odorant.

The most commonly used sensor s in electronic nose are:

(1) Conductivity sensors

- Metal oxide sensors(MOS)
- Conducting Polymers

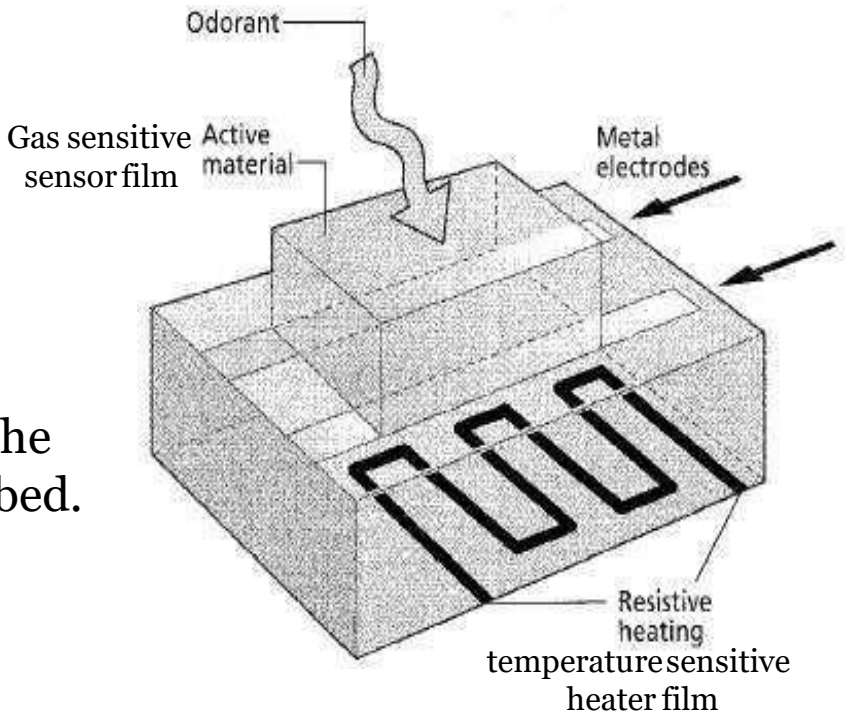
(2) Piezoelectric sensors

- Quartz Crystal Microbalance
- Surface Acoustic Wave

(3) MOSFET sensors

(1) Conductivity Sensors:

(1a) MOS (Metal oxide sensors)



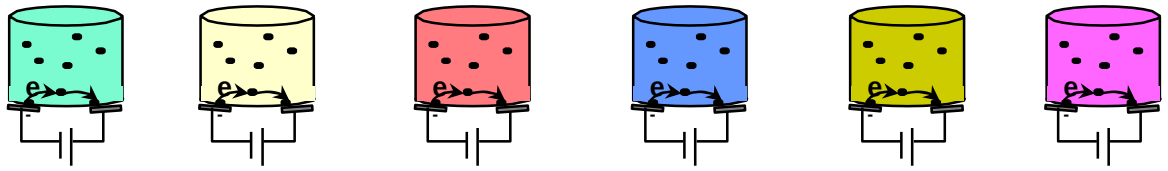
➢**Adsorption of gas molecules provoke changes in conductivity .**

➢This conductivity change is the measure of the amount of volatile organic compounds adsorbed.

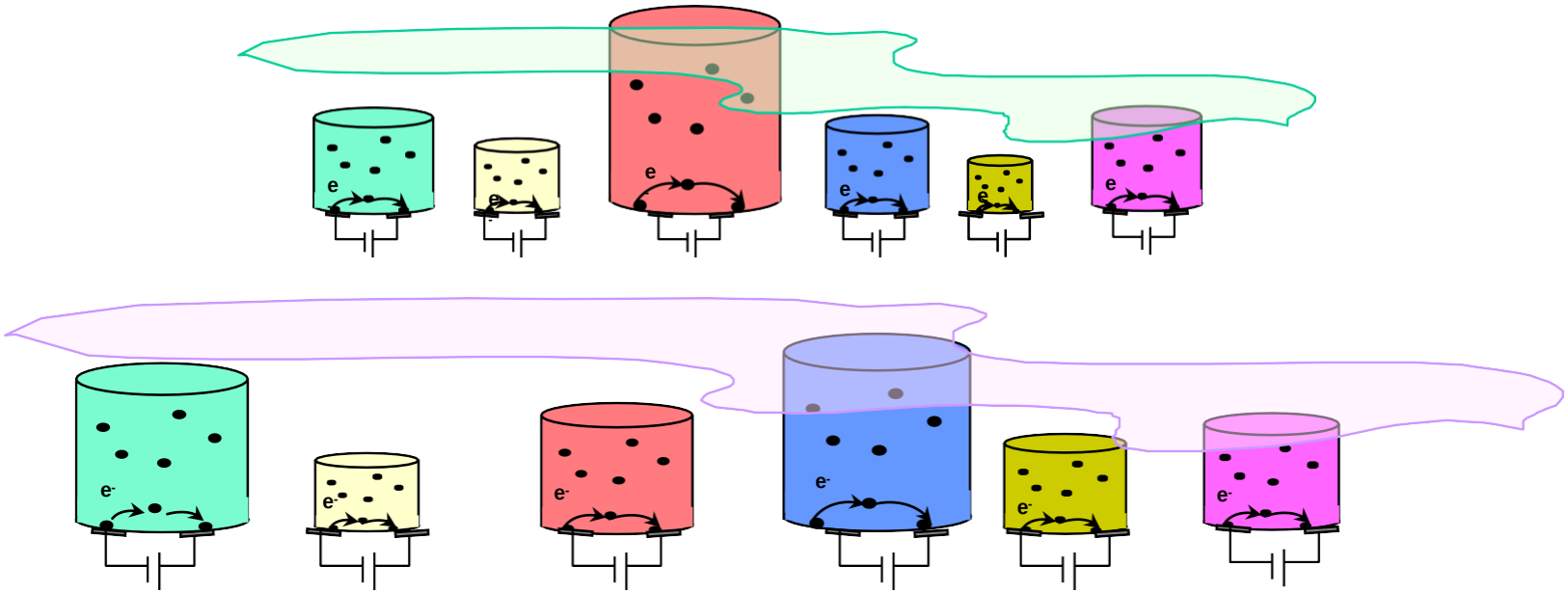
(1b) Conducting polymers

➢Conducting or conductive polymer gas sensors operate based on **changes in electrical resistance caused by adsorption of gases onto the sensor surface.**

If there has been no change in the composition of the air, the films stay at the baseline resistance and the percent change is zero.



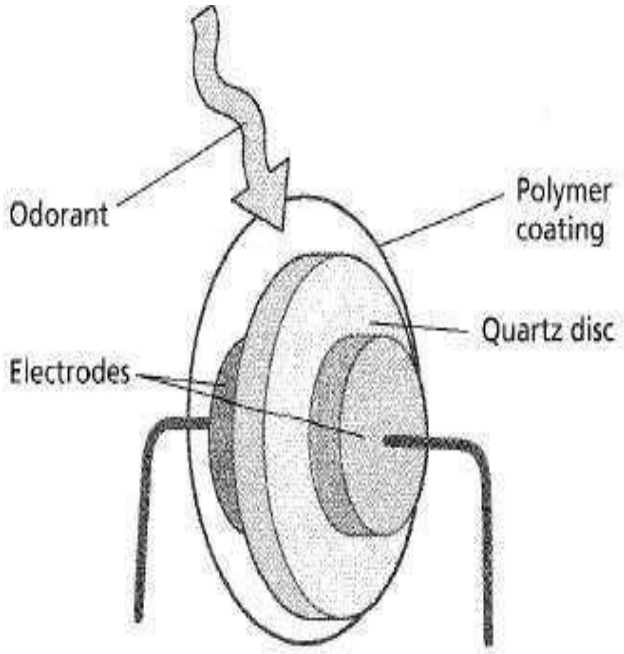
If a different compound had caused the air to change, the pattern of the polymer films' change would have been different as shown below:



(2) Piezoelectric Sensors:

- Adsorption of gas onto the surface of the polymer leads to change in mass on the sensor surface.
- This in turn produces a change in the resonant frequency of the crystal.
- This change in frequency is proportional to the concentration of the test material.

(2a) Quartz Crystal Microbalance (QCM):



- Consists of a resonating disk with metal electrodes on each side connected to lead wire
- Resonates at a characteristic frequency (10-30 MHz) when excited with an oscillating signal
- Polymer coating serves as sensing material
- Gas adsorbed at the surface of the polymer increases the mass, reduces resonance frequency
- Reduction is inversely proportional to mass adsorbed by the polymer

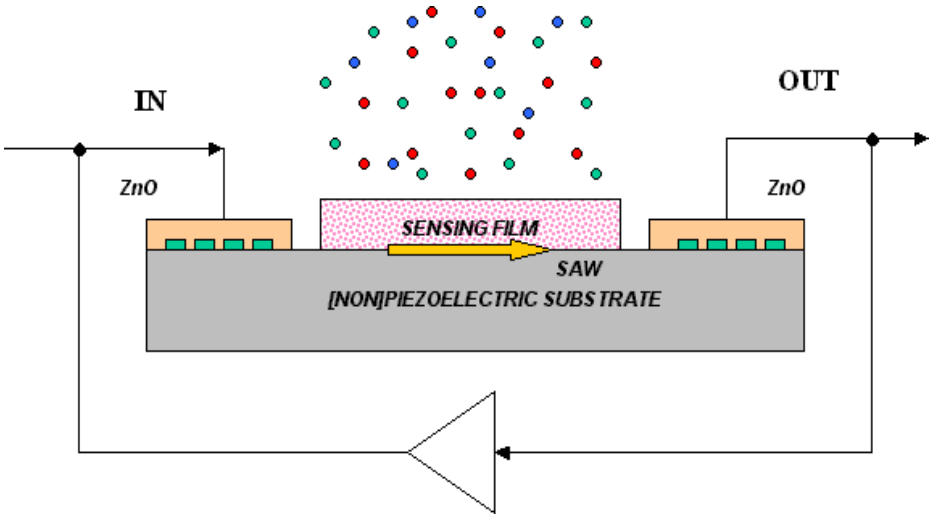
(2b) Surface acoustic-wave (SAW):

- An ac signal is applied across the input metal transducer
- Fingers of this gas sensor creates an acoustic wave that "surfs" the piezoelectric substrate

➢When the wave reaches the metal fingers of the output transducer, ac voltage is recreated

➢Voltage is shifted in phase as a result of the distance travelled.

➢Phase shift depends on the mass & the absorption properties of the sensing polymer layer



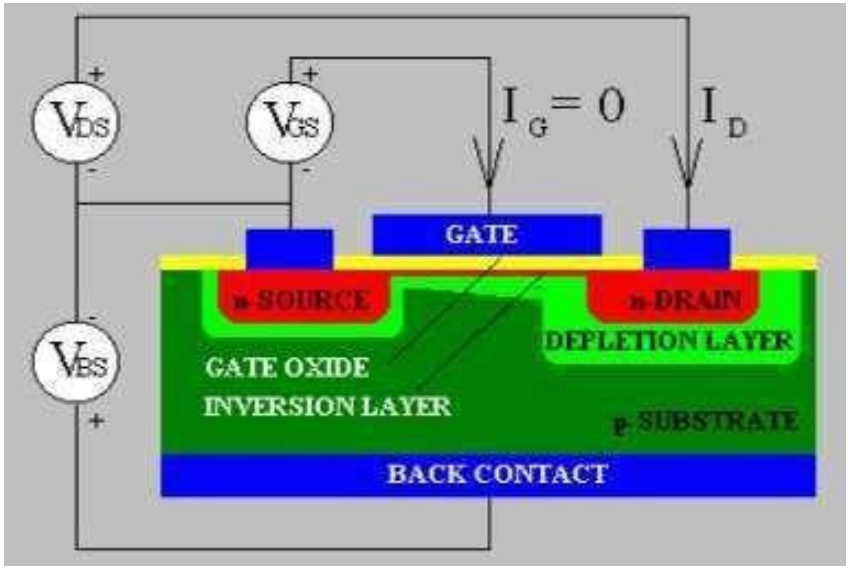
➢ SAW devices are less sensitive than QCMs

(3) MOSFET Sensors:

➢A volatile organic compound produces a reaction in the sensing layer(gate).

➢This causes the physical property of the gate to change.

➢Thereby the threshold voltage is changed and thus the channel conductivity.



Computing System

- An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information.

- The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example.

- An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process.

- Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well.

➢In case of ENOSE with 9 sensors, ANN takes inputs from all the sensors and then computes the corresponding output as shown,

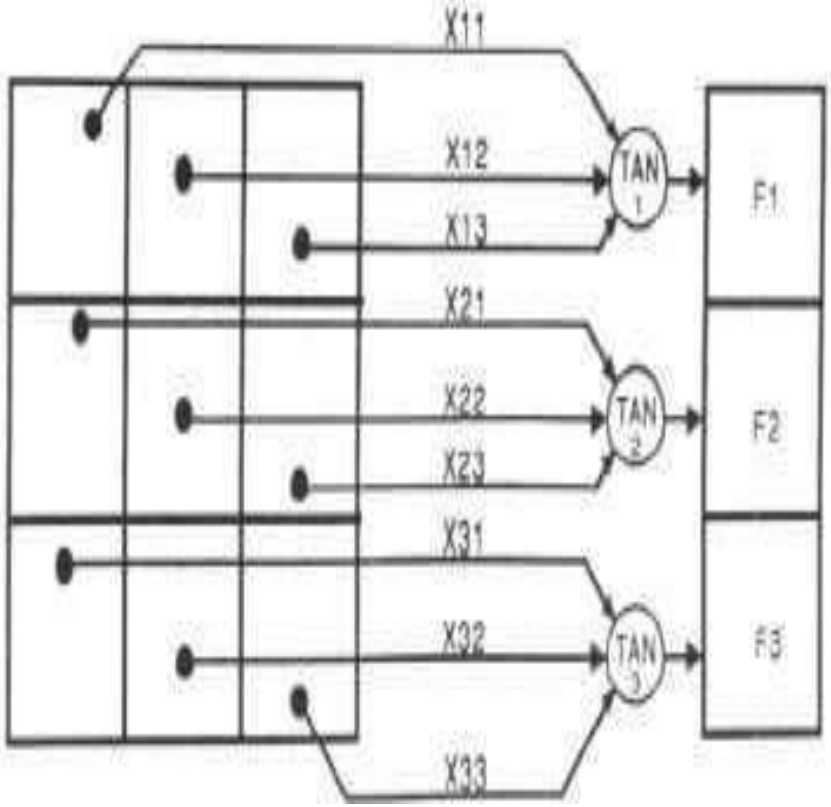
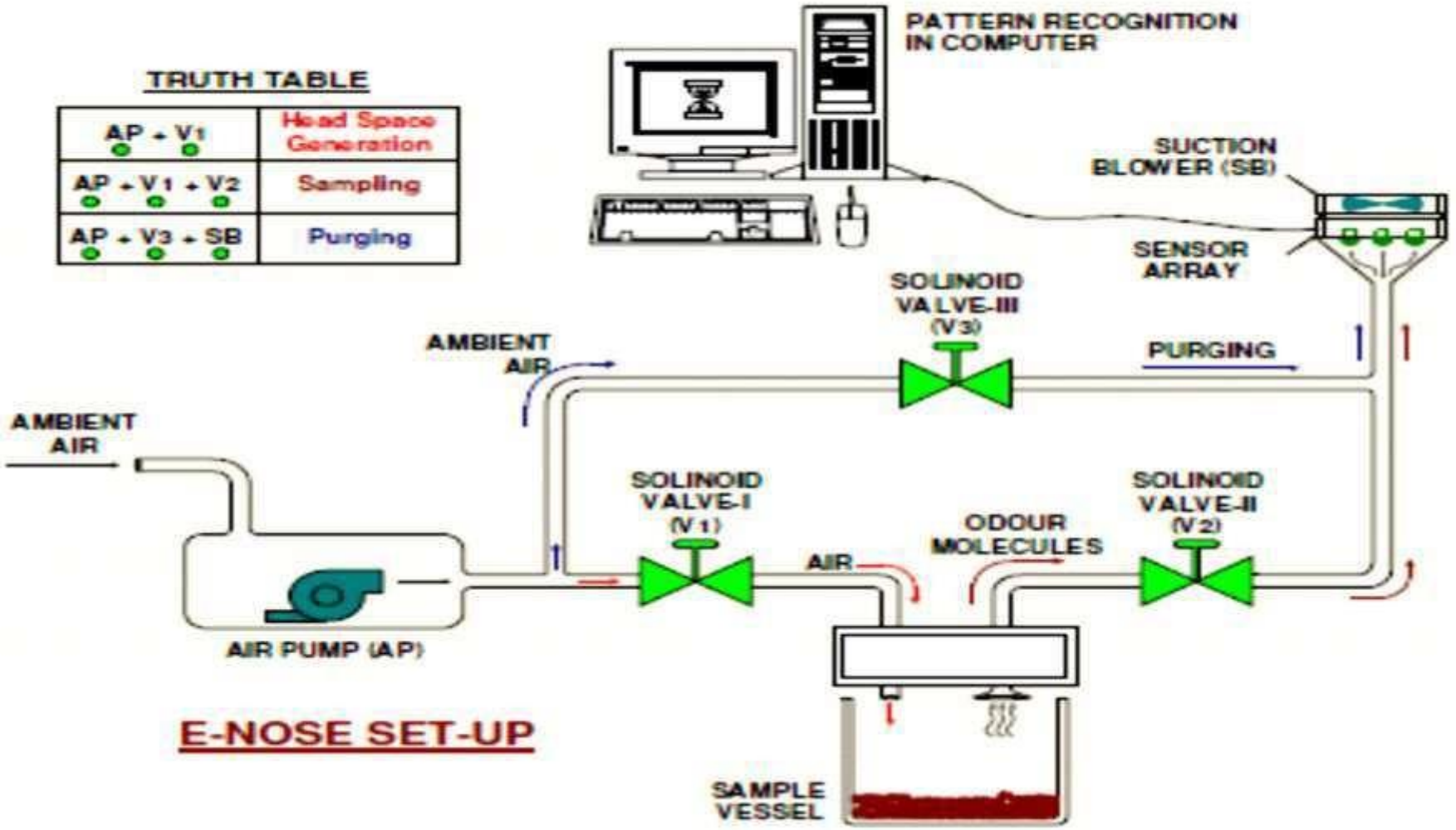


Fig: Output of E-nose

Experimental Setup



Applications

The applications(current) of an electronic nose include:

- Medical diagnosis and health monitoring
- Environmental monitoring
- Application in food industry
- Detection of explosives
- Space applications(NASA)
- In research and development industries
- In quality control laboratories
- In process and production department

❖ Medical diagnosis and health monitoring

I. Respiratory disease diagnosis

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

• E-nose can diagnose respiratory infections such as pneumonia.

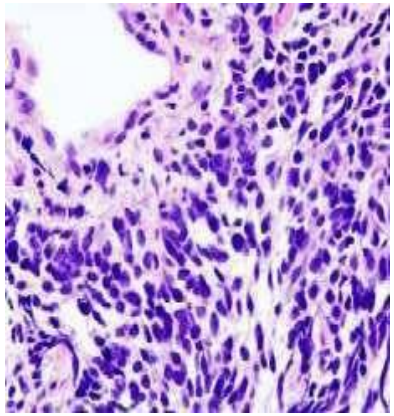
• It does so by comparing smell prints from the breath of a sick patient with those of patients with standardized readings.

• It is also being studied 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 distinguishing 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.

❖ Environmental monitoring by e-nose

Environmental applications of electronic noses include:

- analysis of fuel mixtures
- detection of oil leaks
- testing ground water for odours
- identification of household odours
- identification of toxic wastes
- air quality monitoring
- monitoring factory emissions etc.

❖ Applications of e-nose in food industry

Analysis of fruit ripening

•Fruit ripening is associated with an accumulation of aromatic volatiles during ripening.

•Information from the noses can help in removal of rotten fruits at the appropriate time.

• This can help in avoiding storage losses due to rots and fruit diseases.

❖ Detection of explosives

•E-nose is being developed for military and security applications in the detection of explosives and hazardous chemicals.

❖Space applications---e-nose and NASA

JPL E-Nose:

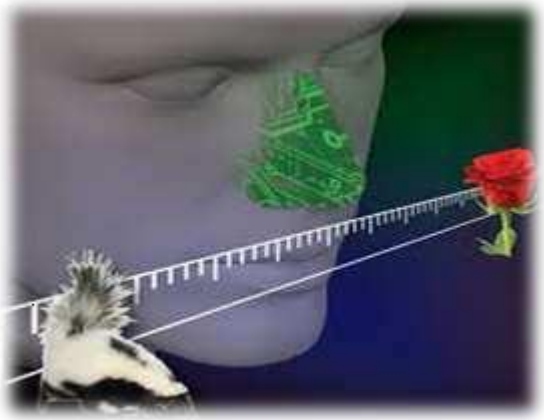
•It is a full-time, continuously operating event monitor used in the International Space Station.

•Designed to detect air contamination from spills and leaks in the crew habitat

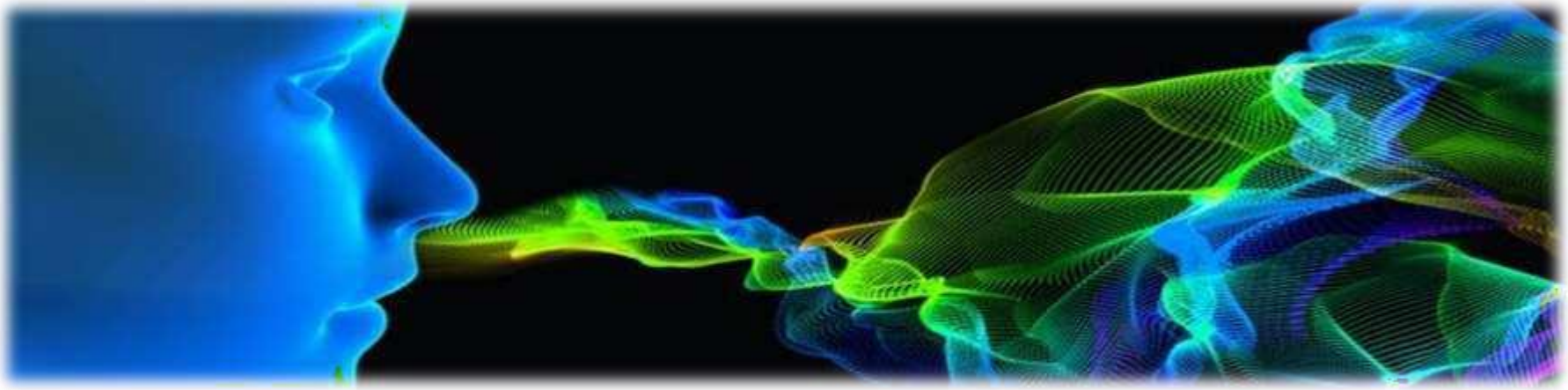
• Provides rapid, early identification and quantification of atmospheric changes caused by chemical species to which it has been trained.

• Can also be used to monitor cleanup processes after a leak or a spill.

Future scope



- *Research is being done on IC E-Noses*
- *Miniaturizing current Technology*
- *Improvement in sensitivity for lower levels of organisms or smaller samples.*
- *Minimizing cost*



Future scope

Digital Scent Technology

•*To sense, transmit & receive smell through internet.*

• *Scent is detected and processed using E Nose.*

•*A scent is indexed along two parameters, its chemical makeup and its place in the scent "spectrum" and then digitized into a small file.*

• *Broadcast: The digital file is sent, attached to enhanced web content.*

• *Smell Synthesizer: The smell synthesizer means the device which is used to generate the smells.*

Electronic Nose

❖Advantages

1. Detection of poisonous gas is possible
2. Can be done in real time for long periods
3. Cheaper than Trained human sniffers
4. Individuals vary, e-nose don't
5. Digital representation of odour is possible.

❖Limitations

1. Time delay between successive tests.
2. Insensitivity to some species.

Conclusion

✓Humans are not well suited for repetitive tasks. Electronic nose has the potential to become standard tool for smelling. Researches are still going on to make electronic nose much more compact than the present one and to make e-nose ICs.

✓It also initiates for a new era of representing odour as an electronic/digital data like we have done on picture and sound.

✓With the senses of 'vision' and 'hearing' already in place, and the sense of 'touch' being developed (hepatic technology), the robots will soon have all the five human senses.

And I don't think the day is too far when they will have the so-called 'sixth' sense!