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PATTEN RECOGNITION FOR ELECTRONIC NOSE BASED ON ARTIFICIAL NEURAL NETWORKS

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***Abstract* – Electronic Nose gas sensors are used to detect various chemical vapors present in Environment. Each sensor has its own kind of response from sensory arrays. The various pattern recognition methods are used to process the signals from a sensor array employed in E-nose and predict the toxic vapors present in environment. In this paper, Principal Component Analysis and Artificial Neural Network approach has been used as Pattern Recognition method to predict the toxic gases.**

Keywords: Electronic Nose, PCA- Principal Component Analysis, ANN- Artificial Neural Network.

1. INTRODUCTION

Wireless sensor with E-nose is a hardware device, comprises an array of sensors to sense various mixtures of toxic gases, vapors present in Environment. The real world comprises various toxic gases such as Ammonia, Carbon Monoxide, Chlorine, Hydrogen Sulfide, Nitrogen Dioxide, Nitric Oxide, and Sulfur Dioxide, which affects Human lives very sensitively. It is necessary to develop a sensor with improved pattern recognition techniques to identify and detect such toxic vapors present in Environment. A single sensor with single gas identification method is not effective in identifying mixture of toxic gases. E-nose with Multi gas sensor array can be used to detect mixture of toxic gases in such environment. The sensor array composed of chemically sensitive material interface to a transducer (figure 1). The chemical species, i.e., the input vapors are measured when the analyte molecules to interact with the chemically sensitive material present in sensor array. Whenever an analyte interact with sensor array, the sensor generate physical change. This could be sensed by transducer and passed as an output signal to the system. Number of gas sensitive materials has been used in a large variety of sensors including semiconductor, piezoelectric, optical, catalytic and electrochemical gas sensors. The sensor can be chooses by depending upon the advantages like small size, low cost fabrication, high sensitivities in detecting very low concentrations. The aim of pattern recognition technique is to classify patterns for a vapor among mixture of vapors. The sensor output derived in the form of signals as frequency versus time. Raw signals are converted into a digital data using A/D Converter. After conversion, feature extraction phase starts. In this phase features of each vapors can be extracted. Feature reduction performed to reduce the dataset using normalization technique. Through this redundant data can be removal, the Feature reduction makes the learning process easier. PCA algorithm can be used for feature reduction and ANN is used to recognize the pattern for each vapor. In classification, sample data can be used to train and test the system with predicted output. In training phase network has been trained with sample input dataset with appropriate output dataset. In test phase the original input has been given and the predicted output has been obtained.

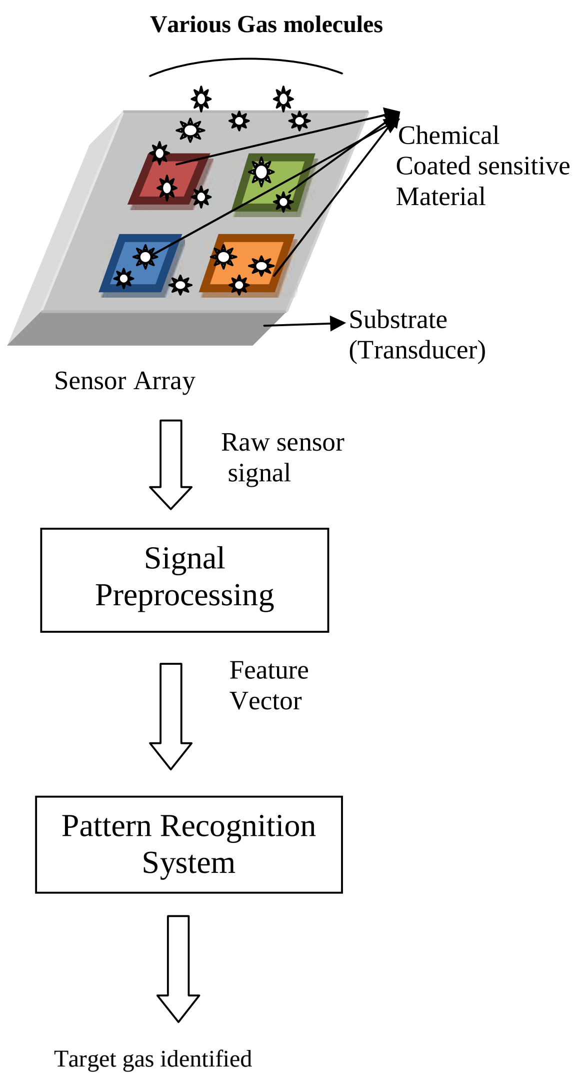


Figure 1: Schematic diagram of E-nose

2. SIGNAL PREPROCESSING

In signal preprocessing, the sensor signals are derived to perform signal conditioning, feature extraction, feature reduction process. Figure 2 shows the signal preprocessing.

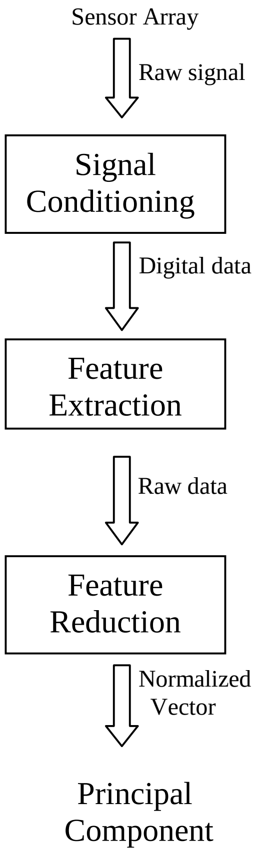


Figure 2: signal preprocessing

The signal preprocessing composed of various steps involved in the process of converting a raw sensor signals derived from sensor array into a reduced vector data sets.

2. 1. Signal conditioning

The sensors may have mixture of signal with various interferrent. Signal handling provides the way to describe the proper signal among interference present in mixture of vapors. Figure 3 shows the sensing response of E-nose. Though signal has generated as analog, it could be converted as digital for processing. A/D converter has used to convert analog signal into digital signal as digital data. This could be done in signal handling phase. The output of signal handing is presented to feature extraction.

2. 2. Feature Extraction

Feature extraction is the process of deriving a formatted input from sensor. Each sensor presented in sensor array has its own feature. The features can be chosen depending on identification of vapor from a mixture of gases.

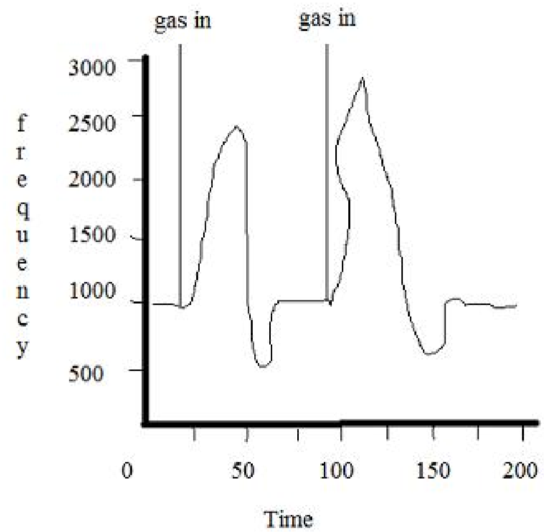


Figure 3: sensor response

2. 3. Feature Reduction

The feature reduction is the process of presenting normalized data set from a large volume of data opted from sensor. Normalize is the process of reducing redundant data. The sensor data may contain many interferrents like redundant data which are not related to data set. Such data should be deducted. Figure 4 shows the normalization process.

	Time / ppm		
f r e q e n c y	**918**	**960**	**998**
	4026	**4098**	**4098**
	215	**215**	**480**

⇩

5.8	**0**	**0**
0	**3.2**	**0**
0	**0**	**4**

Figure 4: feature reduction

PCA algorithm can be used in feature reduction.

PCA- Principal Component Analysis

Principal Component Analysis is identified as one of the simplest and powerful tool to classify large volume of sensor data. PCA is statistical distribution methods that can be reducing the redundant data by extracting significant information from various parameters.

Methodology of PCA

1. Extract the sensor data from E-nose as input data set.
2. Find the mean and subtract it from each value.
i.e., $x1 = x - \ddot{x}$ $y1 = y - \bar{y}$
3. Extract covariance matrix for the input data
$$CM = (\sum(x - \ddot{x})(y - \bar{y}))/(n-1)$$
4. Calculate the Eigen vectors and Eigen values of that covariance matrix. Extract the feature vector from covariance matrix.
5. Derive new data set by multiplying transposed feature vector with original transposed dataset.
6. Finally principle component has been obtained.

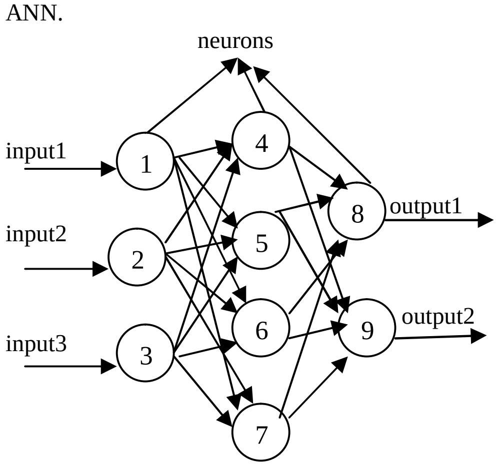
The signal preprocessing phase ends with deriving principal component.

3. PATTERN RECOGNITION

Pattern recognition can be defined as transformation of an input data set, such as sensor signals from an E-nose to an output set of attributes, such as type of vapor or concentration. Here in this paper ANN were applied to model the different classes.

Artificial Neural Network

An Artificial Neural Network is usually called as Neural Network. It is nonlinear information processing device, which are built from interconnected elementary processing device called neurons. Artificial Neural Network is a mathematical or computational model inspired by biological neural networks. A Neural Network consists of an interconnected group of artificial neurons, and it processes the information using a connectionist approach to computation. Figure 5 shows the schematic of ANN.



1,2,3 –input layer neurons
4,5,6- hidden layer neurons
7,8,9 –output neurons

Figure 5: schematic of ANN

Training of an ANN

Network is trained by providing related targets and an iterative method to activate function. Once the network gets trained with target data set, then the unknown data set is fed as input and target output can be extracted. In the present paper, the input data used in ANN algorithm is shown in table 3.1,

	Compound1 in various ppm			Compound2 in various ppm		
	50	100	150	50	100	150
Sensor1	918	960	998	730	1050	1385
Sensor2	4026	4098	4098	280	360	420

Table 3.1 Input to Train ANN

The compounds are the various toxic vapors such as Ammonia, Carbon Monoxide, Chlorine, Hydrogen Sulfide, Nitrogen Dioxide, Nitric Oxide, and Sulfur Dioxide. The sensor1, sensor2 are various chemically sensitive material coated sensors present in sensor array. Each sensor produced a signal depending on various concentrations such as different ppm/frequencies. The E-nose sensing response data, i.e., input data in matrix form has given to Neural Network (table 3.1).

1	1	1	0	0	0
0	0	0	1	1	1

Table 3.2 Target data matrix to train Neural Network

The target data is also created in the form of resultant matrix contains 1's and 0's only. Whenever the target compound identified by E-nose, corresponding target matrix element set to '1', otherwise target matrix element set to '0'. Table 2 shows the target data matrix. Figure 6 shows the Neural Network window in Matlab software. The Input data matrix and the target data matrix are fed into the network and it is trained iteratively using different training function and by adjusting number of layers and neurons to get predicted target.

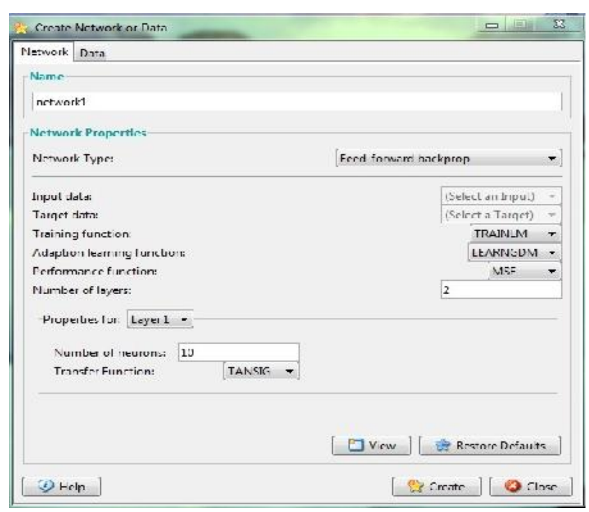


Figure 6: ANN Training Window

4. CONCLUSION

In this study, we have presented an improved pattern recognition system to a chemical coated sensitive material presented in E-nose gas sensor array to detect toxic gases. Our aim is to improve selectivity and reliability in pattern recognition when measuring multiple gases simultaneously. We achieved this aim by using a pattern recognition algorithm ANN and PCA. Our proposed method produced the greatest success rate than any other algorithms used in various gas sensor detection systems.

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