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Applications of Electronic Nose using Neural Networks

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Abstract : In this paper we have used a metal oxide sensor based electronic nose (EN) for two very useful applications:

a) To identify quality of Tea

To analyse five tea samples with different qualities, namely, Drier Month, Drier Month again over fired, Well Fermented normal fired in oven, Well Fermented over fired in oven, and Under Fermented normal fired in oven. The flavour of tea is determined mainly by its taste and smell, which is generated by hundreds of Volatile Organic Compounds (VOCs) and Non Volatile Organic Compounds present in tea. These VOCs are present in different ratios and determine the quality of the tea. For example Assamica (Sri Lanka and Assam Tea) and Assamica Sinesis (Darjeeling and Japanese Tea) are two different species of tea giving different flavour notes. Tea flavour is traditionally measured through the use of a combination of conventional analytical instrumentation and human organoleptic profiling panels. These methods are expensive in terms of time and labour and also inaccurate because of a lack of either sensitivity or quantitative information. In this paper an investigation has been made to determine the flavours of different tea samples using an EN and to explore the possibility of replacing existing analytical and profiling panel methods. The technique uses an array of 4 metal oxide sensors (MOS), each of, which has an electrical resistance that has partial sensitivity to the headspace of tea. The signals from the sensor array are then conditioned by suitable interface circuitry. The data were processed using Principal Components Analysis (PCA), Fuzzy C Means algorithm (FCM). We also explored the use of a Self Organizing Map (SOM) method along with a Radial Basis Function network (RBF) and a Probabilistic Neural Mtwork (PNN) classifier. Using FCM and SOM feature extraction techniques along with RBF neural network we achieved 100% correct classification for the five different tea samples with different qualities. These results prove that our EN is capable of discriminating between the flavours of teas manufactured under different processing conditions, viz. over-fermented, over-fired, under fermented etc.

b) To identify type of smoke

In this application, we use this electronic nose to classify the smell from 3 types of burning materials and then we apply the standard back propagation and recurrent back propagation neural networks to train and classify those burning smell. In the experiment, we test 3 kinds of joss stick, 2 brands of cigarette, and a mosquito coil. Moreover, we also measure the difference of concentration of smoke by varying the number of burning joss stick. The results show that it is able to classify the smoke correctly. The idea of this research would be able to apply for making a smart smoke detector in order to be able to detect a harmful burning material precisely before it is too late to stop the fire.

Index Terms— Electronic nose, Neural Network, quality of tea, type of smoke .

1. APPLICATION ONE: USE OF ELECTRONIC NOSE TO DISTINGUISH BETWEEN QUALITIES OF TEA

To humans, the sensation of flavor is due to three main chemoreceptor systems. These are gustation (sense of taste by tongue), olfaction (sense of smell by nose) and trigeminal (sense of irritation). Taste is used to detect non-volatile chemicals, which enter the mouth while the sense of smell is used to detect volatile compounds.

Due to large number of organic compounds present in tea, it is difficult to process tea to an absolute standard. The volatile compounds present in tea determine its quality. In conventional tasting, it is very difficult to keep a consistency in the standard of tea quality from batch to batch during a production process. The quality is ensured by a human taste panel, which may vary due to different factors. The aroma and flavour are two quality factors of tea, which depend upon the number of volatile compounds present and their ratios. Human panel tasting is inaccurate, laborious and time consuming due to adaptation, fatigue, infection and state of mind. An electronic nose (EN) can be a better altenative to conventional methods for tea tasting and quality monitoring during production process. An EN is an increasingly fast, reliable and robust technology. Tea industries all over the world presently use certain standard terminology of tea flavour, however, there is no mention about a quantitative description or score on these flavour terms. The Tocklai Tea Research Association, Assam, (India) has adopted standard terminology but some of

them overlap. Twenty-five non-overlapping flavour terms had been identified out of about 40 generally used flavour notes. An EN may provide a more objective platform to augment the conventional methods for tea tasting and quality monitoring during production process.

1.1 Purpose of Electronic nose

As stated above, an attractive and alternative strategy for monitoring the quality of tea samples manufactured under different processing conditions potentially can be achieved by sensing the organic aromatic volatiles emitted by tea samples, using Electronic Nose systems**.** Electronic Nose systems appear to be very promising for a number of reasons. The main ones are that Electronic Nose systems are based on inexpensive, nonspecific solid-state sensors, which are sensitive to the gases that are emitted by tea samples. Furthermore, once an Electronic Nose has been 'trained', it does not require a skilled operator and can potentially obtain the results in the order of few tens of seconds. In the Electronic Nose system, a pattern recognition engine enables the system to perform complex aroma analysis of the sensor signals. Artificial neural networks (ANNs) have been extensively used to perform this pattern recognition, and good results have been reported previously in the classification of foodstuffs, such as eggs**,** beverages**,** coffees, fish and meat. The back-propagation trained multilayer perceptron (MLP) paradigm is the most popular pattern recognition method in aroma analysis today. Other promising techniques include LVQ, PNN and RBF. Here in this paper, we report on the use of an Electronic Nose, employing an array of four tin oxide sensors, in combination with different pattern recognition engines (MLP, LVQ, PNN and RBF) to predict -the quality of tea.

Five tea samples manufactured under different processing conditions from Assam, India, were considered for conducting these experiments to get to a result. These five different tea samples with different qualities are as follows:

1. Drier month tea sample.
2. Drier month again over fired tea sample.
3. Well fermented normal fired in oven tea sample.
4. Well fermented over fired in oven tea sample.
5 Under femented normal fired in oven tea sample.

Each sample, without any additional manipulation, was placed over the period of the experiments. Temperature and humidity was also recorded so that their effects could be corrected if necessary.

The sensor system used in the experiment comprised of four tin oxide odour sensors from the same manufacturer housed in a sensor chamber. The sensors were chosen on the basis of sensitivity of the sensors to different gases; the selected sensors were designed to respond to gases such as the cooking vapours, ammonia, hydrogen sulphide, alcohol, toluene, xylene etc.

Using these sensors and suitable experimental apparatus, five different data sets were gathered through the experiment corresponsding to the five types of tea considered. Using appropriate data clustering algorithms, better classification of data into different clusters was achieved.

The data sets were analysed using four supervisd Artificial Neural Network(ANN) classifiers, Multilayer Perceptron(MLP), Linear Vector Quantization(LVQ), Probablistic Neural Network(PNN) and Radial Basis Function Network(RBF).
The analysis was highly successful.

2. Application Two:-Smoke Detection and differentiation using electronic nose

The inspiration after reading several papers about the development of artificial olfactory sensing system encourages us to make our own artificial nose', which are widely used in the variety of electrical appliances, such as microwave oven and air cleaner. Our electronic nose is designed as simple as possible by using the normal air at room temperature to provide enough oxygen for the oxidation process of gas sensors. If the metal oxide element on the surface of the sensers heated at a certain high temperature in air, the oxygen is absorbed on the crystal surface with the negative charge. The change in the

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negative charge of the metal oxide surface, which causes by absorbing the deoxidizing gas, makes the grain boundary potential barrier changed. When the oxidation of deoxidizing gas changes the grain boundary potential barrier of the sensor, the resistance of the sensor also varies as the partial of pressure of oxygen changes.

Based on the characteristics of the metal oxide sensors, we choose the proper sensors that can detect the deoxidizing gas from the burning material to be the sensing devices of our machine. First process of the olfactory system is to sniff the smell and flow the molecule to the olfactory receptor part, so we make a sampling box providing with an electric fan to flow the smell to the sensor box that contains several metal oxide sensors which act like olfactory receptors. Secondly, the olfactory receptor responses information to the limbic system and then transfers to the cortex brain, so we use a data logger to record the electrical voltage from sensors, and then use these data to be the information for Artificial Neural Network (ANN), which acts like the human brain and in this step human can recognize the smell, as the same that we try to classify smell by ANN. The third step is the cleaning process before human can detect the other smell precisely by breathing a fresh air, so we add additional electrical fans inside the sensor box to suck out the deoxidizing gas from the machine to speed up the sensors to return to the normal condition. We start our first experiment on this machine by trying to classify 3 kinds of simple smoke.

2.1 The Experiment

In the experiment, we choose three kinds of burning materials that are easily found in the market. The first kind is three types of joss stick. Second kind is two types of cigarette and the third kind is mosquito coil. We also vary the concentration of the smoke by burning 1, 2 and 3 sticks of each type of joss stick, which is the least harmful smoke. The list of burning materials in this experiment is shown in Table 1.

Inside this electronic nose, there are two sensors arrays, Sensors Array1 and Sensors Array2.Each array contains 8 different sensors. In this paper, we use only the data from SA1 to analyze. Generally, a metal oxide sensor has some effects from the humidity and temperature. In order to prove the robustness of the machine on these effects, 20 sets of data were collected in

different condition. For the temperature effect , it was measured during the winter and spring season, which have a high difference in temperature. For humidity, it was measured in the rainy day and shiny day. Even the temperature of the room was changed for measuring the data in this experiment to provide the normal air in different environment. Each data set contains 12 signals of burning materials in Table l.

Burning Material	Type	Concentration
Joss Stick	Purple	3 sticks
		2 sticks
		1 stick
	Brown	3 sticks
		2 sticks
		1 stick
	Green	3 sticks
		2 sticks
		1 stick
Cigarette	Marlboro light	1 Cigaratte
	Castor mild	1 Cigaratte
Mosquito coil	Kinsho	1 coil

Table 1: Burning materials with concentrations

Before measuring the voltage signal of each smoke, we must measure the voltage signal of the normal air at that time every second for a period of 1 minute and find the average value (vair) to use as an air reference point. Then the voltage signals of the sensors when absorbing with smoke, vsmoke , re collected every 2 seconds for a period of 2 minutes on each type of smoke sample. Then the total change in signal on each period, Vsmoke is calculated by

$$Vsmoke,t = vsmoke,t - vair$$

where t =period 1 to 60.

This data was used to train and test by ANN directly, but the training time was so slow, so the data is normalized by

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norm(Vsmoke,t)=(Vsmoke,t-V)/σv

where V the mean of all data in each data set and σv, is the standard deviation of all data in each data set. After that we use the normalized data to train and test with Standard Back-Propagation (SBP) and Recurrent Error Back-Propagation (RBP).

2.2 SBP Case

The result show the number of test data sets that can be classified by the SBP after training with the parameters shown in Table 2. The perfect classification, partial classification, and miss classification case are the case that the output value show the correct output value above 80%, between 50-80%, and less than 50%, respectively. From the result, all of the tested data are perfectly classified with the output value above 99% in case of joss stick and most data of cigarette and mosquito coil, but in some data of cigarette and mosquito coil, the output value show correctly output around 91%. In the case of mosquito coil, we need to select 5 data in to the training set because the data of mosquito coil from data to data are so noisy. In the other way, the data from joss stick is less noisy, so we can feed less data of joss stick into the training set.

2.3 RBP Case

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We use the same judgment category as SBP case in that if the average output value shows the correct output value above 80%, we call it perfect classification. In the case of RBP, the data from last cycle will effect the output of next cycle. So, in the case of noisy data like the case of cigarette and mosquito coil that data are very similar in some period of time and vary from data to data. So, it is not so easy to provide a proper training set until we get a good result. All of the results are perfectly classified with the output value above 97% in case of joss stick data and most data of cigarette and mosquito coil, but some data of cigarette and mosquito coil only have the output value above 83% which is less accuracy than the SBP case.

3. Conclusion:

The electronic nose we have used in this report created using metal oxide and applying the concept of neural networks to this electronic nose we have created a device which can overcome the problems faced by olfactory system of humans.

This is perfectly demonstrated by the two applications shown in our report. This technology is a research goldmine and can be used to improve many existing applications