Intelligent Classification Hazardous Gas Using Sensors Array

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***Abstract*—This paper presents an environmental pollution monitoring solution using intelligent classification system. Air is one the basic needs for human and other species in our natural ecosystem. Air quality may affect the harmonious ecosystem of human and living species that presence in the surrounding environment. The rapid growth of heavy modern industries is one of the factors that contributes to air quality contamination. A heavy industry such an oil and gas process plant may sometimes involves in unavoidable accident of pipeline leakage that polluting natural air. Hence, there is a need to introduce a scientific air quality classifier based on chemical array sensors. Electronic Nose (E-nose) is one of the chemical-based sensor arrays instruments which has a capability to measure odor-profile based sample data. Several intelligent classification systems can be employed in E-nose. In this work, an intelligent classification system namely Case Based Reasoning (CBR) technique was employed. The experimental results show that the intelligent classification technique using CBR has successfully classified the hazardous gas (butane and hexane) odor-profile with 78.3% rate of accuracy.**

***Index Terms*—CBR, E-nose, hazardous gas, intelligence classification**

I. Introduction

A. Environmental Impact

Nowadays, environment pollutants are one of the major concerns in our human society. Human need the basic necessities of life such as fresh air, the land, the fresh water for drinking and plants that depend on good environment [1]. All of these needs require special control quality bodies.

Environment control quality bodies are responsible for industrial, domestic and planning environment. Among the listed environment, industrial environments are having major concerns in environment pollution index which effect air quality and healthy environment. In addition, there are several heavy, medium and light industries that involve in industrial environment [2]. Oil and Gas industries have several problems pertaining to hazardous gas release from process plants, which contribute to the increasing of air pollution index [3]-[5].

In many decades ago, there are several incidents in oil, gas and petrochemical industries that involved in a series of accidents which registered as the case of fatalities and explosion such as BP Deep Water Horizon (Gulf of Mexico,2010) [6], Petrobras P-36 platform (Brazil, 2001) [7], the Exxon-Valdez (Alaska, 1989) [8], filtering Phillips (Texas 1989) [9], the Piper Alpha oil platform (North Sea, 1988) [10]-[12], San Juan Ixhuapetec (Mexico, 1984) [13], Bophal (India-1984) [14] and others incidents [15]. There are huge impacts of the accidents such as economic losses, loss of skilled workers and the vital impact was an environmental pollution which affects the health of public of the surrounding. The incidents happened on offshore and onshore platforms [16] and [17].

There were some solutions that have been proposed such as de-inventoried pipelines for storm possibilities that have been successfully practiced in management plan [18], quantitative risk assessment [19] and leakage monitoring system using sensors [20].

According to the available international data in [21]-[23], there are several causes of gas leakage incidents such as erosion, mechanical failure, construction defect and others unknown causes [17].

B. Electronic Nose (E-nose)

E-nose technology is one of the device that is designed for pipelines gas leakage detection [24]. This technology had appeared around late 1980s which mimic human nose. It detects odor profiles and processes odor-profiles information. Human olfactory system consists of 10000 sensors which are generally sensitive. However, it is not really a selective type as compared to E-nose [25] and [26]. It has an array of sensors, in order to classify hazardous gas leakage from the pipeline. This device can

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be installed at strategic areas in the process plant to detect gas leakage [27] and to classify hazardous gas [28]. Over the past decade, the scientists developed an e-nose for monitoring, detection and quantification of environmental chemical pollution odor-profile [27]. The pattern recognition of an odor-profile measured from array of sensor can be pre-analyzed using statistical method as a scientific proof [29].

C. Statistical Method

Several statistical methods have been introduced for E-nose sample data analysis. One of the well-known statistical methods is a box plots. The Box plot is a useful statistical method in identifying outliers and comparing data distributions [24].

The statistical data representation can be further pre-processed using data normalization technique [30]. Normalization can eliminate errors appear in data sample [31].

D. Intelligent Classification

There are numerous artificial techniques that can be used to classify hazardous gas odor-profile data such as Principal Component Analysis (PCA) [32], Discriminant Factor Analysis (DFA) [33], k-Nearest Neighbor (k-NN) [34] and [35], Artificial Neural Network (ANN) [36] and [37] and Case Based Reasoning (CBR) [38] and [39].

In the CBR system, old experiences are used to solve new problems or adapting old solution to meets new demand [40]. The CBR system consists of four phases; Retrieve, Reuse, Revise and Retain. These phases were recalled to refer the older cases when a problem is retrieved. Whereas in retain phase, similarity distance is computed and the older case that have closest range to the new case is referred [41] and [42].

The accuracy percentage of CBR method was calculated using Equation (1):

$$Total\ Accuracy = \left(\frac{(A_1 + A_2 + A_3)}{3}\right) \times 100 \qquad (1)$$

where,

A_1 = sum of correct the highest similarity percentage

A_2 = sum of correct the second highest similarity percentage

A_3 = sum of correct the third highest similarity percentage

II. Experimental Section

A. Data Measurement

A sample of butane (G1) and methane (G2) were measured by releasing into E-nose chamber that consists of a unit of sensor array where each sensor is responsive to different type of volatile compound. Then, the set of data for both samples were tabulated as in Table I. D is the data measured while N is the number of samples measured. The data were pre-processed using normalization (0-1) technique for both samples for error removal.

TABLE I. Sample Data Measurement

Data (n)	***Sensor 1***	***Sensor 2***	***Sensor 3***	***Sensor 4***
D_1	D_{11}	D_{12}	D_{13}	D_{14}
D_2	D_{21}	D_{22}	D_{23}	D_{24}
D_3 . . . . . . D_N	D_{31} . . . . . . D_{N1}	D_{32} . . . . . . D_{N2}	D_{33} . . . . . . D_{N3}	D_{34} . . . . . . D_{N4}

Then, the pre-processed data were extracted and the odor-profile pattern was plot in a graphical representation to visualize the variance of both samples. After that, the data were analyzed using boxplot analysis. Then, a unique feature from analyzed data was extracted based on variance within and across the group.

From the sensor response, the value was divided into 10 cases whereby each case representing 10 measurements. Each measurement consists of four attributes (sensor array). Then, Sensor Centroid (SC) value was calculated for each case. Each data case will be stored into CBR database. It will be retrieved and reused for new cases by calculating the similarity of the cases.

The significant feature extracted from analyzed data was set as a case and the number of sensors was set as attributes in the CBR.

III. Result and Discussion

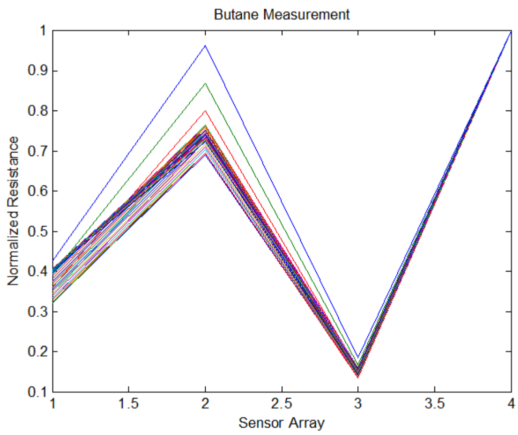

Figure 1. Measurement of G1.

Fig. 1 and Fig. 2 show the pattern of sample (G1) and (G2) respectively. From the result obtained from the plot using the MATLAB, the visualization pattern across the group sample of G1 and G2 are having a slightly small variance on Sensor 1 (S1), Sensor 2 (S2) and Sensor 3 (S3).For Sensor 4 (S4), it indicates the value is similar showing the maximum peak of the normalization. This visualization shows that sensor S1, S2 and S3 are less sensitive as compared to sensor S4. However, for pattern recognition, sensor S1, S2 and S3 are more significant for classification as compared to sensor S4.

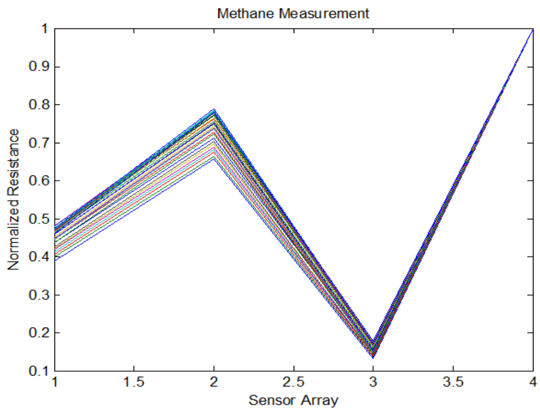

Figure 2. Measurement of G2.

Fig. 3 and Fig. 4 show boxplot of sample G1 and G2 respectively. Boxplot consists of minimum, maximum, first quartile, median and third quartile features point. Based on Fig. 3 and Fig. 4, the blue line of the boxplot indicates the first quartile and third quartile. The median was indicated as a red line in the boxplot graph. The minimum and maximum point was indicated as black line which known as a whisker.

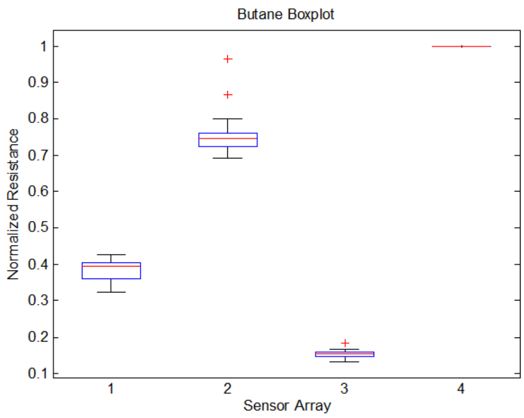

Figure 3. Boxplot of sample G1.

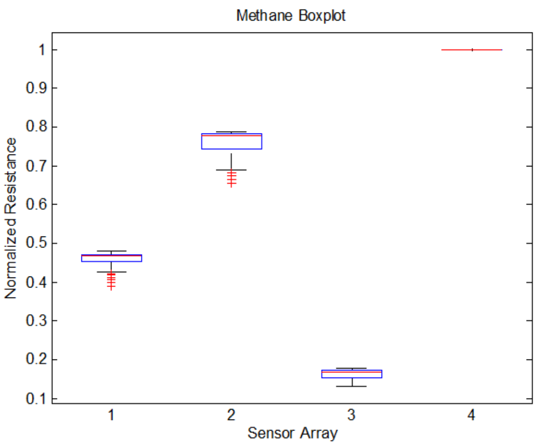

Figure 4. Boxplot of sample G2.

Based on the Fig. 3 and Fig. 4, the response of the each sensor has shown different value of the boxplot. For both sample G1 and G2, Sensor S1 shows the smaller width of the boxplot as compared to boxplot in sensor S2. Whilst the boxplot in sensor S1 was bigger than boxplot in sensor S3which has the lowest response compared to other sensors were detected in sample G1 and G2. There are no boxplot produced in sensor 4 but it consists of one red line which shown the value of minimum, maximum, first quartile, median and third quartile were same.

In addition, boxplot of sample G1 shows that the highest response was at sensor S4. It shows that S4 is the most sensitive sensor based on resistance response.

Fig. 5 shows the graph of SC for sample G1 and sample G2. There are different values of SC at sensor S1, sensor S2 and sensor S3 and have the same value at sensor S4. From Fig. 5, it shows that, the values between the pattern of sample G1 and sample G2 are different. Since the different value of SC was detected, SC was chosen as the attributes of the CBR.

Previous results show the pattern recognition graphical visualization technique. In general, the samples have been classified based on significant differences of pattern recognition.

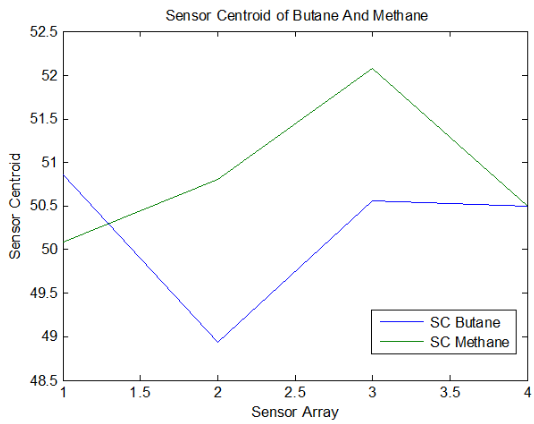

Figure 5. Sensor centroid for sample G1 and G2.

Table II shows the percentages of CBR classification results based on 5 measurements with 4 numbers of sensors (S1, S2, S3 and S4). The local weight for five measurements were differently set to find the significant differences between sample G1 and G2. It shows that, measurement 4 with local weight of 7, 5, 3 and 10 for S1, S2, S3 and S4 respectively has produced the highest classification rate of accuracy.

TABLE II. ACCURACY PERCENTAGE

No.	Local Weight				Accuracy
	S1	S2	S3	S4	Percentage (%)
1.	1	1	1	10	73.33
2.	3	7	5	10	75.00
3.	5	3	7	10	58.33
4.	7	5	3	10	78.33
5.	10	10	10	10	73.33

IV. CONCLUSION

The CBR results point out that the odor-profile data (sample G1 and G2) has been classified using sensor centroid (SC) extracted feature with the classification rate 78.33%. The rate of the classification can be further increased by manipulating the local weight of attributes (S1, S2, S3 and S4).

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