Gaharu Sensor: Classification Using Case Based Reasoning (CBR)

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***Abstract*—Gaharu or agarwood is a high value commodity in agricultural sector which is widely used in industry related to perfume product and aromatherapy product. The high grade gaharu determine its quality which influence the market price. Thus some trader manipulating the grading to raise higher price but the actual quality is lower. This paper proposed the intelligence classification technique using an Electronic Nose (E-nose) measurement. The sensor array in the E - nose are used for the inputs of the Case Based Reasoning (CBR) for intelligent classification. The experimental result shows that the technique accomplished to classify with high accuracy which is 86.7% nearly approach to 100% of accuracy.**

***Index Terms*--Agarwood, E-nose, CBR, Intelligent Classification, Gaharu.**

I. INTRODUCTION

Agricultural defined as encompassing crop, forest product and the process of the state's agricultural production. Therefore, agricultural can give economic impact to the state's because the agricultural industry purchases goods and services from other industries and hires local labor [1]. One of the high value commodities in agricultural industry is agarwood or gaharu. It mostly uses for traditional aromatic, incense smoke and perfume – burning chip wood and essential oil and in [2], [3]. In the eight century, gaharu also used as medical product that's been recorded in Sahih Muslim and Ayurvedic medical text the Susruta Samhita. In addition, over the past about 30 years, the demand for gaharu has been risen [4], [5].

There is no specific reference of grading standard to determine the gaharu quality as high grade, commercial grade, or low grade. The grading is decide by common perception and experience among region involved in agarwood industry. A study proposes the quality of gaharu referred to the resin content where the high grade consists of high resin [6]. The common accepting grading of gaharu oil is grade A+ was 100% of purity and grade A was 95 % to 99%, while the purity of grade B lower than purity of grade A [7]. The common characteristics that can be recognized for grade A was dark, dense, concentrated and heavy while other characteristic as in Table I [8], [9]. This characteristic can be manipulated by traders and they can change the characteristic of other grade or other wood in order to get the higher price to sell because the better the grade the price was higher [10]–[12].

In order to detect the quality of gaharu, there are several methods for detection such as Gas Chromatography- Mass Spectrometry (GC-MS), Solid Phase Micro-extraction (SPME) in the chemical field and electronic nose (E-nose) for gaharu quality detection in electronic field. GC-MS is an instrument that can separate and analyzed samples based on chemical compound usually used for gaharu essential oil while SPME is a solvent-less extraction technique, based on adsorption which usually for analyze samples and for burning chip of gaharu [13]-[16]. An E-nose is able to detect odors for a variety of applications such as cherry essential oil, liquor, perfumes and others [17], [18].

Table I
Grades and Prices of Gaharu at local levels, 1985-2007

		Terengganu 1985	Terengganu 1999-2000	Hulu Perak 2002-2007	Central Pahang August 2007
Grade	Characteristics	Price (RM/kg)	Price (RM/kg)	Price (RM/kg)	Price (RM/kg)
A	Dark, dense, concentrated and heavy	1,000	3,200-4,000	3,000-7,000	10,000
B	Purple dark, less dense, small holes	250	1,800-2,500	1,500-4,000	5,000-7,000
C1	Yellow dark stripes	150	400-800	500-1,500	2,000
C2	Dark yellow	-	40-80	50-200	150
D	Gaharu remains	-	8-30	4-50	-

Fig.1: Grades and prices of gaharu at local levels, 1985-2007

There are several methods that can imply to classify the quality of gaharu essential oil such as an Artificial Neural Network (ANN), Principal Component Analysis (PCA), k-Nearest Neighbor (k-NN) and also Case Based Reasoning (CBR) [19]-[21]. CBR is mean by using stored case to solve the new case. There are several steps for classifying using CBR which is retrieve, reuse, revise and retain [22]. Retrieve is the most crucial step in CBR which is to recall a previous case that stored in CBR. Then, it will retrieve the best similar cases to compare with new case. The best of similarity cases will reuse in order to revise the case and retained it when it was solved [23].

Therefore, this study recommends the classification technique by a combination of the E - nose and CBR for agarwood or gaharu sensor based on pure and mixed gaharu with other essential oil. The E - nose was used to detect the odor profile of samples. While, CBR classifies the odor based on profile from the E-nose.

II. Experimental Section

The essential oil was extracted using hydro distillation process which is using alcohol in order to extract the essential oil from the plant which cannot undergo the steam distillation process. Then, the essential oil will analyze by GC-MS which is most frequently used technique to classify the compound in essential oil [24]. While, for incense smoke or burning chip using SPME method to get chemical compound analysis, which is to classify to chips A, B and C.

The essential oil has been processed using hydro distillation to get pure gaharu essential oil. Then, it will mix with other essential oil such as lemon or lavender to make it into three samples of essential oil, which is pure gaharu, gaharu mix with lemon and gaharu mix with lavender.

The system acquisition of data as shown in Figure 1. The E - nose will take the repeated reading data of the sample which determined by GC-MS. The data from the E-nose, which consist of an array of sensor in order to get the pattern of the each sample. The data will analyze and CBR will do the classifying of the sample. Then, the similarity is used for accuracy percentage of CBR as follow in Eq. (1)

$$Accuracy\ Percentage = \left(\frac{\sum_{i=1}^{3} x_i}{3}\right) \times 100 \quad \text{Eq.(1)}$$

Where,

χ = highest similarity percentages

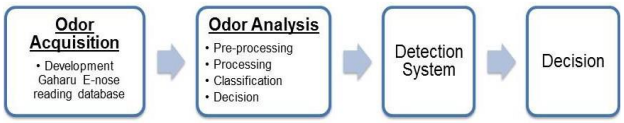

Fig. 1: Data Acquisition System

III. Result and Discussion

TheE-nose data whichnormalizedtoobtain standard valuefrom 0 to 1. The data havebeenprocessedintothegraph plot in ordertoobtain a patternforeachsample as odorprofile of gaharu.

Figure 2, Figure 3 and Figure 4 show a normalized sample measurement data for pure gaharu essential oil and mixed gaharu essential oil. The data of measurement collected from an array of sensor which is to obtain pattern profile to differentiate the quality of gaharu. The three figures above have conclude that there are slight differences between those figures by its features profile. Its show that, this oil can be manipulated by traders which the human nose cannot detect the differences between those samples.

In addition, these features were improved by using boxplot. The purpose of using boxplot is to summarized and visualized the difference between those samples of gaharu essential oil.

The simple boxplot displays five statistics, which is minimum, first quartile, median value, third quartile, and maximum value. As we known, these statistics were calculated for a single continuous variable, but the simple boxplot takes it a step beyond. The simple boxplot displays the several categories of a discrete variable by separating the continuous variable of five statistics as mentioned.

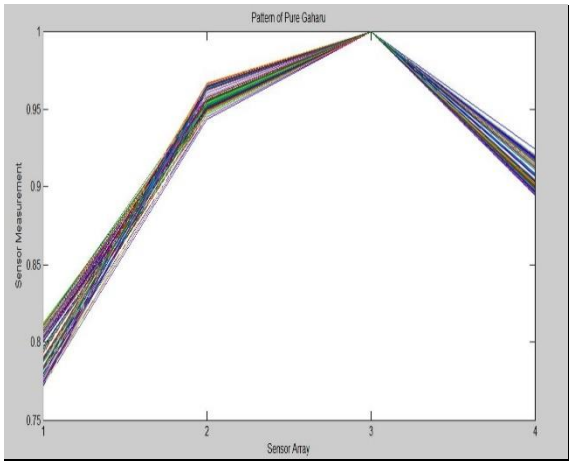

Fig. 2: Normalized data for Pure Gaharu

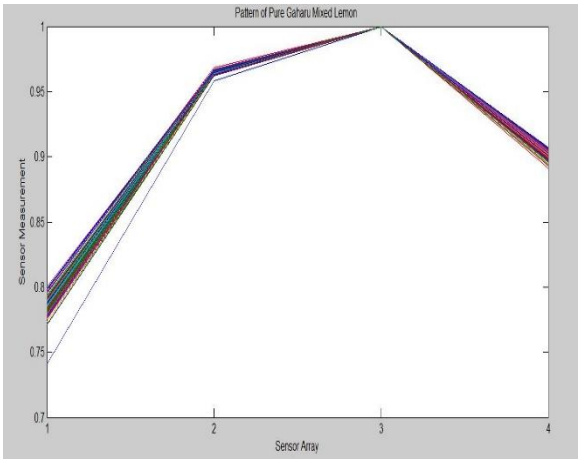

Fig. 3: Normalized data for Gaharu mixed lemon

Figure 5, Figure 6 and Figure 7 visualized the differences between those samples from 4 sensors respectively. The red center line which is median values was in the box of lower and upper quartiles which known as Inter-quartiles range. While, the maximum and minimum values of each sensor as a line in boxplot which known as a whisker. From those boxplot figures, sensor 3 records the best data for all samples where the reading are consistent thus result the smallest variant. The CBR data record for pure gaharu mixed lemon and pure gaharu mixed lavender almost identical as shown by Figure 6 and Figure 7 respectively. The largest variant recorded by sensor 1 for pure gaharu as Figure 5 and it is different compared to mixed gaharu samples where the variant are smaller. Overall the boxplot of the four sensors is slightly different.

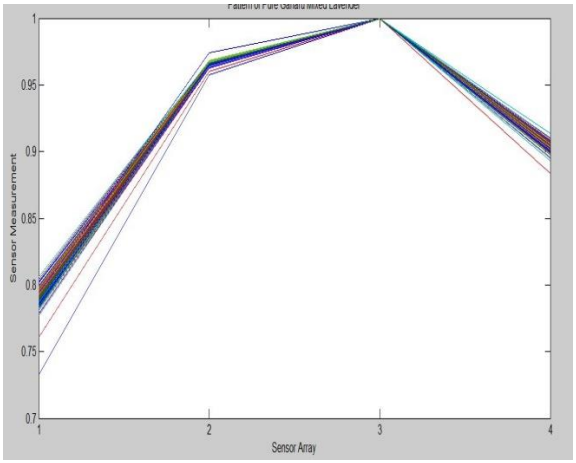

Fig. 4: Normalized data for Gaharu mixed Lavender

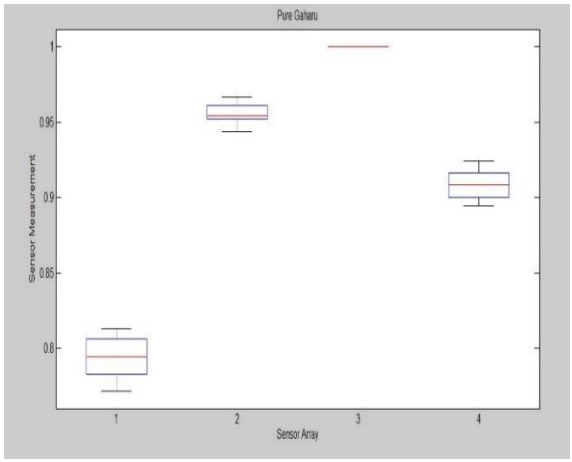

Fig. 5: Box plot for pure gaharu

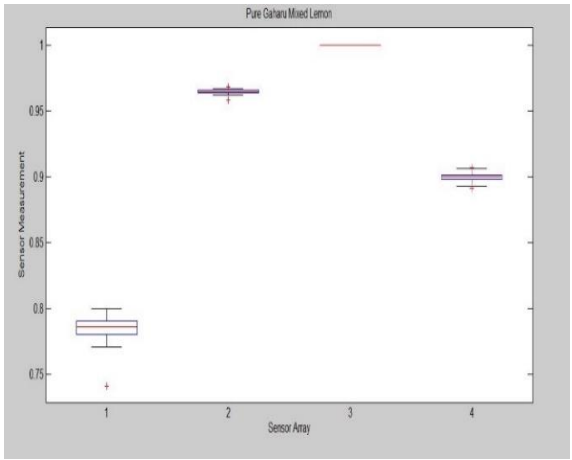

Fig. 6: Box plot for pure gaharu mixed lemon

The pattern of boxplot and the normalized sample graph shows that there are differences of pattern between those samples. Then, the significant data of mean were selected to training for classifier which is CBR. Each samples have 10 cases to get classify. Since the classifier has 20 cases maximum range, the 10 cases of each sample are trained for 2 samples of each classifier training and testing samples. The training and testing will find the percentage of similarity and at the end of the classifier will show the accuracy percentage of classifying between those samples. The average of accuracy percentage recorded as per Table 2.

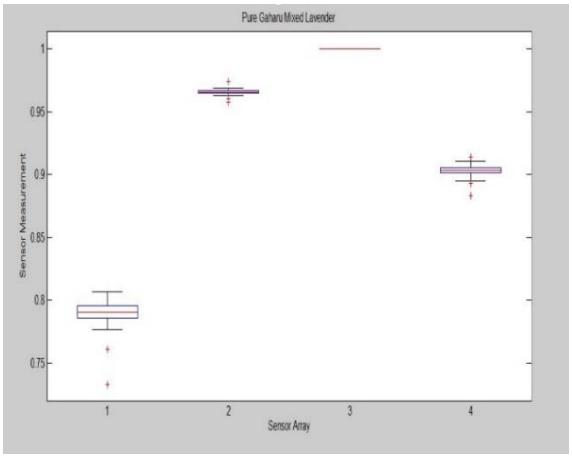

Fig. 7: Box plot for pure gaharu mixed lavender

Table II
Accuracy Percentage of CBR

No.	Classifying Cases	Accuracy Percentage
1	Pure gaharu and Pure mixed Lemon	86.7%
2	Pure gaharu and Pure mixed Lavender	86.7%

Table III
Statistical Analysis of the Case Based Reasoning for Pure Gaharu and pure mixed lemon

Performance Evaluation	**Highest Percentage (K1)**	**Second Highest Percentage (K2)**	**Third Highest Percentage (K3)**	**Average**
Criteria	*Values*	*Values*	*Values*	*Values*
Total Cases	20	20	20	20
Pure Gaharu (P)	10	10	10	10
Pure mixed Lemon (N)	10	10	10	10
True Positive (TP)	9	7	6	7.333
True Negative (TN)	10	10	10	10
False Positive (FP)	1	3	4	2.667
False Negative (FN)	1	3	4	2.667
Sensitivity = TP/(TP+FN)	0.900	0.700	0.600	0.733
Specificity = TN/(FP+TN)	0.909	0.769	0.714	0.797
Accuracy = (TP+TN)/ (P+N)	0.950	0.850	0.800	0.867

The classifier accuracy percentage success rate for both sample data test is 86.7 %. The data were classified by using

similarity percentage of 20 samples case for testing and training samples. The summary of accuracy by statistical based on CBR highest similarity for 20 cases including sensitivity, specificity and accuracy shown in Table 3 and Table 4.The sensitivity and specificity a bit lower compared to the accuracy which is 0.733 and 0.797 respectively for both sample test data. The results of CBR performance measure will be improved significantly by increasing the size of the samples.

Table IV
Statistical Analysis of the Case Based Reasoning for Pure Gaharu and pure mixed lavender

Performance Evaluation	**Highest Percentage (K1)**	**Second Highest Percentage (K2)**	**Third Highest Percentage (K3)**	**Average**
Criteria	*Values*	*Values*	*Values*	*Values*
Total Cases	20	20	20	20
Pure Gaharu (P)	10	10	10	10
Pure mixed Lavender (N)	10	10	10	10
True Positive (TP)	9	7	6	7.333
True Negative (TN)	10	10	10	10
False Positive (FP)	1	3	4	2.667
False Negative (FN)	1	3	4	2.667
Sensitivity = TP/(TP+FN)	0.900	0.700	0.600	0.733
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Accuracy = (TP+TN)/ (P+N)	0.950	0.850	0.800	0.867

IV. CONCLUSION

This study of the application of CBR in classifying the purity of gaharu was accomplished through the accuracy percentage of CBR. The purity of gaharu and mixed gaharu with other essential oil classify based on features and statistical value which is by graph plot and boxplot features.

The result shows the classification nearly approaches 100% of accuracy which is 86.7%. In addition, this study can be further refined for better classification using CBR.

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