ANN based Colour Detection in Tea Fermentation

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Abstract

Colour and texture are important parameters in foods processing industries. Both these two factors represent meaningful visual stimuli and can be represented by a model for quality control of the products. Some food processing industries give emphasis on the coloury compounds towards quality of the food items. Intensive processing in complex controlled environments of tea fermentation requires supervision and control of the process as early as possible. The design and development of a PC based color matching system is attempted for the Tea industry. In this paper a comparison / matching technique for colour of test image with a standard data set is adopted. The neural network technique is considered for making the algorithm more trained and adaptable to detect the optimum colour of tea during fermentation. The result is compared with the decision made by tea tasters in the tea industry.

Key words: Tea fermentation, colour matching, Neural network, tea quality etc.

1. Introduction

ANN- based system are often encountered in industrial inspection for quality and process control, eg detection of defect objects in the productions of steel, textiles, fruits, vegetables, plants or other food processing industries [**M E Petersen, D de Ridder & H Handels, 2001**]. For designing of an image colour matching aid for the food processing industries using neural network or other methods, the accuracy is of extreme importance for determining quality of the products. The quality of made-tea depends upon lots of parameters prior to the final product. In fact tea quality depends on several natural and man-made factors. Out of the several factors, one of the most sensitive factors is the detection of the optimum condition during fermentation. This is an oxidation process in which tea attains its necessary colour and flavour generally available in cup of tea. Both the parameters aroma and flavour are the determining factors for the acceptability of black tea as a universal beverage. Again tea flavour and colour are complex problems since there are numbers of volatile and non-volatile compounds formed during this oxidation process on fine granules of green tea. The situation is further complicated by the fact that the flavour is unstable and its odour is changing with time as and when chemical composition of the tea changes. The non-volatile compounds imparting to the liquor its characteristic colour and tastes gradually change and after obtaining the optimum condition they are degraded sharply. As a matter of fact, the quality of made-tea can be determined by visual inspection of the optimum colour during the process. The human experts, since the beginning of the industry, have been traditionally measuring tea flavour and colour with smelling and eye approximation respectively. This human sensory panel decision for colour and flavour determination is purely subjective, and may vary from person to person. Again this is time consuming and inexact due to various reasons such as individual variability, adaptation, fatigue, infection, mental state etc. As a result, the constancy in producing good quality tea by the factories fails in various occasions. Analyzing the degradation of quality in made-tea efforts are being made to asses some attributes like colour aroma/flavour of the tea sample in fermentation stage with the aid of instruments [**P K Mahanta, 1988; P Kumar, 1999**]. This paper describes the use of machine vision for monitoring quality of made-tea by extracting visual features measured from fermented tea images.

2. Colour in tea

Fermentation is one of the most fundamental processes and that is one of the most recognizable determining factor for the quality of made-tea. The stages prior to this stage merely condition the leaves for reactions to take place during fermentation. A series of chemical reactions take place during this process due to the severe damage to the leaf cells. Although heat, light and pH effect the degradation of carotenoids, which is mostly influenced by oxidised flavonols formed during fermentation.

Some non-volatile compound such as theaflavins (TF) and thearubigins (TR) are produced in fermentation stage. These compounds together impart to tea liquor and taste. In addition to the formation of TF and TR, some other chemical changes also take place in the leaf tissues during fermentation process. Proteins get degraded, caffeine content goes up, the chlorophyll are transformed into pheophytins and some volatile compounds are generated due to transformations of certain aroma precursors present in tea leaf. These changes also contribute towards the colour and flavour of made-tea [**P K Mahanta and M Hazarika, 1985**]. At some optimum condition of tea fermentation, the colour of the tea changes from green to deep coppery red [**P K Boruah, 1992**], which is a matter of interest for the tea tasters for determination of tea quality.

3. Computer based colour matching

An attempt is made to establish the theoretical background and the practical implementation for the fermentation control by colour matching techniques in the tea industry by computer intelligence.

An automated intelligent color measuring / matching system is developed, which will be able to detect the completion of fermentation process correctly ensuring quality of tea. We have attempted for testing the colour with HSI (Hue, Saturation and Intensity) colour model using digital camera. The usefulness of this model ranges from the design of imaging systems for automatically determining the ripeness of fruits and vegetables, to systems for matching colour samples or inspecting the quality of finished colour goods [**R C Gonzalez & R E Woods, 1993**]. Besides, this model is robust to the practical imaging parameters such as viewing direction, surface orientation, illumination direction, and illumination intensity in comparison to the other colour models such as RGB [**T Gevers & A W M Smeulders, 1999**].

Experiment has been carried out using artificial neural network training method of Perceptron Learning Rule to discriminate between test coloured images of fermented-tea and a set of standard fermented tea images. Since hue and saturation represent the all colour information of an image, training is carried out with these two colour attributes only. Besides, both the colour attributes of all the images are transformed from the conventional RGB colour model. No attempts have been reported in open literature about use of image processing technique in tea industry for quality testing.

4. Quality assurance

Quality of the made-tea is estimated through out the experiment in accordance to the nine out of several main descriptors of tea tasting [**M Bhuyan and S Borah, 2001**]. The tea testing terms CHARACTER, BODY, FRUITY, COLOUR, CREAM, BAKEY, HEAVY, PUNGENT and THIN is considered here. The importance of these terms is that on the basis of which the tea tasters make their decision about the quality of the made-tea and every descriptor has the correlation with the tea fermentation process. Due care has been taken to ensure that other stages of manufacture prior to fermentation and after fermentation have less degradation effect in quality.

5. Experimental procedure

One approach that is generally used in colour image recognition /matching is the use of Artificial Neural Networks (ANN). The availability of a large set of samples (Images) data makes the ANN approach more suitable in such application of colour matching in food processing industry. Perceptron learning algorithm is carried out for training the network in the training phase, which can solve the problem more precisely. The Hue and Saturation of the data set images are used as the inputs to the feature vectors. Again one most deserved assumption is that, in the colour-matching problem as in the case of food processing industries, the colour intensity is almost equally distributed throughout the image object. Therefore, two layers ANN is sufficient for colour matching in determining the optimum colour of fermented tea image. Figure 1. In the figure, x_{11}, x_{12}, x_{13} …x_{mn} are the inputs and w_{11}, w_{12}, w_{13} …w_{mn} are the weights for the inputs. Finally O_1 and O_2 are the outputs for decision (similar and Dissimilar). The value of Perceptron's decision function d(x) is given by .

$$d(x) = \sum_{i=1,\, j=1}^{mn} w_{ij} x_{ij}$$

If d(x) > 0, then image $\in$ Similar and if d(x) < 0, then image $\in$ Dissimilar.

Two sets of image data are being used, one for the standard colour images (Similar) and the other is for the different (Dissimilar). Both the image databases are created on the basis of the sensory panel decision with quality descriptors already mentioned. Several images are acquired on completion of the process over a long period of time

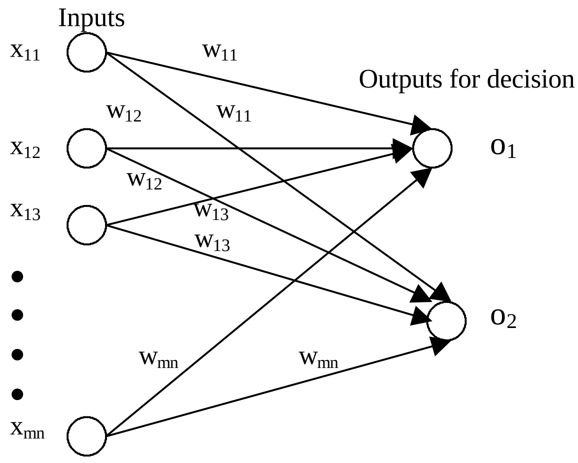

Figure 1: The structure of the network for colour matching

and only 20 out of those are chosen as the standard (Similar) data set, whose final product is of reasonable strength scored by the sensory panel. The rest of the images corresponding to which the final product quality was not selected by sensory panel are considered as the images of different colour. These images correspond to non-optimal fermentation (Under fermentation and over fermentation). Again the inputs x_1, x_2, x_3, etc. are the either Hue or Saturation of the data set images.

The perceptron learning rule is adopted for these two separable sets. The weight adjustment is done for both of the two categories of the image object, which are to be classified into the two output vectors. The weights to the input vectors (hue and saturation) are trained in two separate networks for both the sets of sample data. The randomly chosen weight vectors for the first iteration are adjusted by training with the whole the database of both the classes. Adjustment of the weights are done by the following iterative equation –

$$w_{i+1}=w_i + \eta[d_i – y_i]\, x_i$$

Where, w_{i+1} à New adjusted weight
w_i à Old weight
η à The learning rate (≈ 0.01)
$d_i = 1$, when image $\in$ similar
$= - 1$, when image $\in$ Dissimilar
$y_i = 1$, when $d(x) > 0$
$= - 1$, when $d(x) < 0$.

This process is being continued until the proper weights are achieved. One important point to note here is that in the training process there should be as less number of iterations for weight adjustment. When the training is over, the final weights for both hue and saturation from the training phase are tested separately for some images of known class. Observing a satisfied level of accuracy, those weights are accepted for final application i.e., the testing of input image for colour.

6. Results

The requirement of quality differs from customer to customer. Therefore, the quality determination is not an easy process in tea industry. Several images are tested with this ANN-based computer aided approach out of which, only 10 results are shown in the table I. The quality of the made-tea is estimated with only one main descriptor Strength. Again the strength is expressed in terms of some arbitrary categories such as poor, a little/only fair, some/ fairly good, good, very good etc.

Table I.

Test samples	The value of Perceptron's decision function		Computerized decision (Yes / No)	Quality assurance (Strength)
	Hue	Saturation		
Sample1	1.9894e+005	1.2343e+005	Yes	Some
Sample2	2.5437e+005	1.7782e+005	Yes	Good
Sample3	2.3291e+005	2.0879e+005	Yes	Good
Sample4	-2.4001e+004	1.4319e+005	No	A little
Sample5	3.0485e+005	2.7619e+004	Yes	Good
Sample6	2.0842e+005	1.6514e+005	Yes	Some
Sample7	-1.2958e+005	0.9862e+005	No	Some
Sample8	3.7821e+004	3.2955e+005	Yes	Good
Sample9	2.4619e+005	2.1931e+005	Yes	Good
Sample10	-2.5634e+004	-1.7620e+005	No	A little

7. Conclusion

Test conducted on 50 images (20 of standard class and 30 of different class) reveals that the approach gave only three wrong result among the 28 tested images with an encouraging accuracy of 94%, which is acceptable. Another important point is that in the training process, the approach took a maximum of two numbers of iterations for adjusting one weight. Thus it can be concluded that the designed approach is having a good degree of convergence and accuracy.

In real world, it is not easy to achieve 100% accuracy, a goal that industries would like to achieve. But in some sense, it can assure better performance which is not deserved in human decision. Again, the colour is not the only quality-determining factor of food product; it is not possible to achieve an accomplished accuracy by considering only the colour of the product. Thus the approach should be extended for some other parameters which will make the result more efficient. Since the aroma is also a most dominant parameter for quality determination during fermentation of tea, an efficient electronic application for the odour determination during the fermentation process will be the future work for such intelligent approach of colour determination.

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