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Studies on Correlation between Tea Process Parameters and Overall Liquor Rating using MLR and ANN Based Technique

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Abstract—*This paper describes the correlation study of tea process parameters especially the fermentation and drying condition with the tea quality termed as Overall Liquor Rating (OLR) evaluated by human experts called tea taster. A network based instrument to collect different process parameters of tea fermentation and drying is developed and installed in a tea factory near Mangaldoi, Assam, India. The corresponding OLR is collected from the tea taster. Multivariate linear regression (MLR) analysis is carried out with these data by taking process parameters as input and OLR as corresponding output. Artificial Neural network based technique is also implemented on these data. Back Propagation multilayer perceptron (BPMLP) is chosen for the purpose. A comparison of both these analysis is also depicted in this paper where ANN based technique is showing better result than MLR based technique.*

1. INTRODUCTION

Tea is the most consumed beverage throughout the world and Assam is the single largest region producing 51% of total tea produced in India and 1/6 th of the world. Several stages or processes has to be performed for tea production and that is depicted in Fig. 1[1].

Among all these processes, the conditions at which fermentation and drying processes are performed play a pivotal role in the final quality of the product. Colour and flavour undergo changes from green to coppery brown and grassy to floral smell respectively during fermentation and these changes strongly depend on process conditions [2]. It is an oxidation process and it starts with exposing the leaves to air after CTC. Temperature and relative humidity (RH) are the key process parameters in the fermentation process. In the process of drying enzyme reactions in the earlier stages are terminated, free moisture is removed and new compounds are produced by the application of heat. Use and exposure of excessive heat can result in loss of quality [3].

Precise measurement of these parameters like temperature and RH of fermentation, dryer temperature etc are important to get the good quality tea. However, monitoring and control of these parameters are done by manually or even by guesswork [4]. So a network based instrumentation system is required in the factory environment for process monitoring. It is also important to find the optimum condition to get good quality tea.

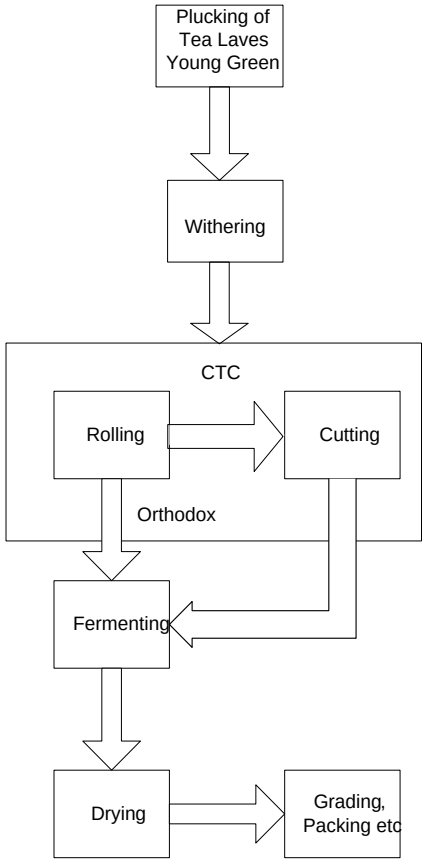

Fig. 1: Block diagram of the tea processing stages

Sarma et al. developed such system for monitoring RH and temperature of fermentation room [5, 6, 7] and dryer temperature [8, 9]. Moghavvemi et al. [10] also developed a RH and temperature measurement instrument with built-in sensing circuitry. But networking capability is not incorporated with these systems and need individual central monitoring and data logging system. A system is described in [7] which is implemented in the tea factory to monitor only the fermentation condition. However, the system described in [11] is useful for the fermentation and drying process.

ANN based techniques are used effectively to quantify tea quality. Electronic nose based techniques were employed to collect data from the fermentation process of black tea and correlated these data with the results of colorimetric tests and tea tasters' mark [12]. Optimum fermentation time can also be detected by electronic nose based technique where electronic nose data accurately matched with the colorimetric as well as tea tasters' mark [13]. In the studies of Bhattacharya et. al., electronic nose as well as electronic tongue data were correlated with the tea tasters' marks to classify black tea quality [14, 15]. Different neural network topologies like back propagation multilayer perceptron (BP-MLP), radial basis function (RBF), probabilistic neural network (PNN), learning vector quantization (LVQ) [16] were used to standardize tea quality using electronic nose / electronic tongue data. A neural network based electronic nose system to discriminate the aroma of different tea grades were developed by Borah et. al. where different neural network classifiers namely BP-MLP, RBF and constructive probabilistic neural network (CPNN) were used [17].

This work deals with the following objectives-

1. Collection of tea process parameters from the tea factory by implementing the developed instrument [11].
2. Collection of tea quality data i.e. OLR from tea taster
3. Correlation study of these data using MLR and BPMLP
4. Comparative study of both these methods

2. METHODOLOGY

Detailed methodology is illustrated in the Fig. 2. Tea process parameters are collected from the installed system and the OLR is collected from the tea taster. Tea process parameters are taken as inputs and OLR are taken as outputs for the study. MLR and ANN based model has been developed to study the correlation between the inputs and outputs. These two models are compared based on the correlation and RMSE found from training and validation.

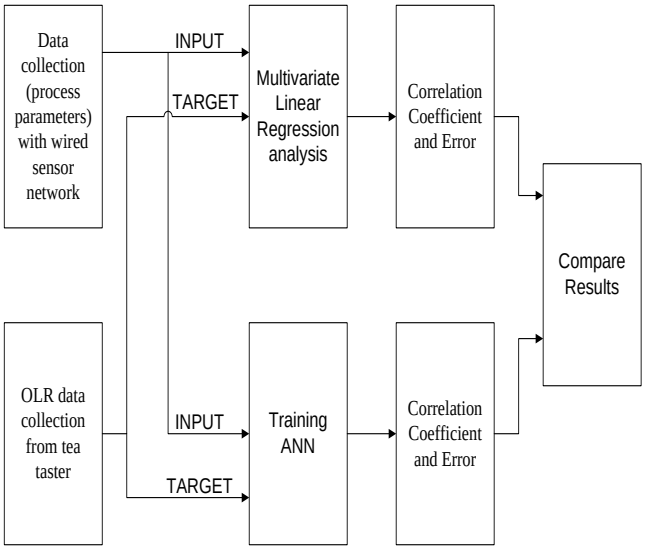

Fig. 2: Block Diagram representation of the detailed methodology

3. DEVELOPMENT OF THE NETWORK BASED INSTRUMENT

An RS 485 network based instrument to record different tea process parameters is used [11]. Basic block diagram of the instrument is shown in Fig. 3. Four sensor nodes are used for the factory, out of which three are used for the fermentation room and one is required for dryer temperature monitoring. Fermentation room monitoring nodes are able to record the temperature and RH of the fermentation room. A thermocouple based sensor node is developed to measure the temperature of the dryer.

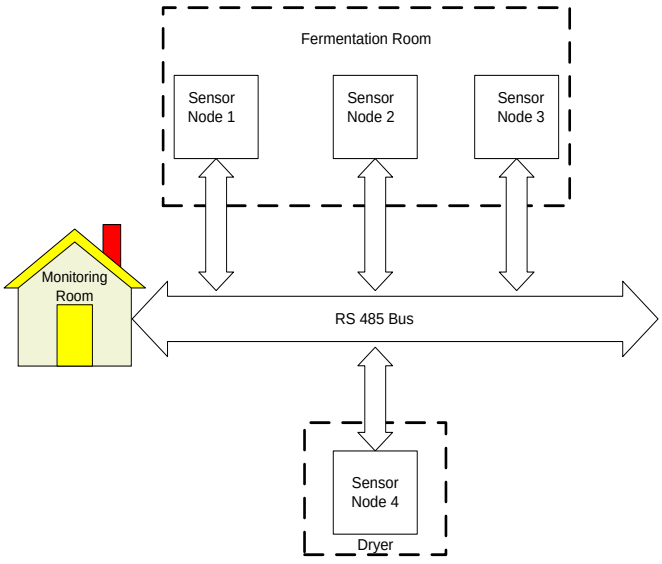

Fig. 3: Block Diagram of the Process Parameter Monitoring System of Tea Factory

4. DATA ANALYSIS AND CORRELATION STUDY

4.1 Data collection and preparation

The data from the sensor nodes are taken as input for the study. The description of the data as input parameters are depicted in Table 1. The OLR provided by tea tasters are taken as output for the study. The OLR basically summarizes all the liquor quality parameters into a single numeric expression. A sample of quality assessment data provided by tea taster is shown in the Table 2. The process parameters from the tea factory for 81 days (during 26th June 2014 to 5th January 2014) are taken for the purpose of creating the models. The corresponding tea quality is also taken in to account. Total 321699 numbers of data points are collected during the stated period. The collected data set is divided in to two groups after normalizing the data. The training and validation data, which are subdivided using a suitable algorithm where 80% of the total data are assigned for training and 20% are assigned for validation purpose. The data are chosen randomly [18].

4.2 Multivariate linear regression analysis

Multivariate linear regression is carried out to find the relationship between the input data and the output data. It is a way to model the relationship between two or more variables and the output variable by fitting a linear equation [19]. The result of the model is presented in the Table 3. Root mean square error is also shown there. It is observed that percentage of correlation is similar in both dataset i.e. for training and validation. The MLR model for Tea quality prediction is presented by the following mathematical equation (equation 1)

$$Q_T = -0.6815 + 1.2814RH1_N + 0.5920T1_N - 0.6037RH2_N + 1.9324T2_N - 0.2716RH3_N + 0.7109T3_N - 0.2934DT_N \quad (1)$$

Where Q_T denotes the tea quality and the other variables denotes the same meaning as depicted in Table 1; however suffix N denotes their normalized value.

4.3 ANN analysis

A four layer BP-MLP model with single input layer, double hidden layer and one output layer is constructed. Gradient descent algorithm is used for the training purpose. The input layer is configured with the process parameters collected from the tea factory the output layer is managed with OLR provided by the tea taster. The input layer consists of seven nodes, the two hidden layers consist of ten nodes each and the output layer having single node. Optimum BP-MLP model is shown in the Fig. 6 [18,19]. Since there is no standard rule on number of hidden layer, number of nodes on the hidden layer and the network topology, so the optimum model is found from the trial and error method [14].

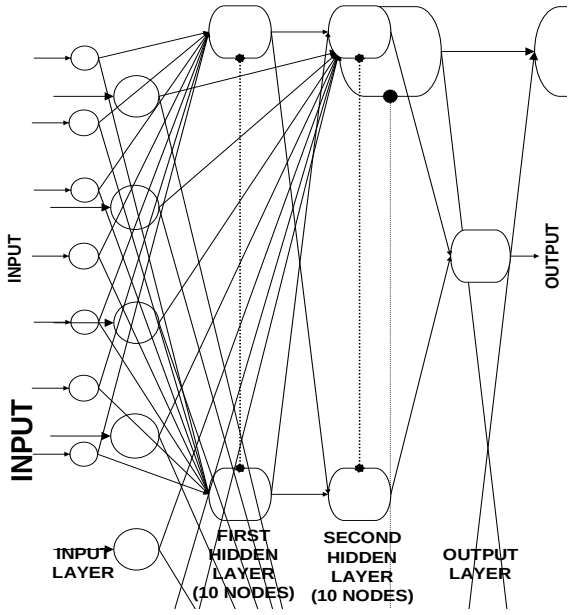

Fig. 6: The optimum MLP architecture

More than 63% Correlation is found from this analysis. The results are illustrated in Table 4.

4.2 Comparison

It is clearly seen from the above study that the MLR results are comparatively poor with respect to the ANN model. A comparison is represented in Table 5.

Table 1: Description of the input parameters

Input parameters	Description	Symbol
1	Temperature of the fermentation room provided by Sensor node 1	T1
2	RH of the fermentation room provided by Sensor node 1	RH1
3	Temperature of the fermentation room provided by Sensor node 2	T2
4	RH of the fermentation room provided by Sensor node 2	RH2
5	Temperature of the fermentation room provided by Sensor node 3	T3
6	RH of the fermentation room provided by Sensor node 3	RH3
7	Temperature of the dryer inlet provided by Sensor node 4	DT

Table 2: Sample data of tea quality as given by tea taster

Sample date	OLR
6/26/2014	3.6
7/13/2014	5.3
8/9/2014	4.6
9/6/2014	2.3

Table3: Result of multivariate linear regression

Methodology	Training/ Validation	% of Correlation	RMSE
Multivariate Linear Regression	Training	58.22	0.14
	Validation	57.65	0.14

Table 4: Result of the ANN model using the fixed training and validation data

Architecture	**Training/ Validation**	**% of Correlation**	**RMSE**
A feed forward back propagation neural network with SIGMOID transfer function	Training	63.90	0.13
	Validation	63.90	0.13

Table 5: Comparison table

Model	**Training**		**Validation**	
	% of Correlation	**RMSE**	**% of Correlation**	**RMSE**
MLR	54.82	0.14	58.22	0.14
BPMLP(ANN)	63.90	0.13	63.90	0.13

5. CONCLUSION

Network based tea process parameter monitoring system is implemented in a tea factory near Mangaldoi, Assam. Tea process parameters are collected from the factory and the corresponding OLR is also collected from the tea taster. The correlation between the tea process parameters and OLR is evaluated here using two different techniques. MLR and ANN base techniques were implemented and ANN based technique is reasonably better then the MLR based technique.

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