Chapter 6

Summary of the Work and Conclusion

The results of the complete work are summarised in this chapter. The future view points are also discussed for further improvement. The principal contributions of this research are presented here. Section 6.1 summarises the instrumentation system developed for the purpose and its advantages and disadvantages. Statistical analysis of data collected from the tea factory and results from different statistical methods are discussed in this section. Different design considerations of soft computing model and results from those techniques are also discussed. A comparison of statistical techniques with soft computing methods is depicted. In the next section (6.2) the main conclusion of the research is portrayed. The last section gives the future view points of the work. Various networking protocols/methods for instrumentation design for future improvement is depicted in this section. Further, possible methods of soft computing are also mentioned to quantify tea quality which may improve the accuracy of prediction and performance of the model as a whole.

6.1 Summary of the Work

Measurement system with sensor network has been developed and installed successfully in a tea factory near Mangaldoi, Assam, India after successful testing in the laboratory. It has the following components

a) Temperature and Relative Humidity Monitoring sensor node for fermentation room and ambient condition has been developed. It is developed with LM35 for temperature and HIH-4000-003 for RH. Sensor nodes are calibrated with standard saturated binary salt solution. Uncertainty of measurement is also found out for the system using type A evaluation method which specify the precision of

measurements. The accuracy found for the system is ±1% for RH and ±1°C for temperature.

b) Temperature monitoring system for dryer inlet using thermocouple has been developed. Calibration method is described in chapter 2. Uncertainty of measurement of the sensor node is estimated by the same method to find the precision of measurement. The accuracy found for the system is ±1°C for temperature.

c) Wired sensor network employing RS 485 protocol for sensor networking purpose is also developed.

d) Data acquisition software is developed using NI LabVIEW to monitor the acquired parameters and logged these data in hard disk of computer.

The completed instrumentation system comprising of all the above components is tested in the laboratory and then it is installed in the tea factory to collect the process parameters. The corresponding tea quality is collected from the tea taster in the range of 0 to 10. Principal component analysis is carried out by taking 100 representative samples of each group from 10 different groups of tea to visualize the pattern of the data. More than 93% useful information are stored in first two principal component and more than 99% useful information are stored in first three principal component. Maximum samples are clustered in well defined manner, so correlation between the process parameters and OLR is confirmed.

Multivariate linear regression is carried out to find the relationship between the input data and the output data. The MLR model shows more than 40% correlation between the process parameters and OLR with RMSE equal to 0.17. But the prediction result shows only 20.86 % classification rate.

An ANN based computational model is developed to investigate the correlation between the process parameters and OLR. The optimum ANN model consists of input layer

with 7 nodes, two hidden layers having 10 nodes each and the output layer with one node. The optimum condition is also found out from the stated model. The model is validated with ten-fold cross validation method and some independent data is also used for that purpose. From ten-fold cross validation, an average of 74% correct correlations is obtained from training and validation set respectively. Average RMSE found is 0.13 for training and validation. The model is also validated with independent data and more than 50% correct correlation is found. RMSE found in this case is 0.13.

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 6.1.

Table 6.1: Comparison table between MLR and ANN based technique

Model	**Training**		**Validation**	
	% of Correlation	**RMSE**	**% of Correlation**	**RMSE**
MLR	41.72	0.17	41.71	0.17
BPMLP(ANN)	74.30	0.13	74.40	0.13

The optimum values of the process parameters can be found out from the model and these values can be useful for controlling the processes to get the best quality tea. The trend of optimum values is presented in Table 6.2.

Table 6.2: Typical trends of optimum conditions

Fermentation Room		Dryer Inlet
RH (%)	**Temperature (^{0}C)**	**Temperature (^{0}C)**
82	32	92
92	28	90
92	30	84
93	30	78

The novelty of this work over the previous work related to tea quality prediction is that this work has been carried out in the factory environment by installing the developed instrumentation system rather than a controlled environment. Most of the previous works cited here are carried out with the end product and classified the tea quality accordingly. In this attempt it is focused on finding the optimum process conditions so that the quality improvement is possible.

6.2 Conclusion

The instrumentation system having networking capability and data logging feature for tea process parameter monitoring has been developed. It is installed in a tea factory after testing in the laboratory and found to be working satisfactorily for the last three years (2013-2015). Data collected from the tea factory is analysed by statistical method. PCA has been done to visualize the pattern of the data and it shows well defined clusters for different tea qualities. MLR based model is also developed to study the correlation between tea process parameter and the OLR provided by tea tasters. It shows more than 40% correct correlation with RMSE equals to 0.17. ANN based approach is applied to study the correlation and to predict the tea quality where more than 70% correct correlation is found with RMSE equals 0.13. ANN model is tested with independent data and it is showing more than 50%

classification rate. The statistical as well as the ANN model is compared and ANN model is found to be better than the statistical one. The optimum conditions of the tea process parameter are also found out from the model and it is depicted in Table 6.2.

6.3 Future Work

The instrumentation system consists of the sensor nodes capable of sensing temperature and RH which is connected in RS 485 based wired network. This wired network can be replaced by wireless network in future. The advantages of implementing wireless topology are basically the ease of installation, scalability, wide range of densities, programmability, maintainability etc. Another important future aspect is to cover more processes like withering, CTC and the garden parameters which affects the quality of tea. Parameters considered for this study can also be increased by associating different sensors and processes. For example moisture content of withered leaves, moisture content of end product, temperature and RH of CTC process, time of fermentation etc.

Different soft computing approach can also be implemented for the optimum model. The neural network implemented here is very standard so some other robust classifiers like Support Vector Machine (SVM) and Radial Basis Function (RBF) based architectures can be used and comparison of all the models can be made. Fuzzy-Neuro computing and different fusion based approach may also stand for good result.