Artificial Intelligence Elman Backpropagation Computing Models for Predicting Shelf Life of Processed Cheese

Sumit Goyal and Gyanendra Kumar Goyal

Abstract— **This paper presents the latency of Artificial Neural Network based Elman models for predicting the shelf life of processed stored at 30°C. Soluble nitrogen, pH, standard plate count, yeast & mould count, and spore count were taken as input parameters, and sensory score as output parameter. Mean square error, root mean square error, coefficient of determination and nash - sutcliffo coefficient performance measures were used for testing prediction potential of the developed models. In this study, Elman models predicted the shelf life of processed cheese very close to the experimentally determined shelf life.**

Index Terms— **ANN, Shelf Life, Elman, Backpropagation, Processed Cheese**

I. Introduction

PROCESSED cheese is very nutritious and generally manufactured from ripened Cheddar cheese, but sometimes less ripened Cheddar cheese is also added in lesser proportion. Its manufacturing technique includes addition of emulsifier, salt, water and sometimes selected spices. The mixture is heated in jacketed vessel with continuous stirring in order to get homogeneous paste. This variety of cheese has several advantages over raw and ripened Cheddar cheese, such as tastier and longer shelf life. It is a protein rich food, and is a comparable supplement to meat protein. Neural Networks have become very famous topic of interest since last few years and are being implemented in almost every technological field to solve wide range of problems in an easier and convenient way. Such a great success of neural networks has been possible due to their sophisticated nature as they can be used with ease to model many complicated functions. In human body, neural networks are the building blocks of the nervous system which controls and coordinates the different human activities. Neural network consists of a group of neurons (nerve cells) interconnected with each other to carry out a specific function. Each neuron or a nerve cell is constituted by a cell body call cyton and a fiber called axon. The neurons are interconnected by the fibrous structures called dendrites by the help of special gapped connections called synapses. The electric impulses (called Action Potentials) are used to transmit information from neuron to neuron throughout the network. Artificial neural networks (ANNs) have been developed based on the similar working principle of human neural networks. Artificial Neurons are similar to their biological counterparts. The input connections of the artificial neurons are summed up to determine the strength of their output, which is the result of the sum being fed into an activation function, the most common being the Sigmoid Activation Function which gives output varying between 0 (for low input values) and 1 (for high input values).

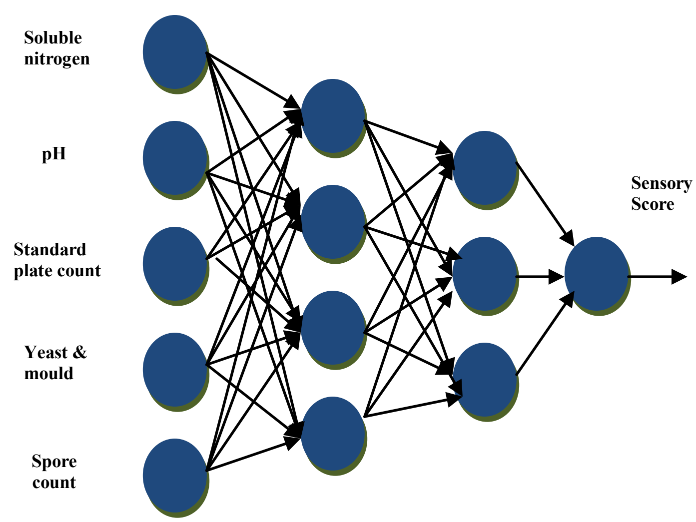

Fig.1. Input and output parameters for Elman backpropagation models

The resultant of this function is then passed as the input to other neurons through more connections, each of which are weighted and these weights determine the behavior of the network. An ANN is devised for specific applications, such as

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pattern recognition or data classification, through a learning process [1]. ANNs predicted shelf life of Kalakand [2], milky white dessert jeweled with pistachio [3], and instant coffee flavoured sterilized drink [4, 5]. Time-Delay and Linear Layer ANN models were developed for predicting shelf life of soft mouth melting milk cakes [6], and soft cakes [7]. Radial Basis models were successfully applied for predicting shelf life of brown milk cakes [8]. The objective of this research is to develop Elman single and multilayer backpropagation computing models for predicting the shelf life of processed cheese stored at 30^{o} C.

II. Material and Methods

A. Data Modeling

The data consisted of 36 samples, which were divided into two subsets, *i.e.,* 30 were used to train and 6 to validate the Elman backpropagation models. Soluble nitrogen, pH, standard plate count, yeast & mould count, and spore count were taken as input variables, and sensory score as output variable for developing Elman single and multilayer models (Fig.1).

Several combinations were tried and tested, as there is no defined rule of getting good results rather than hit and trial method. As the number of neurons increased, the training time also increased. Algorithms like *Levenberg Marquardt algorithm, Gradient Descent algorithm with adaptive learning rate, Bayesian regularization, Powell Beale restarts conjugate gradient algorithm* and *BFG quasi-Newton* algorithms were tried. Backpropagation algorithm based on *Bayesian regularization* was finally selected for training the networks, as it gave most promising results. ANN was trained upto100 epochs with single as well as double hidden layers and transfer function for hidden layer was *tangent sigmoid* while for the output layer, it was *pure linear* function.

The Neural Network Toolbox under MATLAB software was used for developing the models. Training pattern of Elman models is presented in Fig.2.

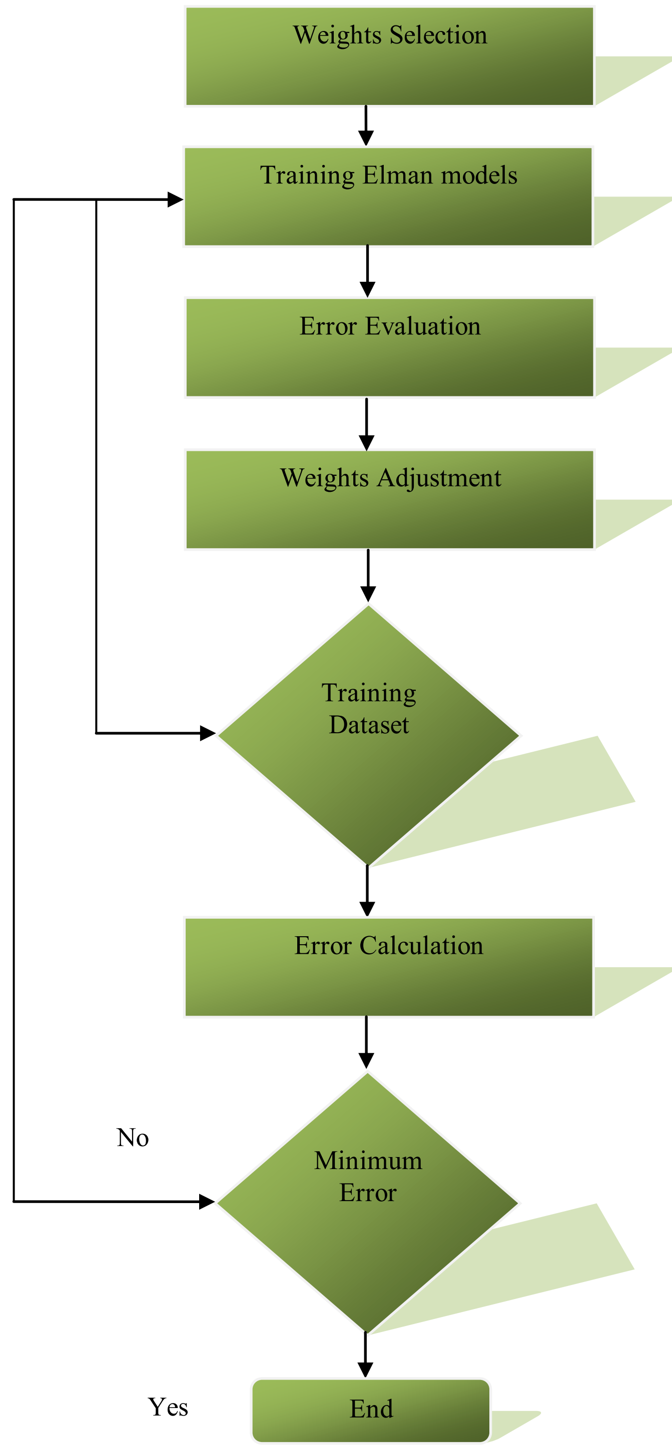

Fig .2. Training pattern of Elman models

B. Measures for Prediction Performance

Mean Square Error (MSE) (1), Root Mean Square Error RMSE (2), Coefficient of Determination: R^2 (3), and Nash - Sutcliffo Coefficient: E^2 (4) were used in order to compare the prediction ability of the developed models.

$$MSE = \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{n} \right)^2 \right] \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n} \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp}} \right)^2 \right]} \quad (2)$$

$$R^2 = 1 - \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp}{}^2} \right)^2 \right] \quad (3)$$

$$E^2 = 1 - \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp} - \overline{Q}_{\exp}} \right)^2 \right] \quad (4)$$

Where,

$Q_{\exp}$ = Observed value;

Q_{cal} = Predicted value;

$\overline{Q}_{\exp}$ =Mean predicted value;

n = Number of observations in dataset.

Table 1: Performance of single layer for predicting sensory score

Neurons	MSE	RMSE	R^2	E^2
3	7.04669E-05	0.008394454	0.991605546	0.999929533
5	0.000176202	0.013274109	0.986725891	0.999823798
7	0.001911122	0.043716386	0.956283614	0.998088878
9	0.000191461	0.01383696	0.98616304	0.999808539
11	0.000227001	0.015066536	0.984933464	0.999772999
13	0.00022446	0.014981988	0.985018012	0.99977554
15	0.000428985	0.020711958	0.979288042	0.999571015
17	0.001079962	0.03286278	0.96713722	0.998920038
20	0.000437028	0.020905211	0.979094789	0.999562972
25	0.000491983	0.022180685	0.977819315	0.999508017
30	**1.21846E-05**	**0.003490644**	**0.996509356**	**0.999987815**

Table 2: Performance of multilayer for predicting sensory score

Neurons	MSE	RMSE	R^2	E^2
3:3	**8.77114E-06**	**0.002961612**	**0.997038388**	**0.999991229**
4:4	0.006907863	0.083113554	0.916886446	0.993092137
5:5	2.93847E-05	0.005420764	0.994579236	0.999970615
6:6	0.007876012	0.088746898	0.911253102	0.992123988
7:7	0.000225112	0.015003729	0.984996271	0.999774888
8:8	0.007324755	0.085584785	0.914415215	0.992675245
9:9	0.008067535	0.089819455	0.910180545	0.991932465
10:10	0.000224894	0.014996482	0.985003518	0.999775106
11:11	7.57117E-05	0.008701245	0.991298755	0.999924288
12:12	0.000252731	0.015897527	0.984102473	0.999747269
13:13	2.35759E-05	0.004855497	0.995144503	0.999976424
14:14	0.01241181	0.111408301	0.888591699	0.98758819
15:15	0.000110574	0.010515413	0.989484587	0.999889426
16:16	0.000117277	0.01082945	0.98917055	0.999882723

III. Results and Discussion

Elman model's performance matrices concerning the single layer and multilayer models for predicting sensory scores based on equations 1, 2, 3 and 4 are presented in Table 1 and Table 2, respectively.

The developed Elman ANN single and multilayer models showed that single layer model with 30 neurons performed the best **(MSE: 1.21846E-05, RMSE: 0.003490644, R^2: 0.996509356, E^2: 0.999987815);** while multilayer with 3:3 neurons **(MSE: 8.77114E-06, RMSE: 0.002961612, R^2: 0.997038388, E^2: 0.999991229)** performed the best. On comparing them with each other, it was observed that multilayer model performed better. Therefore, it was selected for predicting the shelf life. The comparison of Actual Sensory Score (ASS) and Predicted Sensory Score (PSS) for single layer and multilayer models are illustrated in Fig.3 and Fig.4, respectively.

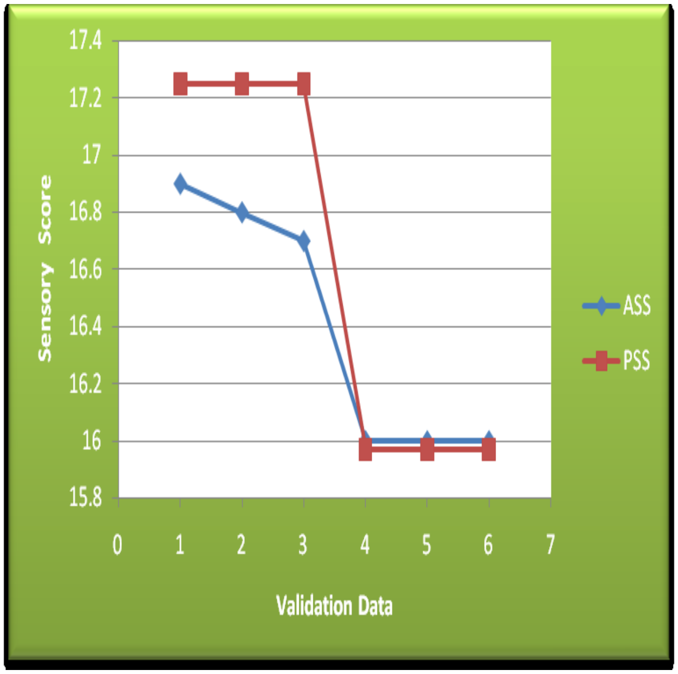

Fig. 3. Comparison of ASS and PSS single layer model

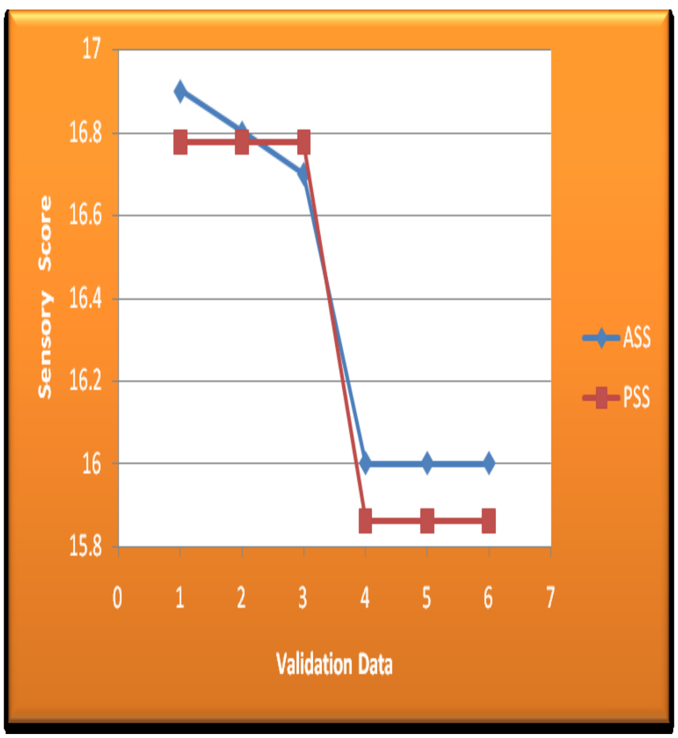

Fig. 4. Comparison of ASS and PSS for multilayer model

Coefficient of determination (R^2) was calculated based on the total variation as explained by sensory scores. Period of storage (days) for which the processed cheese has been in the shelf is illustrated in Fig.5.

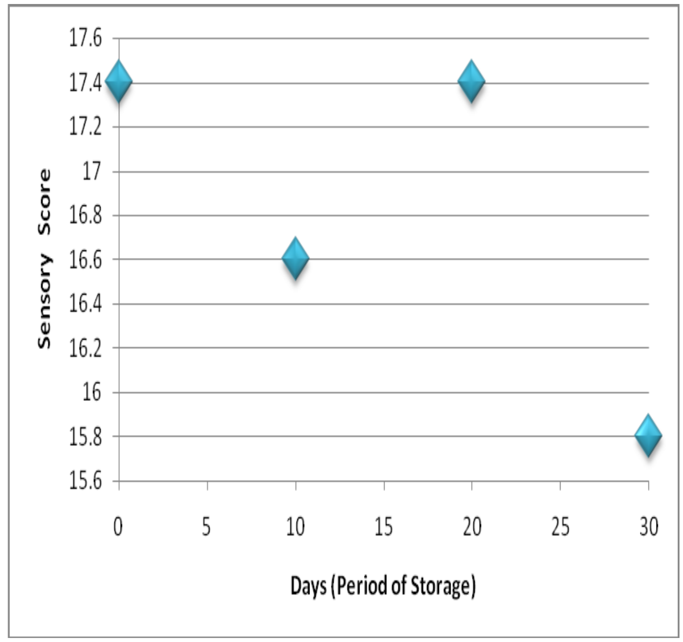

Fig.5. Sensory score and period of storage for processed cheese

The shelf life is calculated by subtracting the obtained value of days from experimentally determined shelf life, which was found to be 29.31 days. The predicted value is quiet close to the experimentally obtained shelf life of 30 days suggesting that the developed model is quite effective in detecting the shelf life of processed cheese.

IV. Conclusion

Soluble nitrogen, pH, standard plate count, yeast & mould count, and spore count were taken as input variables, and sensory score as output variable for developing Elman models for predicting the shelf life of processed cheese stored at 30^o C. Mean square error, root mean square error), coefficient of determination and nash - sutcliffo coefficient were used in order to compare the prediction ability of the developed models. Bayesian regularization was selected for training Elman ANN models. Regression equations were developed for predicting the shelf life of processed cheese which gave 29.31 days shelf life vis-à-vis 30 days experimentally obtained shelf life. From the study it is concluded that the developed Elman models are very efficient for predicting the shelf life of processed cheese.

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