A Comparative Study of Neural-Network & Fuzzy Time Series Forecasting Techniques – Case Study: Wheat Production Forecasting

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Summery
Various forecasting methods have been developed on the basis of fuzzy time series data, but accuracy has been matter of concern in these forecasts. As in fuzzy time series methods forecasted values depend to some degree on our interpretation of the output of the forecasting model thus different interpretation may lead to different results, this makes the process quite subjective. An objective method, based on artificial neural network of forecasting is proposed .The proposed method is compared with various fuzzy time series forecasting methods.

Key words
Agriculture Production, Forecasting, Fuzzy time series, Neural Network

1. Introduction

Forecasting the behavior of complex system has been a broad application domain for neural networks. In particular, such as electric load forecasting [1], [2], economic forecasting [3], forecasting natural physical phenomena [4] , river flow forecasting [5] and forecasting student admission in colleges[18] have been widely studied.

Other than neural network based forecasting, Fuzzy time series forecasting emerged as a noble approach for predicting the future values in a situation where neither a trend is viewed nor a pattern in variations of time series are visualized and moreover the information (data) are imprecise and vague. Song and Chissom [6] successfully employed the concept of fuzzy sets having linguistic variables presented by Zadeh [11, 12] and the application of fuzzy logic to approximate reasoning by Mamdani [13] to develop the foundation of fuzzy time series forecasting. Song and Chissom [13, 14] implemented his developed time invariant and time variant models on the historical time series data of student enrollments of university of Alabama. Chen [14] presented a simplified time invariant method for time series forecasting by using the arithmetic operations in place of max-min composition operation used by Song and Chissom [7]. Further, Chen [14] applied the high order fuzzy time series model for forecasting the enrolments and found some points of ambiguity to the trends in forecast and suggested to use high order fuzzy logical relationship group to deal with ambiguity. S.R. Singh [10] presented an improved and versatile method for fuzzy time series forecasting using a difference parameter as fuzzy relation for forecasting. Rajesh Joshi [17] used a fuzzy time series model for agricultural production forecasting comprises of the development and implementation of fuzzy series model using metrological parameters as indicators for forecasting.

In this paper to achieve the objectivity over the subjectivity of fuzzy time series based methods a neural network based methods has been proposed. The proposed method has been implemented on the historical data and influencing parameters (temperature, sunshine and rainfall) of crop (wheat) production of Pant Nagar farm, G.B. Pant University of agriculture and technology, Pant Nagar (India) [17]

Agriculture production system is one of the real life problems falling in the category having uncertainty in known and some unknown parameters, hence become a natural choice for implementation of fuzzy time series forecasting models in its production system. The uncertainty lies in the crop production due to some uncontrolled parameters of, which ‘weather’, ‘agro meteorological’ variables are key contents. Further, the crop production being dealt with the field data, precision of data is always a matter of concern. Past experience shows that the crop production system may observe the large variation in production data as the system is effected by many uncertain production parameters and uncertain occurrence of natural calamities. The proposed method produces better result than above discussed fuzzy time series based methods.

2. Artificial Neural Networks and Fuzzy Time Series

In view of making our study self explanatory, same basic definition and properties of fuzzy time series and neural network g found in [1 – 18] are presented as:

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Definition 2.1: Neural network is a system composed of many simple Processing elements- called neurons, operating in parallel whose function is determines by network structure , connection strength & processing performed at computing
elements.

Definition2.2:Artificial neural network (ANN) is composed of many mathematical processing elements (artificial neurons) that are linked together according to a specific network architecture. The objective of the neural network is to transform the inputs into meaningful outputs. ANN can be used where no mathematical model ($f(x) = x^2$) is available for example, Weather forecasting.

Definition 2.3: Backpropagation learning algorithm is a supervised learning method, and is an implementation of the delta rule. It requires a teacher that knows, or can calculate, the desired output for any given input. It is most useful for feed-forward networks (networks that have no feedback, or simply, that have no connections that loop). The term is an abbreviation for "backwards propagation of errors". Backpropagation requires that the activation function used by the artificial neurons (or "nodes") be differentiable. In general following steps are followed to implement the algorithm:

1. Select the training pattern , design the neural network (say network) and initialize the weights in the network
2. Repeat
   for each training pattern X in the training set do
   i. E = neural-net-output (network, X) ; forward pass
   ii. O = teacher output for X
   iii. Calculate error (E - O) at the output units
   iv. Compute change in weights for all weights from hidden layer to output layer ; backward pass
   v. Compute change in weights for all weights from input layer to hidden layer; backward pass continued.
   vi. Update the weights in the network.
   End
3. Until all patterns classified correctly or stopping criterion satisfied.
4. Return trained network.

Definition2.4:The forecasting error and Average forecasting error are used to measure the accuracy of the forecasting.

Forecasting error = $\frac{Forecasted - Actual\ value}{Acctual\ value} X\ 100$

Computation of wheat production forecast with proposed method.

The proposed method is being implemented on the data of wheat enrollment at University of G.B Pant University

Average forecasting error (in percent)
= $\frac{Sum\ of\ forecasting\ error}{Number\ of\ errors}$

3. Method Used

In this section, we present the stepwise procedure of the proposed method for neural network forecasting model.

1. Define the input parameter (viz. those(X_1, X_2 , X_3 …., X_n) metrological parameter which directly influencing the crop production).
2. Collect the enrollment data of year t and previous years (data for the metrological parameters and actual crop production).
3. Normalized the enrollment data so the every value must be in between 0 and 1.
4. Design the Artificial Neural Network (ANN) with the consideration of number of layers in ANN, number of hidden layer and number of neurons in a particular layer.
5. Select the best suited training algorithm for ANN.
6. Define the transfer function for the each layer as suited for the problem, for which we are designing the neural network.
7. Decide the number of epochs and goal for the training of ANN.
8. Select the programming tool to write the simulator for the proposed neural network.
9. Now train the ANN with the collected enrollment data of previous ‘ m ’ years for selected parameters (X_1, X_2 , X_3 …., X_n) and (O(t-1), O(t-2), O(t-3),…….., O(t-m)) actual productions .
10. Once the ANN is trained for the set goal then apply the test patterns for the years t + 1, t + 2, t + 3 ……. t+p , for which we want to forecast the agricultural products. Output of ANN will be taken as the forecasted values for the corresponding years.
11. Do the Comparative study with fuzzy series forecasting models.
12. Do the error analysis with observed forecasted values and actual production values to validate the model.

of agriculture and Technology, Pant Nagar-26145, Udham Singh Nagar, Uttaranchal , University Farm .

Step 1. The input metrological parameter for wheat production is average weekly rainfall, temperature on sunshine hours (Indicators for forecasting).

Step 2. The historical time series data of enrollment are obtained and further normalized to bring all the values in the range of 0 and 1(Table 2)

Step 3. The proposed Neural Network has three layers. Input layer, one hidden layer and output layer. The hidden layer has 5 neurons and out layer has one neuron only (Figure 1).

Step 4. Back propagation algorithm is used as training algorithm.

Step 5. Transfer function of hidden layer and output layer are tansig and purelin respectively.

Step 9. The neural network is trained for 4000 epochs and goal is 10^{-6} .

Step 8. Matlab is used as tool to write the program for proposed ANN

Step 9. The input enrollment of wheat production of 15 years is used to train the proposed neural network.

Step10. The test enrollment of wheat production of 6 years is used to check the performance of Proposed method and after denormalization we get the forecasted value (Table 3).

Step11. Comparative study of forecasts by various methods to validate the superiority of proposed method (Table 4). The forecasted values for the wheat production have been obtained by using the computational algorithm pretested in Section 2. The forecasted values for the wheat production have also been obtained by the methods of Chen[14,15],S.R Singh [10] and Rajesh Joshi [17]. The forecasted production of wheat obtained by these methods is placed in table 4.

Step12. We have done the error analysis for all the methods used for the comparative study .Table 5 Shows the MSE and average error for various forecasted methods used in this paper. The comparison in Table 5 shows the suitability of the proposed method over the fuzzy time series methods like Chen [15,16] , S.R Singh [11] and Rajesh Joshi [18]. The forecasted values obtained by proposed method are more accurate due to minimum MSE and average error than fuzzy time series models . The further Visualization of the correctness of the proposed method can be done by the Figure3.

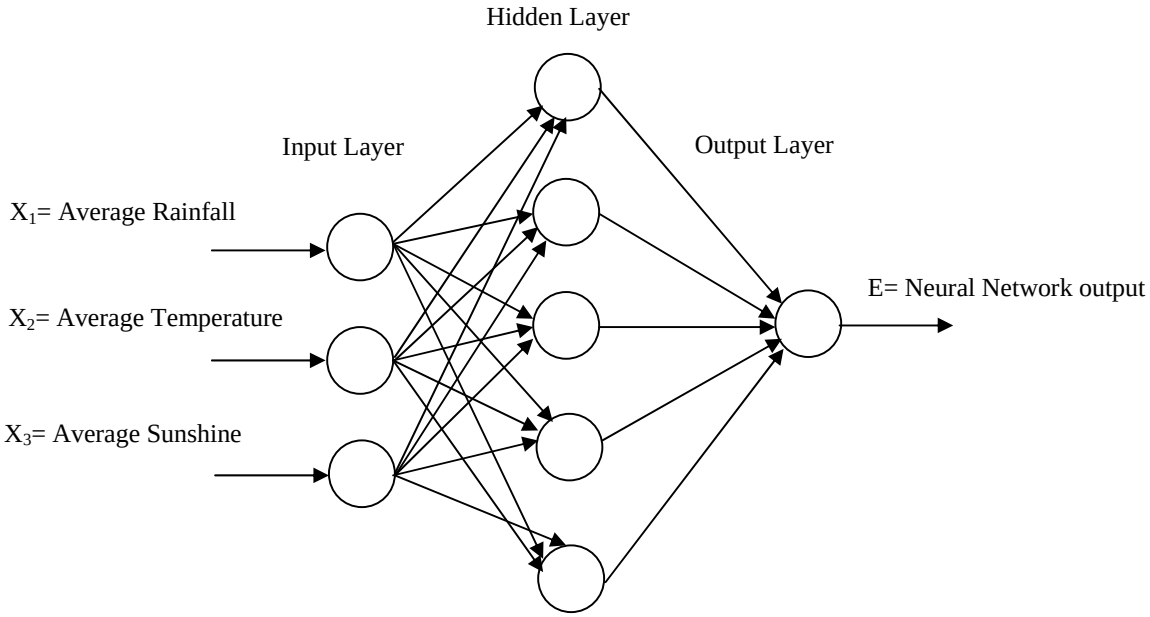

Figure 1: Artificial Neural Network for Wheat Production Forecasting.

Table 2: Normalized Historical Enrollment of wheat

S.N	Year	Average Rainfall /week Mm	Average Temperature /Week ^{o}C	Average Sunshine/Week Hrs.	Actual Production K-G / HA
1	81-82	0.1570	0.4059	0.1408	0.2730
2	82-83	0.1250	0.4105	0.1203	0.2957
3	83-84	0.1960	0.4227	0.1455	0.2382
4	84-85	0.0390	0.4405	0.1375	0.2572
5	85-86	0.0914	0.4207	0.1403	0.2642
6	86-87	0.0704	0.4398	0.136	0.2700
7	87-88	0.0598	0.4436	0.1334	0.2872
8	88-89	0.0803	0.4223	0.1446	0.3407
9	89-90	0.1924	0.4028	0.1229	0.2238
10	90-91	0.1428	0.4280	0.1357	0.2895
11	91-92	0.1200	0.4119	0.1183	0.3276
12	92-93	0.0404	0.4208	0.1241	0.1431
13	93-94	0.0672	0.4402	0.1361	0.2248
14	94-95	0.0340	0.4210	0.1237	0.2857
15	95-96	0.1668	0.4286	0.1227	0.2318

Table3: Actual Enrollment Vs . Forecasted Enrollment of wheat production based on neural network method

S.N	Year	Actual Production KG/HA	Forecasted Production by proposed Model KG/HA
1	96-97	2617	2613.3
2	97-98	2254	2251.8
3	98-99	2910	2913.8
4	99-2000	3434	3439.3
5	2000-01	2795	2787.3

Table 4: A comparative presentation of wheat enrollment forecast by various methods

S.N	Year	Actual Production KG/HA	Forecasted Production by proposed Model	Forecasted Production by Chen Model	Forecasted Production by S.R Singh Model	Forecasted Production by Rajesh Joshi Model
1	96-97	2617	2613.3	2600	2750	2750
2	97-98	2254	2251.8	2750	2150	2450
3	98-99	2910	2913.8	2900	3050	2900
4	99-2000	3434	3439.3	2900	3276.5	3350
5	2000-01	2795	2787.3	2150	2750	2750
6	2001-02	3000	2996.8	2750	2980	3050

Table 5: MSE and Average error of wheat production forecast

Methods	Proposed	Chen [15,16]	S.R Singh [11]	Rajesh Joshi[18]
MSE	21.75833	168347.7	12556.04	11297.67
Average error	0.158333	11.66	3.561667	3.308333

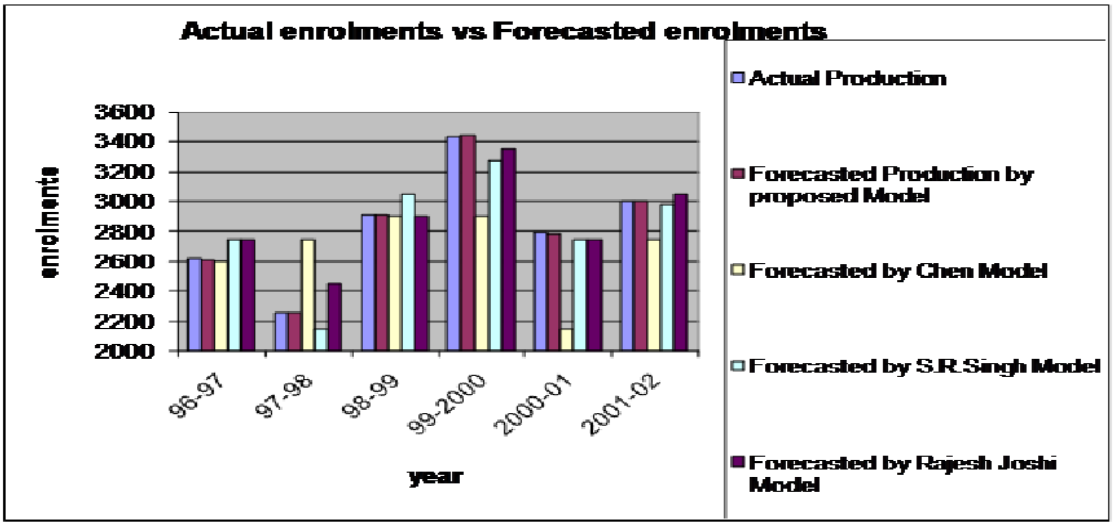

Figure 2: Actual wheat production vs. forecasted wheat production

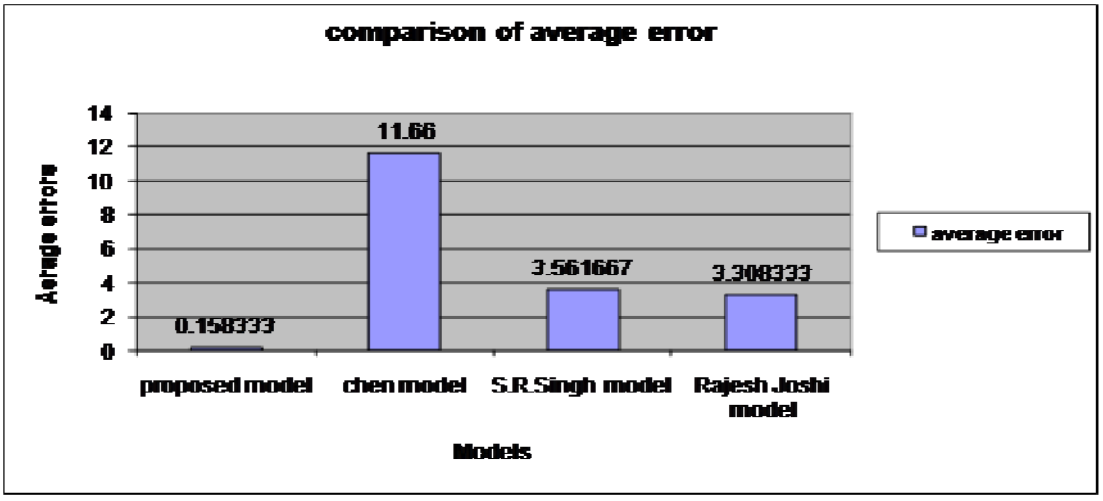

Figure 3: Comparison of average error of wheat forecasted values

4. Conclusion

The goal of this paper has been to use neural network method for the agricultural management based on crop yield. It has been successfully implemented to the forecasting wheat production at Pant Nagar farm. Farm mangers can have some early prediction for their crop by recording metrological parameters. The other goal was to compare neural network method with various fuzzy time series methods. It is observed that it produces more accurate results in comparison of fuzzy time series methods. The neural network method is objective as compared to subjective fuzzy time series methods, since in case of neural network interpretation is done by only designed artificial neural network model. It can easily handle the inaccuracy and any degree of nonlinearity in the data.

References

[1] J. Connors, D. Martin and L. Atlas, "Recurrent Neural network and robust time series prediction", IEEE Trans. Neural Network, Vol . 5, PP. 240 – 254

[2] D.Park, M.Ej – Sharkawi,, R Marks, l. Atlas and M. Damborg, "Electric Load Forecasting usinh an artificial neural network", IEEE Trans. Power Syst., Vol . 6, PP. 442-49, May 1991

[3] A. Refenes and M. Azema-Baras, "Neural network application in financial asset management", Neural Comput. Applicat., Vol . 2, PP . 13-39, 1994

[4] A. Weigend and N. Gerschenfeld, Eds., Time Series Prediction: Forecasting the future and Understanding the past reading, MA: Addision – Wesley, 1994

[5] Amin F. Atiya, Senior member and Samir I. Shaheen, "A Comparison between Neural Network Forecasting Technique – Case Study: River Flow Forecasting ", IEEE transaction on neural networks, vol .10, No. 2, March 1999

[6] Q. Sang, B. Chissom, Fuzzy Time series and its Models, Fuzzy sets and System 54 (1993) 269-277

[7] Q. Sang, B. Chissom, Forecasting enrollments with fuzzy time series – Part I, Fuzzy sets and systems 54 (1993)

[8] Q. Sang, B. Chissom, Forecasting enrollments with fuzzy time series – Part III, Fuzzy sets and systems 64 (1994)

[9] Q. Sang, R.P. Leland, B.S. Chissom, Fuzzy Stochastic Fuzzy Time Series and Its Models. Fuzzy Sets and Systems 81(3) (1996) 321-329

[10] S.R. Singh, A Simple method of forecasting based on fuzzy time series, applied mathematics and computation 186 (2007) 330-339

[11] L.A. Zadeh, Fuzzy set, Fuzzy Set Information and control 8 (1965)338-353

[12] L.A. Zadeh, The concept of a linguistic variable and its application to approximate reasoning. Part I. Information Science 8 (1975) 199-249

[13] E.E. Mamdani, Application of fuzzy logic to approximate reasoning using linguistic synthesis, IEEE Transactions on Computer 26 (1977) 1182-1191

[14] S.M. Chen, Forecasting Enrollments based on Fuzzy Time series. Fuzzy sets and system 81 (1996) 311-319

[15] S.M. Chen, Forecasting enrollments based on higher-order fuzzy time series, Cybernetics and systems. An international Journal 33 (2002) 1-16

[16] S.M. Chen, J.R. Hwang, Temperature prediction using fuzzy time series IEEE Transaction on systems; Man and Cybernetics part b; Cybernetics 30(2) (2000)263-275

[17] Rajesh Joshi, Development of fuzzy time series model for agricultural production forecasting, Ph.D. thesis , G.B. Pant University of Agriculture and Technology, Pantnagar, India July, 2006

[18] Priti Puri, Maitrei Kohl , Forecasting student admission in colleges with neural network, International Journal of Computer Science and Network Security, VOL. 7 No.11, November 2007