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FUZZY-NEURAL TECHNIQUES FOR SHORT TERM FORECAST OF FOOD GRAINS PRODUCTION

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The paper presents a new method to give short term forecast of agricultural production based on fuzzy time series. The agriculture production and productivity is one of the such processes, which is not governed by any deterministic process due to highly non linearity caused by various affective production parameters like weather, rainfall, sunshine, diseases, disaster etc. In such processes Fuzzy time series and Artificial neural network be preferred as these use the relation of dependency and knowledge by learning process of set of training data. The paper presents a method to have short term forecast of agriculture production (course food grains) of Bareilly district (U.P.), INDIA where the time series data obtained through statistical estimators involve vagueness. The study uses the fuzzy set theory and applies the fuzzy time series models introduced by Song & Chissom [1993] and artificial neural network to forecast the production of course food grains. It uses the the time invariant fuzzy time series model and Back propagation algorithm for the forecast. The historical data of course food grains production of Bareilly district (India) have been taken to implement the model. The crop production forecast, obtained through these two fuzzy-neural techniques, have been compared and their performance has been examined.

Keywords: Fuzzy Time Series, Fuzzy Set, Production, Forecasting, Linguistic Value Back Propagation Algorithm.

1. Introduction

Future values of a time series data of many processes are neither exactly governed by mathematical function nor by probability distribution. In such processes, the soft computing techniques: Fuzzy time series and artificial neural network, be preferred as these use the relation of dependency, a generalization of function. Fuzzy Set theory is an intellectual adventure in which the philosophy of mathematics: abstraction and idealization are combined. In fuzzy sets and system, the process of abstraction and idealization make possible the rigorous logical deductions to linguistic variables rather strictly to the crisp numbers. A time series is a sequence of observations taken sequentially in time with an intrinsic feature that the typically adjacent observations are dependent. The time series analysis is concerned with techniques for analysis of such dependency. Both the models: stochastic and dynamic in the time series analysis use the probability structure of sequence of observations to construct the forecast function. The unique features of fuzzy time series models are that it uses the relation, a generalization of functions. Based upon the fuzzy set theory introduced by Zadeh [1965], Song and Chissom[1993] presented the definition of fuzzy time series and outlined its modeling by means of fuzzy relation equations and approximate reasoning. Song and Chissom [1993a] applied the fuzzy time series model to forecast the enrollments of the university of Alabama. Chen[1996] proposed an alternative simplified method of defuzzification using arithmetic operations. Hurang [2001] proposed a heuristic model by integrating problem specific heuristic knowledge with Chen's model to improve the forecasting. All these models have been implemented to forecast the enrollments of the University of Alabama. In the present work the proposed model have been implemented on the historical crop yield forecast, a non linear process, where data in general contain imprecision.

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2. Fuzzy Time Series Models

Let Y(t) (t = …, 0, 1, 2,..), is a subset of R^1, be the universe of discourse on which fuzzy sets f_i (t) (i = 1,2,…) are defined and F(t) is the collection of f_i (i = 1,2,…). Then F(t) is called fuzzy time series on Y(t) (t = …, 0,1,2,…). Further F(t) can be understood as a linguistic variable and f_i(t) (i = 1,2,…) as the possible linguistic values of F(t).

Definition 1. Suppose F(t) is caused by a F(t–1) only or by F(t–1) or (F(t–2)or…or F(t–m) (m > 0). This relation can be expressed as the following fuzzy relational equation:

$$F(t) = F(t-1) \circ R(t, t-1) \qquad (2)$$

or

$$F(t) = (F(t-1) \cup F(t-2) \cup \ldots \cup F(t-m)) \circ R_0 (t, t-m) \qquad (3)$$

The equation is called the first order model of F(t).

Definition 2. Suppose F(t) is caused by a F(t–1), F(t – 2),…, and F(t – m) (m > 0) simultaneously. This relation can be expressed as the following fuzzy relational equation

$$F(t) = (F(t-1) \times F(t-2) \times ... \times F(t-m)) \circ R_a(t, t-m) \quad (4)$$

and is called the m^{th} order model of F(t).

Definition 3: If in (2) or (3) or (4), the fuzzy relation $R(t, t-1)$ or $R_a(t, t-m)$ or $R_a(t, t-m)$ of F(t) is dependent of time t, that is to say for different times t_1 and t_2, $R(t_1, t_1-1) = R(t_2, t_2-1)$, or $R_a(t_1, t_1-m) = R_a(t_2, t_2-m)$ or $R_0(t_1, t_1-m) = R_0(t_2, t_2-m)$, then F(t) is called a time invariant fuzzy time series .Otherwise it is called a time variant fuzzy time series,

In the case of time invariant fuzzy time series ,

$$R(t, t-1) = R,$$
$$Ra(t, t-m) = Ra(m),$$
$$R_0(t, t-m) = R_0(m)$$

In general at different times t_1 and t_2, $R(t_1, t_1-1) \neq R(t_2, t_2-1)$, $R_a(t_1, t_1-m) \neq R_a(t_2, t_2-m)$ and $R_\circ(t_1, t_1-m) \neq R_\circ(t_2, t_2-m)$. There are two reasons for this: first, the universes of discourse on which the fuzzy sets are defined may be different at different times: second the value of F(t) at different times may be different.

Depending upon the complexity of the system, fuzzy time series modeling for a forecast process may use type of relations $R(t, t-1)$, $R_a(t, t-m)$, $R_0(t, t-m)$. Several methods Dubois and Parde[1991], Wu[1986] are available to determine these relations. The commonly used Mamdani [1977] method of determining these relations are as

$$R(t, t-1) = \max_{i,j}\left\{\min(f_i(t-1), f_j(t))\right\}$$

$$R_0(t, t-m) = \max_{p}\left\{\max_{k}\left\{\min_{ik,j}(f_{ik}(t-k), f_j(t))\right\}\right\}$$

$$R_a(t, t-m) = \max_{p}\left\{\min_{j,i1...im}(f_j, f_{i1}(t-1), f_{i2}(t-2), \ldots f_{im}(t-m))\right\}$$

3. METHOD OF FUZZIFICATION

Fuzzy time series model deals with situation where the data are linguistic values, in contrast to the conventional time series approaches that typically manipulate numerical data. If data are available in crisp form, it is to be fuzzified before the fuzzy time series methodology can be applied. Fuzzification process starts with defining the universe of discourse U, which contains the historical data and upon which the fuzzy sets are defined. The study deals with the production of food grains for the Bareilly district(India) in various years starting from 1987-88 to 2001-2002 with assumption that it includes some vagueness incurred due to statistical sampling.

Step 1: Let D_{min} and D_{max} be minimum and maximum production. Based upon D_{min} and $D_{max,}$ we define the universe of the discourse U as $[D_{min}-D_1, D_{max}+D_2]$, where D_1 and D_2 are two proper positive numbers and accordingly, the universe of discourse U = [4000000,1000000]. Further the universe of discourse U is partitioned into six intervals of equal length as follows

u_1 = [400000, 500000],

u_2 = [500000,600000],

u_3 = [600000, 700000],

u_4 = [700000, 800000],

u_5 = [800000, 900000],

u_6 = [900000, 1000000]

Step 2: fuzzy sets $A_1, A_2, A_3, \ldots A_6$ on universe of discourse, having linguistic values as

A_1 = not good,

A_2 = not too good,

A_3 = good,

A_4 = fairly good,

A_5 = very good,

A_6 = excellent,

are to be defined. $u_1, u_2, \ldots u_6$ are chosen as elements of these fuzzy sets. The membership grades of $u_1, u_2, \ldots u_6$ to each A_i (i = 1,2,…6) will decide that how well each u_k (k = 1,2,…6) belong to u_i. We have determined the membership of each element in all the fuzzy sets A_i (i = 1,2,…6) and are expressed as:

$A_1 = \{u_1/1, u_2/.5, u_3/0, u_4/0, u_5/0, u_6/0\}$

$A_2 = \{u_1/.5, u_2/1, u_3/.5, u_4/0, u_5/0, u_6/0\}$

$A_3 = \{u_1/0, u_2/.5, u_3/1, u_4/.5, u_5/0, u_6/0\}$

$A_4 = \{u_1/0, u_2/0, u_3/.5, u_4/1, u_5/.5, u_6/0\}$

$A_5 = \{u_1/0, u_2/0, u_3/0, u_4/.5, u_5/.1, u_6/.5\}$

$A_6 = \{u_1/0, u_2/0, u_3/0, u_4/0, u_5/.5, u_6/1\}$

Where u_i (i = 1,2..6) is the element and the number below '/ ' is the membership of u_i to A_j (j = 1,2,..6)

Step 3: Fuzzify the historical production data to find out the equivalent fuzzy set to each year's production using the step-2. The equivalent fuzzy set to each year's production are shown in table-1.

Table-1

Year	Actual production (MT)	A_1	A_2	A_3	A_4	A_5	A_6	Fuzzified production
1987-88	493622	1	0.5	0	0	0	0	A_1
1988-89	692821	0	0.5	1	0.5	0	0	A_3
1989-90	619327	0	0.5	1	0.5	0	0	A_3
1990-91	690965	0	0.5	1	0.5	0	0	A_3
1991-92	596792	0.5	1	0.5	0	0	0	A_2
1992-93	642295	0	0.5	1	0.5	0	0	A_3
1993-94	718855	0	0	0.5	1	0.5	0	A_4
1994-95	680037	0	0.5	1	0.5	0	0	A_3
1995-96	699796	0	0.5	1	0.5	0	0	A_3
1996-97	808341	0	0	0	0.5	1	0.5	A_5
1997-98	846057	0	0	0	0.5	1	0.5	A_5
1998-99	871368	0	0	0	0.5	1	0.5	A_5
1999-2000	917737	0	0	0	0	0.5	1	A_6
2000-2001	873217	0	0	0	0.5	1	0.5	A_5
2001-2002	870847							

Step 4: Fuzzy logical relationship of the production have been obtained from Table-1, where the fuzzy logical relationship $A_j \to A_k$ means: if the production of year j is A_j then that of year j + 1 is A_k, where A_j is called the current state of production and A_k is called the next state of the production. The fuzzy logical relationship for production are derived as

$A_1 \to A_3$	$A_2 \to A_3$
$A_3 \to A_2$	$A_3 \to A_3$
$A_3 \to A_3$	$A_3 \to A_3$
$A_3 \to A_4$	$A_3 \to A_5$
$A_4 \to A_3$	$A_5 \to A_5$
$A_5 \to A_5$	$A_5 \to A_6$
$A_6 \to A_5$	

Step 5 Based on the Fuzzy logical relationship, we derive the fuzzy logical relationship groups for production, which comes to be

Group-1:	$A_1 \to A_3$
Group-2:	$A_2 \to A_3$
Group-3:	$A_3 \to A_2, A_3, A_3, A_3, A_4, A_5$
Group-4:	$A_4 \to A_3$
Group-5:	$A_5 \to A_5, A_5, A_6$
Gropu-6:	$A_6 \to A_5$

4. METHOD OF FORECAST

Production forecast is carried by following rules:

(1) If the fuzzified production of the year i is A_j, and there is only one fuzzy logical relationship in the fuzzy logical relationship groups as $A_j \to A_k$, where A_j and A_k are fuzzy sets and the maximum membership value of A_k occurs at interval u_k, and the midpoint of u_k is m_k, the forecasted production of year i + 1 is m_k.

(2) If the fuzzified production of the year i is A_j, and there are several fuzzy logical relationships are defined in logical relationship groups such as:

$A_j \to A_{k1}, A_j \to A_{k2}, \ldots . A_j \to A_{kp}$

Where A_j, A_{k1}, A_{k2}, $\ldots A_{kp}$ sre fuzzy sets, and the maximum membership values of A_{k1}, A_{k2}, $\ldots A_{kp}$ occur at intervals u_1, u_2, $\ldots u_p$, respectively and the midpoints of u_1, u_2, $\ldots u_p$ are m_1, $m_2, \ldots m_p$ respectively, the the forecasted production of year i + 1 is $\left(\sum_{x=1}^{P} m_x\right)/p$

(3) If the fuzzified production of a year i is A_j, and no logical relationship is found in logical reationship groups, whose current state of production is A_j, where the maximum membership value of A_j occurs at interval u_j ,and the midpoint of u_j is m_j, then the forecasted production of year i + 1 is m_j.

Based on the above rules, the forecasted values for various years have been calculated are given against the actual production in the Table-2.

Table -2

Year	Actual production (MT)	Forecasted production by implementing Chen's model	Forecasted production by proposed model
1987-88	493622		
1988-89	692821	650000	650000
1989-90	619327	700000	683333
1990-91	690965	700000	683333
1991-92	596792	700000	683333
1992-93	642295	650000	650000
1993-94	718855	700000	683333
1994-95	680037	650000	650000
1995-96	699796	700000	683333
1996-97	808341	700000	683333
1997-98	846057	900000	883333
1998-99	871368	900000	883333
1999-2000	917737	900000	883333
2000-2001	873217	850000	850000
2001-2002	870847	900000	883333

With the above comparison of actual production of food grains of Bareilly district with the forecasted production, one can conclude that the forecasted results are very close to that of actual result. The Computed Mean Square Error(MSE) of the forecast by Chen's model is obtained to be 77952320 where as the MSE of the forecast by proposed method comes out to be 46494072. Base upon the MSE the proposed model forecast is better than Chen's model forecast.

5. Artificial Neural Network

Back Propagation through time is a powerful tool of artificial neural network with application to many areas as pattern recognition, dynamic modeling and nonlinear systems. Back propagation algorithm(BPA) provides an efficient way to calculate the gradient of the error function using chain rule of differentiation. The error after initial computation in the forward pass is propagated backward from the output units, layer by layer. BPA, a generalized Delta rule is commonly used algorithm for supervised training of multi layer feed forward artificial neural network. In supervised learning, we try to adapt an artificial network so that the actual outputs ($\overline{Y}$) come close to some target outputs(Y) for a training set, which contains T patterns. The goal is to adapt the parameters of network so that it performs well for pattern from outside the training set.

5.1 Back Propagation Algorithm

Let the training set be $\{x(k), d(k)\}_{k=1}^{N}$,Where x(k) is the input pattern vector to the network and d(k) is the desired output vector for the input pattern x(k).The output of the j^{th} output unit is denoted by y_j , connections weights from the i^{th} unit in one layer to the j^{th} unit in the layer above are denoted by wij. If m be the no. of output units and dj(k) is the desired output from the j^{th} output unit whose actual output in response to the k^{th} input exempler x(k) is y_j, for j = 1,2,3,……..,m. The sum of squares of the error over all the output unit for this k^{th} exampler by

$$E(k) = (1/2) \sum_{j=1}^{m} [y_j(k) - dj(k)]^2$$

Error E(k) is affected by the output from unit j at the output layer and is determined by

$$\frac{\partial E(k)}{\partial y_j} = yj - dj$$

The net input to output layer is of the form

$$Sj = \sum_i y_i^{(1)} w_{ij} - q_{j}$$

Where $y_i^{(1)}$ is the output from the i^{th} unit in the first layer below the output layer, w_{ij} is connection weight multiplying $y_i^{(1)}$ and θ_j is the threshold of unit j. The negative of threshold is defined to be the bias. Considering the production of course food grains of Bareilly district in different years as input x(k) and production of year to be forecasted as desired output d(k) after applying the BPA, the calculated output is treated as forecast. The steps adapted for calculation of forecasted production i.e. output through BPA is as follows:

Step1: production of year 1987-88 to 1991-92 as input set and production of 1991-92 as desired output.

Step2: production of year 1987-88 to 1996-97 as input set and production of 1996-97 as desired output.

Step3: production of year 1987-88 to 1997-98 as input set and production of 1997-98 as desired output.

Step4: production of year 1987–88 to 1998-99 as input set and production of 1998-99 as desired output.

Step5: production of year 1987-88 to 1999-2000 as input set and production of 1999-2000 as desired output.

Step6: production of year 1987-88 to 2000-01 as input set and production of 2000-01 as desired output.

The algorithm has been implemented through C programming language, considering two hidden layers and computations have been made by various iterations levels like: 100, 200, 500 & 1000. Out of these, the best suitable forecasted values have been obtained by model with 1000 iterations. The results so obtained has been illustrated in Table-3.

Table-3

Year	Input Values	Normalised Input	Desired Output Values	Neural Output Values
1987-88	493622	0.493622		
1988-89	692821	0.692821		
1989-90	619327	0.619327		
1990-91	690965	0.690965		
1991-92	596792	0.596792		
1992-93	642295	0.642295	596792	597075.31
1993-94	718855	0.718855		
1994-95	680037	0.680037		
1995-96	699796	0.699796	680037	680158.50
1996-97	808341	0.808341		
1997-98	846057	0.846057	808341	807260.94
1998-99	871368	0.871368	846057	845271.56
1999-2000	917737	0.917737	871368	870325.75
2000-2001	873217	0.873217	917737	917046.18
2001-2002	870847	0.870847	873217	873094.81

6. Result & Conclusion

The proposed fuzzy time series method has been implemented to have short term forecast for the crop production. Unlike the enrollment of university, the crop production is affected by various parameters. We have considered the indirect relation of various parameters for time series data and presume that their relations are time invariant in view of crop production. The motivation of the study is that the historical crop production data are collected through various sampling techniques involving the vagueness. Further the production forecast has also been obtained through ANN using Back propagation algorithm. To evaluate the performance of forecasting model, average forecasting error was computed. In Chen's fuzzy time series model it comes to 2.554%, where as for proposed fuzzy time series model has 2.447%. However, average forecasting error of Back propagation is 3.96%. It is evident through the study that the fuzzy time series model is even suitable also in the case of numerical values apart from the linguistic values.

Table-4

Year	Actual Producti on	Forecasted by Chen's Fuzzy Time Series Model	Forecasted by Proposed Fuzzy Time Series	Forecaste % d by Artificial Neural Network Model	Error of of Chen's Fuzzy Time Series Model	% Error of Proposed Fuzzy Time of Series Model BPA	% Percenta ge Error Neural Neural Forecast
1992-93	642295	650000	650000	597075.31	1.19	1.19	7.04
1995-96	699796	700000	683333	680158.50	0.072	2.35	2.8
1997-98	846057	900000	883333	807260.94	6.37	4.4	4.5
1998-99	871368	900000	883333	845271.56	3.28	1.37	2.99
1999-00	917737	900000	883333	870325.75	1.93	3.74	5.16
2000-01	873217	850000	850000	917046.18	2.65	2.65	5.01
2001-02	870847	900000	883333	873094.81	2.39	1.43	0.26

The Proposed method of crop production forecast is similar to Chen's method of University enrollment forecast, as it uses simplified arithmetic operations rather than complicated max-min composition presented in [7,8]. In view of considering the weights of various fuzzy logical relationships, it uses the repeated fuzzy logical relations to construct the fuzzy logical relationship groups. It has further supremacy over the Chen's method, as it do not require the knowledge of production for the final target year of forecast. In the study the target year for the forecast was considered to be as year 2001-2002 and hence the actual production of the target year 2001-2002 have neither been used to construct the fuzzy logical relationship nor to construct the fuzzy logical relationship groups. The crop production, forecast computed through the proposed method are quite impressive in terms of error estimate, where the historical production data are not accurate. Further, the computations show that for many years in the data set it is even better than forecast obtained using artificial neural network.

REFERENCES

[1] Za deh L. A., [1965], "Fuzzy Sets, Information & Control", 8, 38-353.

[2] Mamdani, E.E.[1977], "Application of Fuzzy Logic to Approximate Reasoning Using Linguistic Synthesis", IEEE Trans Comput 26, 1182-1191.

[3] Wu W [1986], "Fuzzy Reasoning and Fuzzy Relational Equations", Fuzzy Sets and Systems 20, 67-78.

[4] Werbos Paul J. [1990], "Back Propagation Through Time, What it Does and How to do it", Proceeding of the IEEE, 78,1550-1559.

[5] Duboi, S. D and H Parde [1991], "Fuzzy Sets in Approximate Reasoning Part I", Interface With Possibility Distributions, Fuzzy Sets and Systems 40, 143-202.

[6] Song Q. and Chissom B.[1993], "Fuzzy Time Series and Its Models," Fuzzy Sets and Systems, 54,269-277.

[7] Song Q. and Chissom B.[1993], "Forecasting Enrollments with Fuzzy Time Series"–Part I, Fuzzy Sets and Systems 54,1-9.

[8] Song Q. and Chissom B.[1994], "Forecasting Enrollments with Fuzzy Time Series –Part II", Fuzzy Sets and Systems 64, 1-8.

[9] Joe Sullivan and William H.Woodall[1994], "A Comparison of Fuzzy Forecasting and Markov Modeling", With Fuzzy Sets and Systems 64,279-293.

[10] Shyi-Ming Chen[1996], "Forecasting Enrollments Based on Fuzzy Time Series", Fuzzy Sets and Systems 81,311-319.

[11] Yang CC[1998], "The Use of Back Propagation Neural Network For the Sim", & Analysis of Time Series Data, Transcations of the ASAE, 41,1181-1187

[12] Chen Toli, Mao-Juin J.Wang[1999], Forecasting Methods Using Fuzzy Concepts, Fuzzy Sets and Systems 105, 339-352.