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Fish Production Forecasting in India using Nested Interval Based Fuzzy Time Series Model

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***Abstract:** The livestock and agriculture is like lifeline of Indian villagers and economy. India is ranked first in livestock population and second in fish production. Fish is major part of eating in south and most of eastern part of India and use aquaculture for fish production India s also a major producer of fish through aquaculture, and ranks second in the world. In such condition forecasting of livestock is important in making policies and marketing, planning of products related to livestock and fishes. Fuzzy time series (FTS) is of great importance for such forecasting. But the problem with FTS forecast lies with the accuracy. There are many methods for linguistic values as variables for data of time series, but limitations starts with the error in forecasted and actual value. The present work studies the forecasting of fish production in India rainfall forecasting by FTS using two interval differences is proposed. The presented method is tested on the official data of deptt. of Animal Husbandry, Dairying and Fisheries, Government of India and compared with Chen's models used for university enrollment. The forecasted values shows better result compared to Chen model.*

***Keywords:** Fish production, Fuzzy time series (FTS), Fuzzy logical relations (FLR), Nested difference interval.*

I. INTRODUCTION

When Zadeh [5] introduced the FS theory to deal with having uncertainty and impression, this becomes an amazing tool for many real life problems involving vagueness and impression in the information. Song and Chissom [7], [8], [9] successfully use this idea of having non mathematical variables for FTS model and tested it for University of Alabama's enrollment data. The models given by Song and Chissom [7], [8], [9] became one of the most sought after model for researchers. Chen [10] proposed a model by defining arithmetic operations instead of complicated max-min operators and obtained better results than [7], [9]. Huarng [3], [4] contributed with two models, in one he proposed in heuristic increasing and decreasing relation model which improved the results of forecasting university enrollment and tested on Taiwan Futures Exchange forecasting. In other model [3], [4] presented to choose the effective length of interval which resulting in improving the accuracy of the forecasting values.

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Chen [11] used high order FTS for his model and tested this model on university enrollment forecasting. Singh [12], [13] proposed a third order model with a computational method for FTS forecasting and tested this model on real historical data of

university enrollment with a counter implementation on crop production forecasting. Financial forecasting is another thrilling field for researchers, Bose and Mali [6] presented a data partitioning and rule selection techniques for FTS. Rana

[1] studied on the rice production FTS Forecasting model. Rana [2] worked on time invariant models and presented a comparative study for forecasting crop production using time invariant FTS models and models are compared on the basis of statistical errors. Nested interval differences are differences within one interval. We used nested interval differences in this prediction.

II. MATERIALS AND METHODS

Definition 1. FS A_i is defined as a collection of class of objects with thier grade of membership. Let U represents the Universe of discourse with $U = \{u_1, u_2, u_3 \dots\dots u_n\}$, where u_i are linguistic objects of U then a fuzzy set A_i of U is defined by

$$A_i = \frac{\mu_{A_1}(u_1)}{u_1} + \frac{\mu_{A_2}(u_2)}{u_2} + \frac{\mu_{A_2}(u_2)}{u_2} + \cdots \dots \dots \dots \dots \dots \dots \dots \dots + \frac{\mu_{A_n}(u_n)}{u_n}$$

Where $U = \{u_i; i = 1,2 \dots\}$ is universe and μ_{A_i} is membership function and u_i are word variables.

Definition 2. FS $[f_i(t): i = 1,2, \dots]$ defined on $Y(t)$ and $F(t) = \{f_i\} \; \forall \; i$ then $F(t)$ is called FTS on $Y(t)$.

Definition 3. The equation: $F(t) = F(t-1) o R(t, t-1$ where ' o ' is Max–Min composition operator. Relation R is called Ist order model of $F(t)$ .If again $R(t_1, t_1 - 1) = R(t_2, t_2 - 1)$, for $t_1 \neq, t_2$ then FTS $F(t)$ is called a time invariant.

III. PROPOSED METHODOLOGY

Step I. Define U as $U = [U_{min} - U_1, U_{max} - U_2]$ where U_1 and U_2 are two proper positive numbers.
Step II. Construct equal length sub intervals $u_1, u_2, \dots \dots .. u_m$ from U
Step III. Make FS A_i according to step II subintervals
Step IV. Get FLR after fuzzifying data using "if A_c , A_n is current and next year fuzzify production then the FLR is $A_c \to A_n$ where A_c is called current state and A_n is next state of fuzzified data.
Step V. Using FLR, obtain the fuzzified output.

Step VI. Defuzzify values of step V

ALGORITHM to get forecasted value

$[S_n{}^*]$ is corresponding interval u_n for which A_n has membership= 1

$L[S_n{}^*]$ l.b. of u_n

$U[S_n{}^*]$ u.b. of u_n

$l[S_n{}^*]$ length of u_n

$M[S_n{}^*]$ mid value of u_n

For FLR $A_c \rightarrow A_n$

E_c real data of n^{th} year

E_{c-1} real data of $(n-1)^{th}$ year

E_{c-2} real data of $(n-2)^{th}$ year

F_n forecasted value $(n+1)^{th}$ year

Applying Algorithm for forecasting production of fish in India is as -

Fish production forecasting for $(n+1)^{th}$ year, c = 3 to ...

FLR for k^{th} year to $(k+1)^{th}$ year is $A_c \rightarrow A_n$

Now calculating the nested differences α_c's, β_c's and γ_c's using $\frac{D_c}{4}$, $\frac{3D_c}{4}$ and D_c as

$D_c = \left| |E_c - E_{c-1}| - |E_{c-1} - E_{c-2}| \right|$

$\alpha_c = E_c + \frac{D_c}{4}$, $\alpha'_c = E_c - \frac{D_c}{4}$, $\beta_c = E_c + \frac{3D_c}{4}$, $\beta'_c = E_c - \frac{3D_c}{4}$, $\gamma_c = E_c + D_c$, $\gamma'_c = E_c - D_c$

For using "If Then rule" for nested interval forecasting value F_I, $I = 1\ to\ 6$

If $L[S_n{}^*] \leq \alpha_c \leq U[S_n{}^*]$ then $F_1 = \alpha_c$, $n_1 = 1$, Else $F_1 = 0$, $n_1 = 0$

Next I

If $L[S_n{}^*] \leq \alpha'_c \leq U[S_n{}^*]$ then $F_2 = \alpha'_c$, $n_2 = 1$, Else $F_2 = 0$, $n_2 = 0$

Next I

If $L[S_n{}^*] \leq \beta_c \leq U[S_n{}^*]$ then $F_3 = \beta_c$, $n_3 = 1$, Else $F_3 = 0$, $n_3 = 0$

Next I

If $L[S_n{}^*] \leq \beta'_c \leq U[S_n{}^*]$ then $F_4 = \beta'_c$, $n_4 = 1$, Else $F_4 = 0$, $n_4 = 0$

Next I

If $L[S_n{}^*] \leq \gamma_c \leq U[S_n{}^*]$ then $F_5 = \gamma_c$, $n_5 = 1$, Else $F_5 = 0$, $n_5 = 0$

Next I

If $L[S_n{}^*] \leq \gamma'_c \leq U[S_n{}^*]$ then $F_6 = \gamma'_c$, $n_6 = 1$, Else $F_6 = 0$, $n_6 = 0$

Now $F = \sum_{i=1}^{6} F_i$

If $F = 0$ then $F_n = M[S_n{}^*]$

Else $F_n = (F + M[S_n{}^*])/(n_1 + n_2 + n_3 + n_3 + n_4 + n_5 + n_6 + 1)$

Next k

Application of the proposed method to the fish production data in tones from 1994-95 to 2016-17

Step 1. U = [4777, 8095, 11413]

Step 2. Devide U in equal length of subintervals

$u_1 = [4777, 5330, 5883]$ $u_2 = [5883, 6436, 6989]$

$u_3 = [6989, 7542, 8095]$

$u_4 = [8095, 8598, 9101]$ $u_5 = [9101, 9654, 10207]$

$u_6 = [10207, 10760, 11313]$

Step 3. Defining FS A_i as

A_1 poor production

A_2 average production

A_3 ab. average production

A_4 good production

A_5 excellent production

A_6 bumper production

and the membership grades to these fuzzy sets of linguistic values are defined as

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

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

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

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

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

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

Step 4. FLRs are obtained and are in table 1.

Table 1: Actual and Fuzzified Yield

Year	Actual Yield ('000 Tonnes)	Fuzzified Yield
1994-95	4789	A_1
1995-96	4949	A_1
1996-97	5348	A_1
1997-98	5388	A_1
1998-99	5298	A_1
1999-00	5675	A_1
2000-01	5656	A_1
2001-02	5926	A_2
2002-03	6200	A_2
2003-04	6399	A_2
2004-05	6305	A_2
2005-06	6572	A_2
2006-07	6869	A_2
2007-08	7127	A_3
2008-09	7616	A_3
2009-10	7998	A_3
2010-11	8231	A_4
2011-12	8666	A_4
2012-13	9040	A_4
2013 -14	9579	A_5
2014-15	10335	A_6
2015-16	10795	A_6
2016-17	11410	A_6

Step 5. The forecasted defuzzified fish production is calculated by using the proposed algorithms and put in the table 2.

Step 6. Calculate mean square error (MSE), forecasting error (FE), average FE are as

$$\text{MSE} = \frac{\sum_{i=1}^{n}((\text{actual val.})_i - (\text{fore. val.})_i)^2}{n} \quad (1)$$

$$\text{FE} = \frac{|\text{actual val.} - \text{fore. value}|}{\text{actual val.}} \times 100 \quad (2)$$

$$\text{AFE} = \frac{\text{sum of FE}}{\text{numbers of errors}} \times 100 \quad (3)$$

Table 2: Forecasted Fish Yield ('000 Tonnes)

Year	Actual Yield	Forecasted Yield Present Model	Forecasted Yield Chen Model
1994-95	4789	_	_
1995-96	4949	_	5330
1996-97	5348	_	5330
1997-98	5388	5345	5330
1998-99	5298	5380	5330
1999-00	5675	5303	5330
2000-01	5656	5489	5330
2001-02	5926	6125	6436
2002-03	6200	6179	6436
2003-04	6399	6234	6436
2004-05	6305	6404	6436
2005-06	6572	6324	6436
2006-07	6869	6509	6436
2007-08	7127	7265	7542
2008-09	7616	7205	7542
2009-10	7998	7606	7542
2010-11	8231	8352	8598
2011-12	8666	8317	8598
2012-13	9040	8656	8598
2013-14	9579	9378	9654
2014-15	10335	10760	10760
2015-16	10795	10497	10760
2016-17	11410	10790	10760
MSE	_	76642.39	97642.35
% FE	_		
AFE	_	2.830331	3.570238

Figure 1 shows the year wise comparison between actual fish Yield and forecasted fish Yield by proposed and Chen's models.

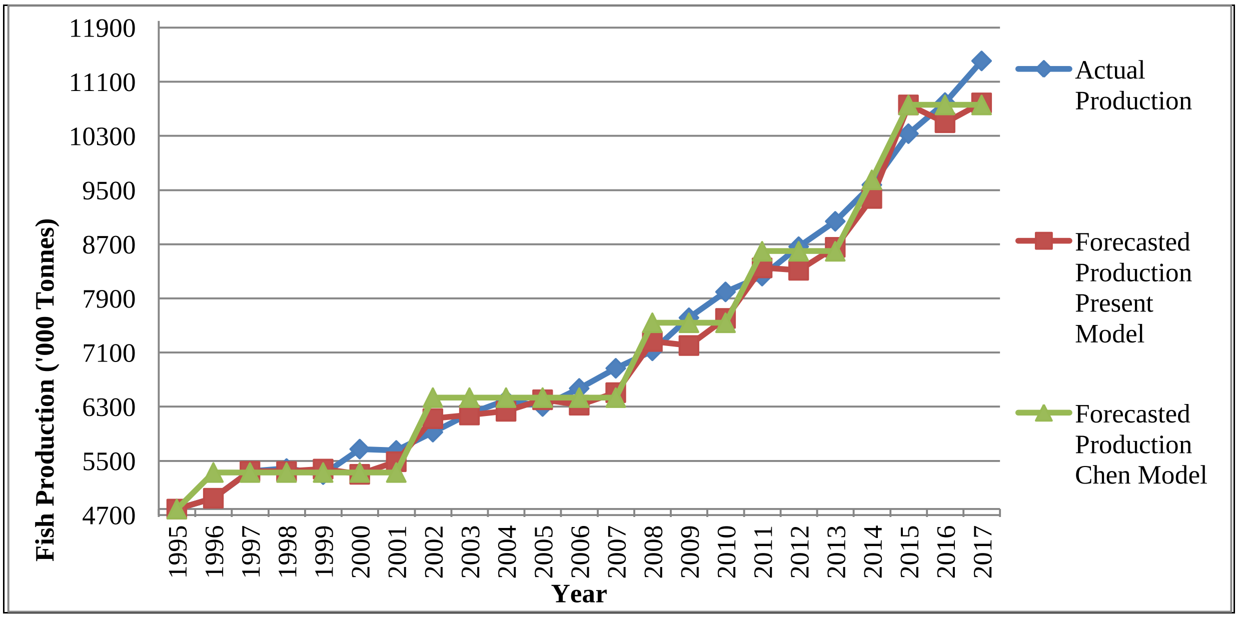

Figure 1. Comparison of forecasted and actual fish production

IV. CONCLUSION

In the proposed work forecast is done using nested differences in an interval which reduces the error in forecasting values significantly. This procedure also simplifies the computational work for the fish production forecasting. For the countries like India depending heavily on agriculture and livestock it will be of great importance to get the information in advance to give an idea regarding production which will improve the management and policies of future planning.

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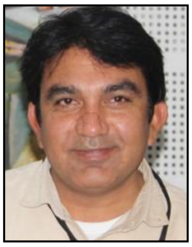

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