A Higher Order Fuzzy Logic Model with Genetic Algorithm Used to Predict the Rice Production in India

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Abstract: ***Forecasting paddy production is considered as a difficult problem in the real world due to in deterministic behavior of the nature. Specifically, rice production is forecasted for a leading year for overall planning of the crop, utilization of the agricultural resources and the rice production management. Likewise, the key challenge of the forecasting rice production is to create a realistic model that can able to handle the critical time series data and forecast with minor error. Prognostication of the Future data is highly correlated with the time series data set. If the accuracy of your prediction is more appropriate, then the value of the forecast will improve as well. This paper represents a new technique depends on Higher Order Fuzzy Logical Relationship. Here, Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) are used to estimate the errors of predicted data. historical data relating to the rice production of 1981 to 2003 is used as secondary data and the error of the predicted data is further reduced using different soft computing technique.***

Keywords: ***Fuzzy logical relationships, MSE, RMSE and Average Error.***

I. INTRODUCTION

Time series forecasting is a crucial topic which deals with the various aspects of the future decision-making process in our everyday life. By set theory and linguistic variable presented by Zadeh [2, 3], Song and Chissom [1] developed the fuzzy time series concept. This is proficient of dealing with vague and imprecise data illustrated in terms of linguistic variables. Song and Chissom [4, 5] furthermore elongated this fuzzy time series theory to make it more efficient to deal with numerical data by adding the idea of fuzzification and defuzzification and applied it in the student enrollment forecasting program of Alabama university. Chen [6] analyzed the problem of large mathematical requirement of the Song and Chissom technique of calculating fuzzy relationships of max-min composition by replacing it with more simple arithmetic functions and applied this technique on the student enrollments of Alabama university. Different techniques of time series forecasting have been re-presented by Tsai and Wu [7], Huarng [8], Sullivan and Woodall [9]. Kim and Lee [10] developed a fuzzy time series prognosticating technique on the basis of sequential values. Fuzzy time series forecasting is also structured as the time variant model by employing high-order techniques in fuzzy time series forecasting. Larger mathematical need is the main problem Song and Chissom [5] technique. To forecast the enrollments of upcoming years, the required numbers of past year's the enrollments data were called the window basis The main purpose of this recent research work is to build a mathematical prediction model depends on the high-order (order 4) fuzzy logical relationship to reduce the average forecasting error of the existing fuzzy time series forecasting method and increases the accuracy of prediction value in agricultural production to help and support the farmers, producers or decision makers. The new approach is applied on the time series data of rice yield of Pantnagar farm G. B. Pant University of Agriculture and Technology, Pantnagar (INDIA). Rice crop production data has been enlisted with respect to quintal per hectare. This study comprises of a computational model construction and examining it on the rice yield production to verify its feasibility in forecasting over the other predictive techniques.

II. BASICS OF FUZZY TIME SERIES

Some fundamental concepts of the fuzzy time series models are summarized and is reproduced as [1,4,5].

Definition 2.1 A fuzzy set is a collection of entities with a continuation of grade of membership. Let 'W' be the Universe of discourse with W={ w_1, w_2, w_3, …w_n }, where W_i are viable semantic values of W, then a fuzzy set of semantic variables X_i of W is explained by $X_i = \mu X_i(w_1)/(w_1) + \mu X_i(w_2)/(w_2) + \mu X_i(w_3)/(w_3) + \ldots\ldots + \mu X_i(w_n)/(w_n)$ here, μX_i is the membership function of the fuzzy set X_i , such that $\mu X_i : W \rightarrow [0,1]$. If w_j is the member of X_i, then $\mu X_i(w_j)$ is the degree of belonging of w_j to X_i (2).

II. I Prediction of Computational Procedures of Rice Yield Production

The execution of the given algorithm has been divided into four models: Chen's arithmetic model (model-1), refined arithmetic model (model-2), Rajaram's modified approach model (model-3) and a combined approach of Rajaram's and Chen's arithmetic model (model-4) for foretelling the rice production on the basis of time series data 1981 to 2003.

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Process 1: The universe of discourse 'W' as [A_{min} - A_1, A_{max} + A_2] to accommodate the time series data, where A_{min} and A_{max} are the minimum and maximum historical production respectively. From table 1, we get A_{min} = 3219 and A_{max} = 4554. The variables A_1 and A_2 are just two positive numbers, properly chosen by the user. If we let A_1 = 3219-19 = 3200 and A_2 = 4554 + 46 = 4600, we get W = [3200-4600]. **Process 2:** Partition the universes of discourse into seven equal length intervals W_1, W_2, ,……..,W_7 and each partition shows the range. W_1 = [3200-3400], W_2 = [3400-3600], W_3 = [3600-3800], W_4 = [3800-4000], W_5 = [4000-4200], W_6 = [4200-4400], W_7 = [4400-4600].

Process 3: Define seven fuzzy sets X_1, X_2.......... X_7 having some semantic values on the universe of discourse W. The semantic values to these fuzzy variables are as follows:

X_1: poor rice production	X_4: good rice production	X_7: outstanding rice production
X_2: below avg rice production	X_5: very good rice production	
X_3: avg rice production	X_6: excellent rice production	

The membership grades to these fuzzy sets of linguistic variables are defined as -

$$X_1= 1/w_1 + 0.5/w_2 + 0/w_3 + 0/w_4 + 0/w_5 + 0/w_6 + 0/w_7$$
$$X_2= 0.5/w_1 + 1/w_2 + 0.5/w_3 + 0/w_4 + 0/w_5 + 0/w_6 + 0/w_7$$
$$X_3= 0/w_1 + 0.5/w_2 + 1/w_3 + 0.5/w_4 + 0/w_5 + 0/w_6 + 0/w_7$$
$$X_4= 0/w_1 + 0/w_2 + 0.5/w_3 + 1/w_4 + 0.5/w_5 + 0/w_6 + 0/w_7$$
$$X_5= 0/w_1 + 0/w_2 + 0/w_3 + 0.5/w_4 + 1/w_5 + 0.5/w_6 + 0/w_7$$
$$X_6= 0/w_1 + 0/w_2 + 0/w_3 + 0/w_4 + 0.5/w_5 + 1/w_6 + 0.5/w_7$$
$$X_7= 0/w_1 + 0/w_2 + 0/w_3 + 0/w_4 + 0/w_5 + 0.5/w_6 + 1/w_7$$

Process 4: Here, fuzzification helps to identify the relationships between the previous values in the dataset and define the fuzzy sets in the previous steps. Every previous value is fuzzified as stated by its highest degree of membership. If the highest degree of familiarity of a certain past time variable, says F(t-1), happens at fuzzy set X_k, then F (t-1) is fuzzified as X_k. In table 2, a general survey of fuzzification of the previous rice production data of different fuzzy time series models are shown. To give examples of this, year 1984 is fuzzified in model-1 and model-4. As table 1, rice yield of 1984 was 3455 (000' tones) which lies within the boundaries of interval W_2. Since the highest membership degree of W_2 occurs at X_2, the past time variable F (1984) is fuzzified as X_2. The previous time series data [13] are fuzzified and are placed in table 1.

II. II The Actual and Fuzzified Data of Rice Production in Table. 1

Year	Production Kg/ hect	Fuzzified production	Fuzzified Rang	Mid-point
1981	3552	X2	3400 – 3600	3500
1982	4177	X5	4000 – 4200	4100
1983	3372	X1	3200 – 3400	3300
1984	3455	X2	3400 – 3600	3500
1985	3702	X3	3600 – 3800	3700
1986	3670	X3	3600 – 3800	3700
1987	3865	X4	3800 – 4000	3900
1988	3592	X2	3400 – 3600	3500
1989	3222	X1	3200 – 3400	3300
1990	3750	X3	3600 – 3800	3700
1991	3851	X4	3800 – 4000	3900
1992	3231	X1	3200 – 3400	3300
1993	4170	X5	4000 – 4200	4100
1994	4554	X7	4400 – 4600	4500
1995	3872	X4	3800 – 4000	3900
1996	4439	X7	4400 – 4600	4500
1997	4266	X6	4200 – 4400	4300
1998	3219	X1	3200 – 3400	3300
1999	4305	X6	4200 – 4400	4300
2000	3928	X4	3800 – 4000	3900
2001	3978	X4	3800 – 4000	3900
2002	3870	X4	3800 – 4000	3900
2003	3727	X3	3600 – 3800	3700

II. III Higher Order Arrangement with Fuzzy Logical Relationship in Table. 2

1st order	2nd order	3rd order	4th order
X2→X5			
X5→X1	X2, X5→X1		
X1→X2	X5, X1→X2	X2, X5, X1→X2	
X2→X3	X1, X2→X3	X5, X1, X2→X3	X2, X5, X1, X2 → X3
X3→X3	X2, X3→X3	X1, X2, X3→X3	X5, X1, X2, X3 → X3
X3→X4	X3, X3→X4	X2, X3, X3→X4	X1, X2, X3, X3 → X4
X4→X2	X3, X4→X2	X3, X3, X4→X2	X2, X3, X3, X4 → X2
X2→X1	X4, X2→X1	X3, X4, X2→X1	X3, X3, X4, X2 → X1
X1→X3	X2, X1→X3	X4, X2, X1→X3	X3, X4, X2, X1 → X3
X3→X4	X1, X3→X4	X2, X1, X3→X4	X4, X2, X1, X3 → X4
X4→X1	X3, X4→X1	X1, X3, X4→X1	X2, X1, X3, X4 → X1
X1→X5	X4, X1→X5	X3, X4, X1→X5	X1, X3, X4, X1 → X5
X5→X7	X1, X5→X7	X4, X1, X5→X7	X3, X4, X1, X5 → X7
X7→X4	X5, X7→X4	X1, X5, X7→X4	X4, X1, X5, X7 → X4
X4→X7	X7, X4→X7	X5, X7, X4→X7	X1, X5, X7, X4 → X7
X7→X6	X4, X7→X6	X7, X4, X7→X6	X5, X7, X4, X7 → X6
X6→X1	X7, X6→X1	X4, X7, X6→X1	X7, X4, X7, X6 → X1
X1→X6	X6, X1→X6	X7, X6, X1→X6	X4, X7, X6, X1 → X6
X6→X4	X1, X6→X4	X6, X1, X6→X4	X7, X6, X1, X6 → X4
X4→X4	X6, X4→X4	X1, X6, X4→X4	X6, X1, X6, X4 → X4
X4→X4	X4, X4→X4	X6, X4, X4→X4	X1, X6, X4, X4 → X4
X4→X3	X4, X4→X3	X4, X4, X4→X3	X6, X4, X4, X4 → X3

II. IV Fuzzy Logical Relationship without Repetition in Table. 3

X2→ X5	X3 → X3	X1 → X3	X7 → X4	X1 → X6
X5 → X1	X3 → X4	X4 → X1	X4 → X7	X6 → X4
X1 → X2	X4 → X2	X1 → X5	X7 → X6	X4 → X4
X2 → X3	X2 → X1	X5 → X7	X6 → X1	X4 → X3

II. V Fuzzy Relationship Group in Table. 4

X1 → X2, X3, X5, X6	X5 → X1, X7
X2 → X1, X3, X5	X6 → X1, X4
X3 → X3, X4	X7 → X4, X6
X4 → X1, X2, X3, X4, X7	

Process 5: Prediction Value = The Value of fuzzy order (X_i)-X_{ij} where $X_j \rightarrow X_i$. The table above gives the relational Matrix of X_i and X_j.

II. VI The Available Data are Fuzzified Based on Gaussian Function Given in Table. 5

Actual value	X1	X2	X3	X4	X5	X6	X7
3552	0.24	1	0	0	0	0	0
4177	0	0	0	0.115	1	0.885	0
3372	1	0.86	0	0	0	0	0
3455	0.725	1	0.275	0	0	0	0
3702	0	0.49	1	0.51	0	0	0
3670	0	0.65	1	0.35	0	0	0
3865	0	0	0.675	1	0.325	0	0
3592	0.04	1	0.96	0	0	0	0
3222	1	0.89	0	0	0	0	0
3750	0	0.25	1	0.75	0	0	0
3851	0	0	0.745	1	0.255	0	0
3231	1	0.845	0	0	0	0	0
4170	0	0	0	0.15	1	0.85	0
4554	0	0	0	0	0	0.23	1
3872	0	0	0.64	1	0.36	0	0
4439	0	0	0	0	0	0.805	1
4266	0	0	0	0	0.67	1	0.33
3219	1	0.905	0	0	0	0	0
4305	0	0	0	0	0.475	1	0.525
3928	0	0	0.36	1	0.64	0	0
3978	0	0	0.11	1	0.89	0	0
3870	0	0	0.65	1	0.35	0	0
3727	0	0.365	1	0.635	0	0	0

III. BASICS OF GENETIC ALGORITHM

Genetic Algorithm (GA) is a procedure for solving both constrained and unconstrained optimized problems which is based on natural selection. This Process is driven from Biological Evolution. At each step, the genetic algorithm randomly selects individuals from the current population (parents) and uses them to produce children of the next generation.

The three basic rules of GA are –

1. ***Selection*** - Select process is more important about the next generation, it's totally depends on parents, which contribute to the population at the next generation.
2. ***Crossover*** – Randomly selects the pair of the best solution (*parents' chromosome)* and then interchanges to form a next generation.
3. ***Mutation*** – Depends on bit-wise probabilistic changing methods like 0 to 1 and vice versa.

Here, the Genetic Algorithm has been used to predict rice production data in India based on Fuzzy Logic Model. This rice production data set is a secondary data set. First, we predict data using first order fuzzification. Then the prediction accuracy is improved using Genetic Algorithm. Commonly, GA uses binary alphabet (0, 1) as notation. Hence, the data have to convert into binary form and that is called chromosomes. When the decimal to binary conversion happens, we manage the equality of bit for each data set. Chromosomes are represented into the decision variable domain. It helps to assess the performance, or fitness, of individual members of a population (9, 10).

In selection procedure, we have applied Roulette Wheel method. A fixed point is chosen on the wheel circumference and the wheel is rotated. The region of the wheel which comes in front of the fixed point is chosen as parent. For the second parent, the same process is repeated. It is clear that a fitter individual has a greater pie on the wheel and therefore a greater chance of landing in front of the fixed point when the wheel is rotated. Therefore, the probability of choosing an individual depends directly on its fitness.

In Crossover Method, after reproduction simple cross over may proceed in the steps. First, members of the newly reproduced strings in the mating pool are mated at random. Second, each pair of strings undergoes crossing over as follows: an integer with position k along the string is selected uniformly at random between 1 and string length less than one [1, l-1]. Two new strings are created by swapping all characters between positions k+1 and l inclusively. For example, two strings S_1 and S_2 are considered. Initial position, S_1=0110101, S_2=1100001. The resulting cross over yields two new string where the prime means the strings are part of new generations:

S_1 = 0 1 1 0 0 0 1

S_2 = 1 1 0 0 1 0 1

Mutation is a process of changing of the bit from 0 to 1 and vice versa with a small mutation probability p_m. The bitwise mutation is performed as bit by bit by flipping a coin with the probability of p_m.

Fitness Function: The fitness function must not only correlate closely with the designer's goal it must also be computed quickly. A fitness function is a particular type of objective function that is used to summarize, as a single figure of merit, how close a given design solution is to achieving the set aims. In this paper Mean Absolute Percentage Error (MAPE) is used as fitness function. The general equation of MAPE is as follow:

MAPE = 1/n ∑ [(│Actual Value – Forecasted Value│) / Actual Value] * 100.

Where n is number of fitted point of data set.

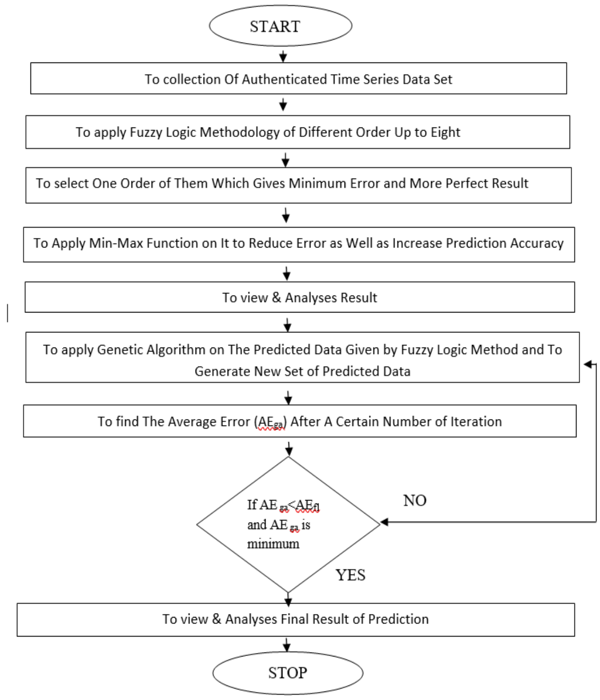
IV. ERROR CALCULATION TECHNIQUE

Accuracy of prediction error calculated in the basis of mean square error (MSE), root mean square error and average error.

1. Mean Square Error (MSE) = ∑ni=1(Actual Value(i) – Forecast Value(i))2 /n
2. Average Forecasting error = ∑ni=1[mod (Ei-Fi) / Ei] / n
   Where Ei =Actual value and Fi = forecast value
3. Residual Analysis –
   Absolute Residual = mod [Actual value – Forecast value]
   Mean Absolute Residual = mod [Actual value – Forecast value]/Actual value.

V. PROPOSED MODEL

In this paper, the prediction model is developed based on the fuzzy logic with genetic algorithm. Below flow chart shows a hybrid model to give minimum error for actual data to prediction data.



VI. RESULT AND DISCUSSION

In this paper we have to use soft computing technique like fuzzy logic as an order wise. Fuzzified productions are selected as the midpoint from the universes of discourse depends on fuzzy logic of different order. The result then further fuzzified based on Gaussian function and produced ultimate result in the purposed model shown as table 6. Fourth ordered fuzzy logic gives optimized result and minimum error. Result accuracy of each order is better as compare to the using normal method of fuzzified.

Table 6. Actual data and higher order predicted data

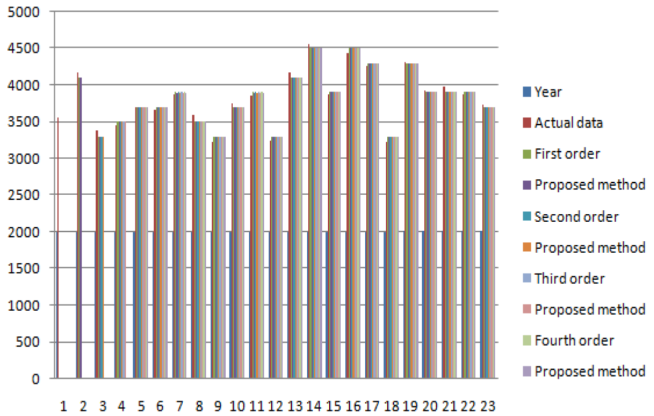
Year	Actual data	First order	Proposed method	Second order	Proposed method	Third order	Proposed method	Fourth order	Proposed method
1981	3552								
1982	4177	4100	4100						
1983	3372	3300	3300	3300	3300				
1984	3455	3500	3499.27	3500	3499.27	3500	3499.27		
1985	3702	3700	3699.51	3700	3699.51	3700	3699.51	3700	3699.51
1986	3670	3700	3699	3700	3699	3700	3699	3700	3699
1987	3865	3900	3899.32	3900	3899.32	3900	3899.32	3900	3899.32
1988	3592	3500	3500	3500	3500	3500	3500	3500	3500
1989	3222	3300	3299.11	3300	3299.11	3300	3299.11	3300	3299.11
1990	3750	3700	3700	3700	3700	3700	3700	3700	3700
1991	3851	3900	3899.25	3900	3899.25	3900	3899.25	3900	3899.25
1992	3231	3300	3300	3300	3300	3300	3300	3300	3300
1993	4170	4100	4100	4100	4100	4100	4100	4100	4100
1994	4554	4500	4500	4500	4500	4500	4500	4500	4500
1995	3872	3900	3900	3900	3900	3900	3900	3900	3900
1996	4439	4500	4500	4500	4500	4500	4500	4500	4500
1997	4266	4300	4299.67	4300	4299.67	4300	4299.67	4300	4299.67
1998	3219	3300	3300	3300	3300	3300	3300	3300	3300
1999	4305	4300	4300	4300	4300	4300	4300	4300	4300
2000	3928	3900	3900	3900	3900	3900	3900	3900	3900
2001	3978	3900	3901	3900	3901	3900	3901	3900	3901
2002	3870	3900	3901	3900	3901	3900	3901	3900	3901
2003	3727	3700	3699.36	3700	3699.36	3700	3699.36	3700	3699.36

We have to show that performance of accuracy at different order and proposed methods in the table below. Accuracy of predictions is calculated by using mean square error, root mean square error and average error.

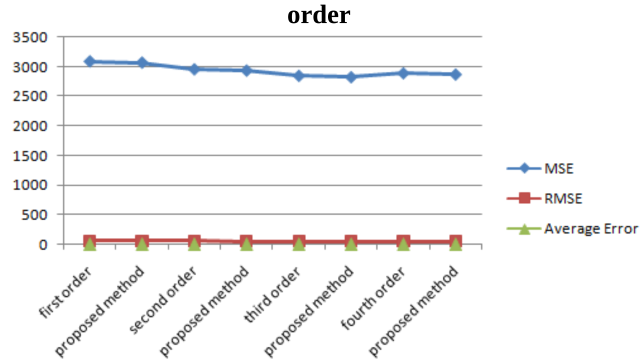
Error calculation	1st order	Proposed method	2nd order	Proposed method	3rd order	Proposed method	4th order	Proposed method
MSE	3092.59	3071.60	2957.524	2935.55	2846.2	2823.127	2889.42	2868.52
RMSE	55.61	55.42	54.383	54.180	53.349	53.133	53.74	53.55
Average Error	0.0133	0.01329	0.01309	0.01305	0.01268	0.01263	0.01242	0.0129

Error calculation techniques are used in table 7.

The rice productions juxtaposition of different fuzzy order, actual data, and proposed method are shown in graph 1. And graph 2. Shows the performance of accuracy and error calculation.



Graph 1. Accuracy of prediction is shows in different order



Graph 2. Performance of error calculation

Further, we have to implementing with Genetic Algorithm and compare to the proposed Gaussian method in fuzzy logic prediction data and get the better accuracy of prediction. Table 8,9 show the prediction data and error comparing with fuzzy data.

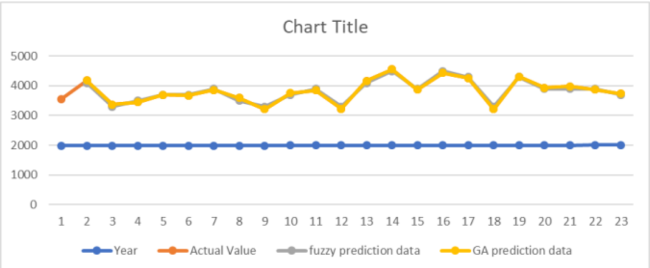
Table 8. Actual Data to Predicted Data Using Fuzzy Logic with Genetic Algorithm

Year	Actual Data	First Order Fuzzy Logic Data	Proposed First order Data	Genetic Algorithm
1981	3552			
1982	4177	4100	4100	4177.9
1983	3372	3300	3300	3372.8
1984	3455	3500	3499.27	3454.5
1985	3702	3700	3699.51	3702.1
1986	3670	3700	3699	3672.8
1987	3865	3900	3899.32	3864.8
1988	3592	3500	3500	3592.5
1989	3222	3300	3299.11	3222.2
1990	3750	3700	3700	3750.7
1991	3851	3900	3899.25	3852
1992	3231	3300	3300	3228.1
1993	4170	4100	4100	4170.7
1994	4554	4500	4500	4554.6
1995	3872	3900	3900	3873.1
1996	4439	4500	4500	4439.9
1997	4266	4300	4299.67	4266.1
1998	3219	3300	3300	3220.7
1999	4305	4300	4300	4306.8
2000	3928	3900	3900	3927.5
2001	3978	3900	3901	3978.3
2002	3870	3900	3901	3871.7
2003	3727	3700	3699.36	3727

Table 9. Accuracy of Prediction Error Comparison

Error Calculation	MSE	RMSE	Average Error
First Order Fuzzy Logic	3092.59	55.61	0.0133
Modified Fuzzy Data	3071.60	55.42	0.01329
Genetic Algorithm	32.02	5.658	0.00502

In the above table we have to show the only first order fuzzy logic with genetic algorithm comparison and get more accurate. In graph 3, show the accuracy of prediction. I have to applied same procedure in all the higher order and genetic algorithm always gives better accuracy.



Graph. 3 Accuracy of Prediction

VII. CONCLUSION AND FUTURE SCOPE

In this study, time series data of rice production from 1981 to 2003 is used for prediction. Soft computing techniques like higher order Fuzzy logic are used to predict the simple and modified data set by using Gaussian function. Proposed methods are given more accurate prediction data for higher order compare to the general methods are used and I have also shown the individually accuracy of error using error calculation techniques in table 7. Further, we have to apply in genetic algorithm and get accuracy of prediction is more accurate as compare to the proposed fuzzy logic. Predicted data and error calculation shows in table 8, 9. In future, we will use different soft computing technique may give better prediction accuracy at the same data set and also applying for different data set of crops and weather-related data.

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