International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:2, No:2, 2008

Roll of Membership functions in Fuzzy Logic for Prediction of Shoot Length of Mustard Plant Based on Residual Analysis

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Abstract**—**The selection for plantation of a particular type of mustard plant depending on its productivity (pod yield) at the stage of maturity. The growth of mustard plant dependent on some parameters of that plant, these are shoot length, number of leaves, number of roots and roots length etc. As the plant is growing, some leaves may be fall down and some new leaves may come, so it can not gives the idea to develop the relationship with the seeds weight at mature stage of that plant. It is not possible to find the number of roots and root length of mustard plant at growing stage that will be harmful of this plant as roots goes deeper to deeper inside the land. Only the value of shoot length which increases in course of time can be measured at different time instances. Weather parameters are maximum and minimum humidity, rain fall, maximum and minimum temperature may effect the growth of the plant. The parameters of pollution, water, soil, distance and crop management may be dominant factors of growth of plant and its productivity. Considering all parameters, the growth of the plant is very uncertain, fuzzy environment can be considered for the prediction of shoot length at maturity of the plant. Fuzzification plays a greater role for fuzzification of data, which is based on certain membership functions. Here an effort has been made to fuzzify the original data based on gaussian function, triangular function, s-function, Trapezoidal and L –function. After that all fuzzified data are defuzzified to get normal form. Finally the error analysis (calculation of forecasting error and average error) indicates the membership function appropriate for fuzzification of data and use to predict the shoot length at maturity. The result is also verified using residual (Absolute Residual, Maximum of Absolute Residual, Mean Absolute Residual, Mean of Mean Absolute Residual, Median of Absolute Residual and Standard Deviation) analysis.

Keywords**—**Fuzzification, defuzzification, gaussian function, triangular function, trapezoidal function,s-function, , membership function, residual analysis.

I. Introduction

THE selection for plantation of a particular type of mustard plant depending on its productivity (pod yield) at the stage of maturity. The problem is this type of plants is produce pod yields after 90/95 days. By observing, the growth of initial stage of plant , it is very difficult to ascertain the amount of pod yields of a mustard plant at maturity. The growth of mustard plant dependent on some parameters of that plant, these are shoot length, number of leaves, number of roots and roots length etc. As the plant is growing, some leaves may be fall down and some new leaves may come, so it can not gives the idea to develop the relationship with the seeds weight at mature stage of that plant. It is not possible to find the number of roots and root length of mustard plant at growing stage that will be harmful of this plant as roots goes deeper to deeper inside the land. Only the value of shoot length which increases in course of time can be measured at different time instances. There are certain weather parameters that may effect the growth of the plant. These parameters are maximum and minimum humidity, rain fall, maximum and minimum temperature ([28]-[30]). The growth of the plant may be affected by the application of magnetic field. The parameters of pollution, water, soil, distance and crop management may be dominant factors of growth of plant and its productivity. Considering all parameters, the growth of the plant is very uncertain, fuzzy environment can be considered for the prediction of shoot length at maturity of the plant. Fuzzification plays a greater role for fuzzification of data, which is based on certain membership functions. Here an effort has been made to fuzzify the original data based on gaussian function, triangular function, s-function, Trapezoidal and L –function. After that all fuzzified data are defuzzified to get normal form. Finally the error analysis (calculation of forecasting error and average error)indicates the membership function appropriate for fuzzification of data and use to predict the shoot length at maturity. The result is also verified using residual (Absolute Residual, Maximum of Absolute Residual, Mean Absolute Residual, Mean of Mean Absolute Residual, Median of Absolute Residual and Standard Deviation) analysis.

In order to handle the fuzzy data, it is necessary to convert the actual data into fuzzy data based on certain membership functions. Here the three membership functions e.g. trapezoidal, gaussian triangular, S-shapped and L-shapped functions are used. Now it is necessary to find out which of these membership functions is suitable for this shoot length data.

[3] explained the definition of fuzzy time series and discussed the models using Fuzzy Relational equations. [1] used a time invariant fuzzy time series model. [2] made a

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comparative study of Fuzzy Forecasting and Markov Model and suggested that Markov Model would give better prospects. They illustrated the methodology by forecasting the enrollment at the University of Alambama from 20 years of data. [4] applied fuzzy logic and approximate reasoning to a practical case of forecasting.

[5] used first order time variant models and utilized 3 layer back propagation neural network for defuzzification. G. A. [6] demonstrated that artificial neural networks could achieve high computation rates by employing massive number of simple processing elements of high degree of connectivity between the elements. This paper presented a systematic approach to design neural networks for optimizing applications. [7] described that a time series model of multiplicative SARIMA(seasonal autoregressive integrated moving average) type suffered from a divergent error level in the multistep ahead forecast of all the specific features of the different days of the week. The authors proposed that the data had to be grouped into various subgroups known as Walsch transform, the components of which were then processed by fading memory Kalman filter algorithm and forecasts were made by taking the inverse transform of the predicted value of the component. F. G. Donaldson and M. Kamstra[8] investigated the use of artificial neural network(ANN) to combine time series forecasts of stock market volatility from USA, Canada, Japan and UK. The authors presented combining procedures to a particular class of nonlinear combining procedure based on artificial neural network. J. V. Hansen and R. D. Nelson[9] presented the neural network techniques which provided valuable insights for forecasting tax revenues. The pattern finding ability of neural networks gave insightful and alternate views of the seasonal and cyclical components found in economic time series data. It was found that neural networks were stronger than exponential smoothing and ARIMA(autoregressive integrated moving average).[10] proposed that artificial neural networks were powerful tool for analyzing data sets where there were complicated nonlinear interactions between the measured inputs and the quantity to be predicted. [11] proposed successive identification method of a fuzzy model. The structure and initial parameters were determined to identify a model called 'initial model', which was identified by the off-line fuzzy modeling method using some pairs of input-output data. [12] proposed a method of classification of weather forecasts by applying fuzzy grade statistics. The rainfall in a certain region could be forecasted as one of three grades. The range of rainfall was chosen depending on the historical data. The membership functions of the fuzzy sets were also designed. [13] described the model of fuzzy self-regression. The main steps were the making of the form of self-related sequence number according to the observed number, the calculation of self-related coefficient and the ascertaining of the forecasting model of fuzzy self-regression. [14] presented various methods of learning and the process of predicting time series analysis, which were ranged from traditional time series analysis to recent approaches using neural networks. It described that back propagation learning had a difficulty in interpreting hidden inputs. In order to solve these problems, a structural learning method was proposed which was based on an information criterion.

A Rule Base was constructed for a Personnel Selection System using Fuzzy Expert methodology [17]. A comparison was made among the fuzzy time series and markov model [18] for the purpose of manpower prediction and it was found that fuzzy time series method was more preferable than markov model.

[19] proposed a novel methodology called genetic programming which they considered as a variant of genetic algorithms(GAs) and that evolved on a dynamic length tree representation the basis of fitness function. The methodology presented was to provide assistance to the attendant indicating that plant's behavior, which was drifting away from normal operation with the strategy to minimize error and optimize the operation.

[20] presented a novel genetically trained neural network(NN) predictor trained historical data. Substantial improvement in prediction accuracy by the neuro-genetic approach had been demonstrated as compared to a regression-tree-based conventional approach and back propagation neural network(NN) approach.

[21] proposed an efficient evolutionary search algorithm, which could exploit the enhanced searching capability of parallel genetic algorithms. The performance of this algorithm with and without migration of chromosomes had been studied. In GAs(Genetic Algorithms), all chromosomes were performing similar operations. This made GAs(Genetic Algorithms) parallelizable relatively easily. There were advantages in parallel GAs(Genetic Algorithms): when several GAs(genetic algorithms) were run on multiple processors simultaneously, higher speed up might result; after some period of evolution, the majority of chromosomes in a single population became very similar. Depending on the parallelism, the level of interactions, pGAs(parallel Genetic Algorithms) might be classified into two groups: (1) Fine-grain pGAs(parallel Genetic Algorithms): Numerous small populations evolved parallelly, with large amount of interaction among them. The next generation was evolved by first replacing each individual by an individual selected from its neighborhood on the grid. Then the crossover of each individual was performed with a mate randomly selected from its neighborhood with a certain probability. (2) Coarse-grain pGAs(parallel Genetic Algorithms): Here small number of relatively large populations was evolved parallelly with little amount of interaction among them.

[22] proposed a new technology for efficient obstacle avoidance and path planning of a mobile robot by exploiting the techniques of neural network(Hopefield network) and genetic algorithms.

A lot of research work has been carried out in the field of forecasting([1] - [5], [7] - [9], [11] - [14]), out of these certain work has been done using fuzzy logic ([1] - [5], [11] - [13]). Research work using neural networks has been done([6], [8] - [10], [14]). Work in the field of genetic algorithm has been carried on ([16], [18], [23]).

In the field of fuzzy logic, the fuzzification plays a greater role. A few research work has been carried out in forecasting the growth of mustard plant ([25],[27] - [30]). The work related to the selection of membership function used for fuzzification has not been done in agriculture field so far, that is the reason for making this effort in this paper.

A Statistical survey has been conducted by a group of certain agricultural personnel on different mustard plant under the supervision of Prof. Dilip dey, Bidhan Chandra Krishi Viswavidayalay West Bengal, India. The data for shoot length of the initial stage(growing stage) of the plant are also available, which are measured at different time instances(after an interval of 7 days, 14 days, 21 days, 28 days). The ultimate aim is to select a suitable membership in fuzzy model which gives minimum error and estimated which plant is growing as per desire standard . These plant must be protected other wise it is to be destroyed. In this paper the models of fuzzy time series with different membership function have been tested on a particular type mustard plant and based on error analysis (calculation of average error) that membership function with minimum error is selected and that will be the suitable membership function to estimated the growth of mustard plant. Finally, the result is also verified using residual (Absolute Residual, Maximum of Absolute Residual, Mean Absolute Residual, Mean of Mean Absolute Residual, Median of Absolute Residual and Standard Deviation) analysis.

II. Methodology

A. Fuzzy Systems

The characteristic function of a crisp set assigns a value of either 1 or 0 to each individual in the universal set, thereby discriminating members and nonmembers of the crisp set under consideration. This function can be generalized such that the value assigned to the elements of the universal set fall within a specific range and indicate the membership grade of these elements in the set in question. Larger values denote higher degrees of set membership. Such a function is called a membership function and the set defined by it a fuzzy set.

The range of values of membership functions is the unit interval [0, 1]. Here each membership function maps elements of a given universal set X, which is always a crisp set, into real numbers in [0, 1].

The membership function of a fuzzy set A is defined by A, A : X ------> [0, 1].

B. Fuzzy Time Series

Let Y(t) (t = ..., 0, 1, 2, ...) , a subset of R' , be the universe discourse on which fuzzy sets f_i (t) (i = 1, 2, ...) are defined and F(t) is a collection of f_1 (t) , f_2 (t), ... Then F(t) is called a Fuzzy Time Series defined on Y(t) (t = ..., 0, 1, 2, ...)

C. Functions for Fuzzification

A **Gaussian** membership function is defined by

$$G(u{:}m,\sigma)=\exp[-\{(u-m)/\sqrt{2}\sigma\}^2]$$

Where the parameters m and σ control the center and width of the membership function. A plot of the Gaussian membership function is presented if Fig. 1.

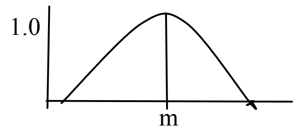

Fig. 1 One typical form of the Gaussian function

The **Triangular** membership function with straight lines can formally be defined as follows:

$$\Lambda(u{:}\alpha,\beta,\gamma)=0 \quad u<\alpha$$
$$= (u-\alpha)/(\beta-\alpha) \quad \alpha<=u<=\beta$$
$$=(\alpha - u)/(\beta-\alpha) \quad \beta<=u<=\gamma$$
$$=0 \quad u>\gamma$$

One typical plot of the triangular membership function is given in Fig. 2.

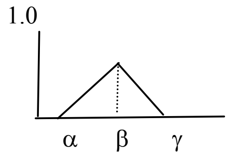

Fig. 2 One typical form of the Triangular membership function

Trapezoidal Function Furnished in Fig. 3.

f(x, a, b, c, d) = 0 when x < a and x > d
(x - a) / (b - a) when a <= x <= b
1 when b <= x <= c
(d - x) / (d - c) when c <= x <= d

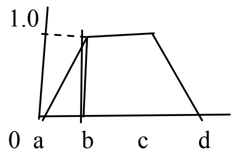

Fig. 3 One typical form of the trapezoidal membership function

S-shaped built-in membership function s-shaped built-in membership function

$$S(u{:}\alpha,\beta,\gamma)=0 \quad u<\alpha$$
$$=2[(u-\alpha)/(\gamma-\alpha)]^2 \quad \alpha<u<=\beta$$
$$=1-2[(u-\gamma)/(\gamma-\alpha)]^2 \quad \beta<u<=\gamma$$
$$=1 \quad u>\gamma$$

One typical form of the S-function is presented below

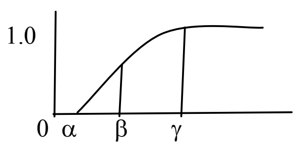

Fig. 4 One typical form of the S-shapped membership function

This function is the converse of the typical γ -function. It can be mathematically expressed by

$$L(u{:}\alpha,\beta)=1 \quad u<\alpha$$
$$= (\alpha-u)/(\beta-\alpha) \quad \alpha<=u<=\beta$$
$$= 0 \quad u>\beta$$

One typical form of the L-function is presented in below

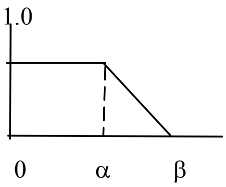

Fig. 5 One typical form of the L-shaped membership function

The generalized **Bell** function depends on three parameters a, b, and c as given by

$f(x;a,b,c)=1/(1+((x-c)/a)^{2b}$

where the parameter b is usually positive. The parameter c locates the center of the curve.

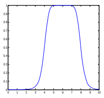

Fig. 6 One typical form of the Bell membership function

B. *Forecasting Error and Average Forecasting Error*

The forecasted error and average forecasting error are calculated using the formula :-

Forecasting error = |(forecasted value - actual value)| / (actual value) * 100 %

Average forecasting error = (sum of forecasting errors) / (total no of errors).

E. Residual Analysis

Absolute Residual = |(Estimated Value – Actual Value)|
Maximum Residual = Maximum(Absolute Residual)
Mean Absolute Residual =|(Estimated Value – Actual Value)| /Actual Value
Mean of Mean Absolute Residual = (Mean of Absolute Residual)/N
Median Absolute Residual = Middle Value of Absolute Residual
Standard Deviation (SD) $=\sqrt{(^n\sum_{i=1} (X_i - X_{mean})/(N-1)}$

III. IMPLEMENTATION

Step 1. The universe U is partitioned into five equal length(10) intervals. The intervals are chosen as u_1 = [10, 20], u_2 = [21, 30], u_3 = [31, 40], u_4 = [41, 50],u_5 = [51, 60], u_6=[61,70]

Step 2.The available data are fuzzified based on gaussian function which is furnished in Table I given below :-

TABLE I
ACTUAL SHOOT LENGTH AND FUZZY SET

Actual Shoot Length	A1	A2	A3	A4	A 5	A 6	Fuzzy Set
19	1.0	0.9	0.0	0.0	0.0	0.0	A1
24	0.6	1.0	0.4	0.0	0.0	0.0	A2
28	0.2	1.0	0.8	0.0	0.0	0.0	A2
33	0.0	0.7	1.0	0.3	0.0	0.0	A3
37	0.0	0.3	1.0	0.7	0.0	0.0	A3
41	0.0	0.0	0.9	1.0	0.1	0.0	A4
45	0.0	0.0	0.5	1.0	0.5	0.0	A4
49	0.0	0.0	0.1	1.0	0.9	0.0	A4
54	0.0	0.0	0.0	0.6	1.0	0.4	A5
57	0.0	0.0	0.0	0.3	1.0	0.7	A5
59	0.0	0.0	0.0	0.1	1.0	0.9	A5
63	0.0	0.0	0.0	0.0	0.7	1.0	A6
66	0.0	0.0	0.0	0.0	0.4	1.0	A6

Step 3.The historical knowledge from Table I about the evolution of the shoot length is obtained to set up the forecasting model. The available data are transformed into linguistic values.

Using the symbols of Song and Chissom [3] , all the fuzzy logical relationships from Table I are obtained as follows :-

TABLE II
FUZZY LOGICAL RELATIONSHIPS

A1 ----->A2 A2 ----->A2 A2 ----->A3 A3 ----->A3
A3 ----->A4 A4 ----->A4 A4 ----->A5 A5 ----->A5
A5 ----->A6 A6 ----->A6

It is to note that the repeated relationships are counted for only once.

Step 4.By definition a time-invariant fuzzy time series has been developed([1], [3], [5]).

Let us define an operator ' X ' of two vectors. Suppose C and B are row vectors of dimension m and $D = (d_{ij}) = C^T$ X B . Then the element d_{ij} of matrix D at row i and column j is defined as $d_{ij} = \min (C_i, B_j)$ (i, j = 1, ..., m) where C_i and B_j are the i-th and the j-th element of C and B respectively.

Let $R_1 = A_1^T$ X A_2, $R_2 = A_2^T$ X A_2, $R_3 = A_2^T$ X A_3, $R_4 = A_3^T$ X A_3, $R_5 = A_3^T$ X A_4, $R_6 = A_4^T$ X A_4, $R_7 = A_4^T$ X A_5, $R_8 = A_5^T$ X A_5, $R_9 = A_5^T$ X A_6, $R_{10} = A_6^T$ X A_6. Now a relation matrix R has been formed as $R(t, t - 1) = R = \cup R_i$ (3) where U is the union operator.

The value of R as follows:-

0.6	1.0	0.6	0.2	0.0	0.0
0.6	1.0	1.0	0.7	0.1	0.0
0.2	0.7	1.0	1.0	0.5	0.1
0.0	0.3	0.7	1.0	1.0	0.6
0.0	0.0	0.1	0.6	1.0	1.0
0.0	0.0	0.0	0.3	0.7	1.0

Using R, the forecasting model is $A_i = A_{i-1} . R$ where A_{i-1} is the shoot length of reading i - 1 and A_i is the forecasted shoot length of reading i and ' . ' is the max - min operator.

Step 5.:The forecasted output is interpreted which are all fuzzy sets. Now it has been translated into a regular number(defuzzification). The predicted values for the shoot length are furnished in Table III.

TABLE III
OUTPUT FUZZY VALUE AND ESTIMATED VALUE

Actual Shoot Length	Output Fuzzy Value	Estimated Value
19	-	-
24	[0.6 1.0 0.9 0.7 0.1 0.0]	25
28	[0.6 1.0 1.0 0.7 0.4 0.1]	30
33	[0.6 1.0 1.0 0.7 0.4 0.1]	30
37	[0.6 0.7 1.0 1.0 0.5 0.3]	40
41	[0.3 0.7 1.0 1.0 0.7 0.6]	40
45	[0.2 0.7 0.9 1.0 1.0 0.6]	50
49	[0.2 0.5 0.7 1.0 1.0 0.6]	50
54	[0.1 0.3 0.7 1.0 1.0 0.9]	50
57	[0.0 0.3 0.6 0.6 1.0 1.0]	60
59	[0.0 0.3 0.3 0.6 1.0 1.0]	60
63	[0.0 0.1 0.1 0.6 1.0 1.0]	60
66	[0.0 0.0 0.1 0.6 0.7 1.0]	65
	[0.0 0.0 0.0 0.4 0.7 1.0]	65

Step 6.Finally the forecasted error and average forecasting error are calculated and furnished in Table IV.

TABLE IV
ESTIMATED DATA AND ERROR BASED ON FUZZY TIME SERIES USING GAUSSIAN FUNCTION

Actual Value	Estimated Value	Error (%)
19	-	-
24	25	41.6
28	30	7.14
33	30	9.09
37	40	8.10
41	40	2.44
45	50	11.11
49	50	2.04
54	50	7.41
57	60	5.26
59	60	1.69
63	60	4.7
66	65	1.5
	65	

Average Error 4.73 %

The same effort has been applied using bell shaped, s-shaped, L shaped, trapezoidal, triangular membership functions. The results are as follows:-

TABLE V
ESTIMATED DATA AND ERROR BASED ON FUZZY TIME SERIES USING BELL SHAPED MEMBER FUNCTION

Actual Value	Estimated Value	Estimated Error(%)
19	-	-
24	29	20.83
28	30	7.14
33	30	9.09
37	40	8.10
41	40	2.43
45	41	8.88
49	50	2.04
54	59	9.25
57	60	5.26
59	60	1.69
63	60	4.76
66	65	1.51
	65	

Average Error 6.23%

TABLE VI
ESTIMATED DATA AND ERROR BASED ON FUZZY TIME SERIES USING S-SHAPE MEMBER FUNCTION

Actual Value	Estimated Value	Estimated error (%)
19	-	-
24	25	4.16
28	30	7.14
33	30	9.09
37	36	2.70
41	40	2.43
45	45	0
49	50	2.04
54	50	7.40
57	57	0
59	60	1.69
63	60	4.761
66	65	1.51
	65	

Average Error 3.30%

TABLE VII
ESTIMATED DATA AND ERROR BASED ON FUZZY TIME SERIES USING L-SHAPE MEMBER FUNCTION

Actual Value	Estimated Value	Estimated Error(%)
19	-	-
24	29	20.83
28	30	7.14
33	34	3.03
37	40	8.10
41	44	7.31
45	50	11.11
49	50	2.04
54	55	1.85
57	57	0
59	57	3.38
63	57	9.52
66	61	7.57
	65	

Average Error 6.30%

TABLE VII
ESTIMATED DATA AND ERROR USING TRIANGULAR MEMBERSHIP FUNCTION

Actual Value	Estimated Value	Estimated Error (%)
19	-	-
24	29	20.83
28	33	17.85
33	34	3.03
37	40	8.10
41	44	7.31
45	44	2.22
49	49	0
54	57	5.55
57	57	0
59	57	3.38
63	57	9.52
66	61	7.57
	65	

Average Error 6.57%

TABLE IX
ESTIMATED DATA AND ERROR BASED ON FUZZY TIME SERIES USING TRAPEZOIDAL MEMBER FUNCTION

Actual Value	Estimated Value	Estimated Error(%)
19	-	-
24	29	20.83
28	30	7.14
33	30	9.09
37	35	5.40
41	35	14.63
45	40	11.11
49	40	18.36
54	40	25.92
57	55	3.50
59	55	6.77
63	60	4.76
66	65	1.51
	65	
Average Error		9.92%

IV. RESULT

It is found that the average error for S-shape function gives the minimum error. Therefore the S-shape function has to be used for fuzzification for this data set. The output forecasted data based on S-shape function can be used for the estimate the shoot length of mustard plant. This result can also be verified using Residual Analysis furnished Table X.

TABLE X
RESIDUAL ANALYSIS (RA)

Membership Function	AR	Max AR	Mean of AR	Mean of Mean AR	Median of AR	SD
Gaussian	2.33	5.0	0.054	0.004	5.0	13.54
Bell-Shaped	2.67	5.0	0.06	0.005	4	13.55
S-Shaped	1.50	4.0	0.035	0.002	0.0	13.55
L-shaped	2.83	6.0	0.068	0.0056	5.0	11.35
Triangulated	2.83	6.0	0.071	0.0059	1.0	11.10
Trapezoidal	4.66	14.0	0.1075	0.0089	5.0	12.61

AR= Absolute Residual
SD=Standard Deviation

V. CONCLUSION AND FUTURE SCOPE

In normal statistical method, prediction is based on available data. If certain error may exist in the actual data, that error data will enter into the model and as a result the prediction will not be accurate. The fuzzification plays a major role in handling the data in fuzzy environment. The fuzzification is based on certain membership function. The selection of a particular membership function depends on the nature of data value to be used. If the selected membership function is not proper, the input fuzzy data is wrong and as a result the output fuzzy data (the data outputted from a mathematical model) will also be wrong and the defuzzified output data will be improper and error will be very high. Thus caution has to be needed for the selection of membership function. In future, the artificial neural network (ANN) base on the fuzzy input and Genetic Algorithm can be used to estimate error and based on the minimum error any of them can be selected to predict the shoot length of mustard plant.

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