Modified Fuzzy Forecasting Approach for Student Enrollment Series

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Abstract

Student enrollment forecasting provides significant information for management in decision making and planning for the institutions of higher education. Nowadays, a modified fuzzy method is used among many other existing methods proposed for forecasting enrollment based on fuzzy time series. Because, the forecasting accuracy rates of the existing methods are not adequate enough. In this paper, a modified fuzzy method is used to forecast enrollment based on fuzzy time series on the enrollment data of Philosophy Department in Jahangirnagar University, Bangladesh. The proposed method yields a higher forecasting accuracy rate and suggests a good choice of forecasting method for effective and efficient management for the institutions of higher education.

1. Introduction

For efficient and effective management, forecasting is considered as a critical tool for strategic as well as tactical decision making [3]. In developed countries, educational institutions use different statistical models to project the number of students to enroll in a certain course or year level [6]. Enrollment forecasting is related to analyzing current trends, understanding the significant impact on the enrollment and revenue outcomes [14]. Predicting the number of students is thus important for estimating the distributed budget into academic institution. It may contribute in formulating strategic and action plan and may be used as information for adopting long term policy [2, 6 & 14].

Classical time series requires many assumptions such as the normality of data, linearity in the auto-correlation coefficient, and statistical parameter estimators. It is almost impossible to find all these assumptions applicable in stochastic time series generation or simulation. But linguistic uncertainties by the fuzzy sets have opened a wide spectrum of applications in diverse fields [17]. Fuzzy application areas include estimation, prediction, control, approximate reasoning, intelligent system design, machine learning, image processing, machine vision, pattern reorganization, medical computing, civil, chemical

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and industrial engineering [13]. This paper, therefore, is an endeavor to forecast student enrollment by the application of Fuzzy model at the Department of Philosophy in Jahangirnagar University, Bangladesh.

2. Literature Review

It is evident that forecasting activities play an important role in decision making. The classical time series methods cannot deal with forecasting problems in which the values of time series are linguistic terms represented by fuzzy sets [16]. Therefore, in their paper, Song and Chissom [8] describe the theory of fuzzy time series methodology to get an advantage over the classical time series. Song et al. present some forecasting methods [11, 8, 9, 10] to forecast the enrollment of the University of Alabama based on the linguistic variable approach called fuzzy approach. Chen [1] also proposes his method based on fuzzy time series to forecast the enrollments of the University of Alabama. He introduces his method and shows its advantage of reducing the calculation time and simplifying the calculation process. In another paper Chen [4] *et al.*, use the differences of the enrollment to present a method to forecast the enrollment of the University of Alabama. In [2], Huang extends Chen's work presented in [1] and uses simplified calculations with the addition of heuristic rules to forecast the enrollments. Later in [14], Chen presents a method based on high-order fuzzy time series for forecasting the enrollment of the University of Alabama. In [8] and [9], Song *et al.*, use the following model for forecasting university enrollment:

$$Ai = Ai - 1 \circ R, \tag{1}$$

Where, $Ai - 1$ denotes the fuzzified enrollments of year $i - 1$ represented by a fuzzy set, Ai denotes the fuzzified enrollments of year i represented by a fuzzy set, the symbol $\circ$ denotes the Max-Min composition operator, and R is a fuzzy relation formed by the fuzzified enrollment of the fuzzy time series.

In [12], Sullivan *et al.*, review the first-order time-variant fuzzy time series model and the first-order time-invariant fuzzy time series model presented by Song and Chissom, where their models are compared with each other and with a time-variant Markov model using linguistic labels with probability distributions. However, the forecasting accuracy rates of the existing fuzzy time series methods for forecasting enrollments are not good enough.

In this study, we present a new method to forecast the enrollments of the students at Philosophy Department in Jahangirnagar University, Bangladesh. The proposed method belongs to the first order time-variant methods. The rest of this paper is organized as follows. In methodology section we briefly review basic concepts of fuzzy time series from [7], [8] and [9]. Also, we describe a step by step procedure of proposed fuzzy time series method to forecast our enrollment data. In result section, we present our forecasting results of the proposed method. Finally, we made a conclusion based on our results.

3. Methodology

3.1. Fundamental Concepts of Fuzzy Time Series

In this section, we briefly review some concepts of fuzzy time series from [14, 2]. The main difference between the fuzzy time series and conventional time series is that the values of the former are fuzzy sets [4] while the values of the latter are real numbers. Roughly speaking, a fuzzy set is a class with fuzzy boundaries. Let U be the universe of discourse, $U = [u_1, u_2,..., u_n,]$. A fuzzy set A of u is defined by

$$A = f_A(u_1)/u_1 + f_A(u_2)/u_2 + ... + f_A(u_n)/u_n, \tag{2}$$

Where f_A is the membership function of A, $f_A: U \rightarrow [0, 1]$, and $f_A(u_i)$ indicates the grade of membership of u_i in A, where $f_A(u_i) \in [0, 1]$ and $1 \leq i \leq n$. The definitions of fuzzy time series are reviewed as follows.

Definition 3.1.1 Let $Y(t)$ $(t = ..., 0, 1, 2 ,...)$, a subset of **R**, be the universe of discourse on which fuzzy sets $f_t(t)$ $(i = 1,2,...)$ are defined and let $F(t)$ be a collection $f_t(t)$ $(i = 1, 2,...)$. Then, $F(t)$ is called a fuzzy time series on $Y(t)$ $(t =...,0,1,2,...)$.

From Definition 3.1, we see that $F(t)$ can be regarded as a linguistic variable [5] and $f_t(t)$ $(i = 1,2,...)$ can be viewed as possible linguistic values of $F(t)$, where $f_t(t)$ $(i = 1, 2,...)$ are represented by fuzzy sets. We also can see that $F(t)$ is a function of time t, i.e., the values of $F(t)$ can be different at different times due to the fact that the universe of discourse can be different at different times. According to [14], if $F(t)$ is caused by $F(t-1)$ only, then this relationship is represented by:

$F(t-1) \rightarrow F(t)$.

Definition 3.1.2. Let $F(t)$ be a fuzzy time series. If for any time t, $F(t) = F(t-1)$ and $F(t)$ only has finite elements, then $F(t)$ is called a time-invariant fuzzy time series. Otherwise, it is called a time-variant fuzzy time series.

In [2], Song and Chissom have used the following two examples to explain the concepts of fuzzy time series using eq. (1) and they observe the weather of a certain place in North America, begin from the first day and ending with the last day of a year, where the common daily words (i.e., "good", "very good", "quite good", "very very good", "cool", "very cool", "quite cool", "hot", "very hot", "cold", "very cold", "quite cold", "very very cold", ..., etc.) are used to describe the weather conditions and these words are represented by fuzzy sets.(2) Observe the mood of a person with normal mental conditions during a period of time, where the mood of a person can be expressed according to his own feeling using fuzzy sets "good", "very good", "very very good", "really good", "bad", "not bad", "not too bad", ..., etc. In [2], Song and Chissom also pointed out that the above two examples are dynamic processes and their observations are fuzzy sets; the conventional time series models are no longer applicable to describe these processes.

3.2. Application of the New Method for Forecasting Enrollment using Fuzzy Time Series

In this section, we apply the new method to forecast the enrollments based on fuzzy time series. This new proposed method defines the universe of discourse and partitions-into some even and equal length intervals. Then, the chronological enrollment data in each interval are redivided and distributed statistically. After that, the linguistic values represented by fuzzy sets based on the re-divided intervals are redefined and to get the fuzzified enrollment the chronological enrollment are fuzzified. Then, fuzzy logical relationships based on the fuzzified enrollment are established. Finally, to determine the trend of the forecasting, where it goes up or down, a set of rules is used. This method is applied step by step as follows:

Step 1: We define the universe of discourse U and partition it into several even and equal length intervals u1, u2, ..., and un. Then assume that the universe of discourse U = [40, 90] is partitioned into five even and equal length intervals u1, u2, u3, u4, and u5, where u1 = [40, 50], u2 = [50, 60], u3 = [60, 70], u4 = [70, 80], and u5 = [80, 90].

Step 2: After getting a statistics of the distribution of the chronological enrollments in each interval we sort the intervals based on the number of chronological enrollment data in each interval from the highest to the lowest. Find the interval having the largest number of historical enrollment data and divide it into four sub-intervals of equal length. Find the interval having the second largest number of historical enrollment data and divide it into three sub-intervals of equal length. Find the interval having the third largest number of historical enrollment data and divide it into two sub-intervals of equal length. Find the interval with the fourth largest number of historical enrollment data and let the length of this interval remain unchanged. If there are no data distributed in an interval, then discard this interval. For example, the distributions of the historical enrollment data in Table 1 is divided into different intervals which is are summarized in Table 2.

Table 1. Year Wise Student Enrollment Data

Year	Enrollments
2001	42
2002	68
2003	55
2004	64
2005	63
2006	68
2007	65
2008	72
2009	78
2010	76
2011	75
2012	84
2013	77
2014	78

Table 2. Distribution of Enrollment Data

Intervals	[40-50]	[50-60]	[60-70]	[70-80]	[80-90]
Number of enrollment data	1	1	5	6	1

After executing this step, the universe of discourse [40, 90] is re-divided into the following intervals:

u1=[40-50]	u2=[50-60]
u3,1 =[60-63.3]	u3,2=[63.3-66.6]
u3,3=[66.6-70]	u4,1=[70-72.5]
u4,2=[72.5-75]	u4,3=[75-77.5]
u4,4=[77.5-80]	u5=[80-90]

Step 3: Defining each fuzzy set A_i based on the re-divided intervals and fuzzify the historical enrollments shown in Table 1, where fuzzy set A_i denotes a linguistic value of the enrollments represented by a fuzzy set, and $1 \leq i \leq 10$. For example, A1 = very very very few, A2 = very very few, A3 = very few, A4 = few, A5 =

moderate, A6 ＝ many, A7 ＝ many many, A8 ＝ very many, A9 ＝ too many, A10 ＝ too many many, defined as follows [13]:

A1 = 1/u1 + 0.5/u2 + 0/u3,1 + 0/u3,2 + 0/u3,3 + 0/u4,1 + 0/u4,2 + 0/u4,3 + 0/u4,4 + 0/u5,

A2 = 0.5/u1 + 1/u2 + 0.5/u3,1 + 0/u3,2 + 0/u3,3 + 0/u4,1 + 0/u4,2 + 0/u4,3 + 0/u4,4 + 0/u5,

A3 = 0/u1 + 0.5/u2 + 1/u3,1 + 0.5/u3,2 + 0/u3,3 + 0/u4,1 + 0/u4,2 + 0/u4,3 + 0/u4,4 + 0/u5,

A4 = 0/u1 + 0/u2 + 0.5/u3,1 + 1/u3,2 + 0.5/u3,3 + 0/u4,1 + 0/u4,2 + 0/u4,3 + 0/u4,4 + 0/u5,

A5 = 0/u1 + 0/u2 + 0.5/u3,1 + 1/u3,2 + 0.5/u3,3 + 0/u4,1 + 0/u4,2 + 0/u4,3 + 0/u4,4 + 0/u5,

A6 = 0/u1 + 0/u2 + 0/u3,1 + 0.5/u3,2 + 1/u3,3 + 0.5/u4,1 + 0/u4,2 + 0/u4,3 + 0/u4,4 + 0/u5,

A7 = 0/u1 + 0/u2 + 0/u3,1 + 0/u3,2 + 0.5/u3,3 + 1/u4,1 + 0.5/u4,2 + 0/u4,3 + 0/u4,4 + 0/u5,

A8 = 0/u1 + 0/u2 + 0/u3,1 + 0/u3,2 + 0/u3,3 + 0.5/u4,1 + 1/u4,2 + 0.5/u4,3 + 0/u4,4 + 0/u5,

A9 = 0/u1 + 0/u2 + 0/u3,1 + 0/u3,2 + 0/u3,3 + 0/u4,1 + 0.5/u4,2 + 1/u4,3 + 0.5/u4,4 + 0/u5,

A10 = 0/u1 + 0/u2 + 0/u3,1 + 0/u3,2 + 0/u3,3 + 0/u4,1 + 0/u4,2 + 0.5/u4,3 + 1/u4,4 + 0.5/u5,

For simplicity, the membership values of fuzzy set Ai either are 0, 0.5 or 1, where $1 \leq i \leq 10$. Then, fuzzify the historical enrollments shown in Table 1 based on [15] and the linguistic values of the enrollments A1, A2, …, A10. The reason for fuzzifying the historical enrollments into fuzzified enrollments is to translate crisp values into fuzzy sets to get a fuzzy time series.

Step 4: Establishing fuzzy logical relationships based on the fuzzified enrollment: where the fuzzy logical relationship " $Aj \rightarrow Aq$" denotes " if the fuzzified enrollments of year n-1 is Aj, then the fuzzified enrollments of year n is Aq". For example, based on the fuzzify historical enrollments obtained in Step 3, we can get the fuzzy logical relationships as shown in Table 3.

Table 3. Fuzzy Logical Relationships

A1->A5	A5->A2	A2->A4	A4->A3	A3->A5
A5->A4	A4->A6	A6->A9	A9->A8	A8->A7
A7->A10	A10->A8	A8->A9		

Step 5: Dividing each interval derived in Step 2 into four subintervals of equal length, where the 0.25-point and 0.75-point of each interval are used as the upward and downward forecasting points of the forecasting. Use the following rules to determine whether the trend of the forecasting goes up or down and to forecast the

enrollment. Assume that the fuzzy logical relationship is Ai → Aj, where Ai denotes the fuzzified enrollment of year n-1 and Aj denotes the fuzzified enrollment of year n, then (1) If j > i and the difference of the differences of the enrollments between years n-1 and n-2 and between years n-2 and n-3 is positive, then the trend of the forecasting will go up, and we use the following **Rule 2** to forecast the enrollments; (2) If j > i and the difference of the differences of the enrollments between years n-1 and n-2 and between years n-2 and n-3 is negative, then the trend of the forecasting will go down, and we use the following **Rule 3** to forecast the enrollments; (3) If j < i and the difference of the differences of the enrollments between years n-1 and n-2 and between years n-2 and n-3 is positive, then the trend of the forecasting will go up, and we use the following **Rule 2** to forecast the enrollments; (4) If j < i and the difference of the differences of the enrollments between years n-1 and n-2 and between years n-2 and n-3 is negative, then the trend of the forecasting will go down, and we use the following **Rule 3** to forecast the enrollments; (5) If j = i and the difference of the differences of the enrollments between years n-1 and n-2 and between years n-2 and n-3 is positive, then the trend of the forecasting will go up, and we use the following **Rule 2** to forecast the enrollments; (6) If j = i and the difference of the differences of the enrollments between years n-1 and n-2 and between years n-2 and n-3 is negative, then the trend of the forecasting will go down, and we use the following **Rule 3** to forecast the enrollments, where **Rule 1**, **Rule 2** and **Rule 3** are shown as follows: **Rule 1:** When forecasting the enrollment of year 2003, there are no data before the enrollments of year 2001, therefore we are not able to calculate the difference of the enrollments between years 2001 and 2000 and the difference of the differences between years 2002 and 2001 and between years 2001 and 2000. Therefore, if |(the difference of the enrollments between years 2002 and 2001)|/2 > half of the length of the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1, then the trend of the forecasting of this interval will be upward, and the forecasting enrollment falls at the 0.75-point of this interval; if |(the difference of the enrollments between years 2002 and 2001)|/2 = half of the length of the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1, then the forecasting enrollmentfalls at the middle value of this interval; if |(the difference of the enrollments between years 2002 and 2001)|/2 < half of the length of the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1, then the trend of the forecasting of this interval will be downward, and the forecasting enrollment falls at the 0.25-point of the interval. **Rule 2:** If (|the difference of the differences between years n-1 and n-2 and between years n-2 and n-3| × 2 + the enrollments of year n-1) or (the enrollments of year n-1 - |the difference of the differences between years n-1 and n-2 and between years n-2 and n-3| × 2) falls in the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1, then the trend of the forecasting of this interval will be upward, and the forecasting enrollment falls at the 0.75-point of the interval of the corresponding fuzzified enrollment Aj with the membership value equal to 1; if (|the difference of the differences between years n-1 and n-2 and between years n-2 and n-3|/2 + the enrollments of year n-1) or (the enrollments of year n-1 - |the difference of the differences between years n-1 and n-2 and between years n-2 and n-3|/2) falls in the interval of the corresponding fuzzified enrollment Aj with the membership value equal to 1, then the trend of the forecasting of this interval will be downward, and the forecasting value falls at the 0.25-point of the interval of the corresponding fuzzified enrollment Aj with the membership value equal to 1; if neither is the case, then we let the forecasting enrollment be the middle value of the

interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1.

Rule 3: If (|the difference of the differences between years n-1 and n-2 and between years n-2 and n-3|/2 + the enrollments of year n-1) or (the enrollments of year n-1 - |the difference of the differences between years n-1 and n-2 and between years n-2 and n-3|/2) falls in the interval of the corresponding fuzzified enrollment Aj with the membership value equal to 1, then the trend of the forecasting of this interval will be downward, and the forecasting enrollment falls at the 0.25-point of the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1; if (|the difference of the differences between years n-1 and n-2 and between years n-2 and n-3| × 2 + the enrollment of year n-1) or (the enrollment of year n-1 - |the difference of the differences between years n-1 and n-2 and between years n-2 and n-3| × 2) falls in the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1, then the trend of the forecasting of this interval will be upward, and the forecasting enrollment falls at the 0.75-point of the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1; if neither is the case, then we let the forecasting enrollment be the middle value of the interval corresponding to the fuzzified enrollment Aj with the membership value equal to 1.

4. Results of Proposed Forecasting Method

We have implemented the proposed method. Table 4 summarizes the forecasting results of the proposed method from 2002 to 2014, where the universe of discourse is divided into 10 intervals and the interval with the largest number of historical enrollment data is divided into 4 sub-intervals of equal length.

Table 4. Actual and Forecasted Enrollment

Year	Actual Enrollment	Fuzzy Enrollment	Forecasted Enrollment
2001	42	A1	
2002	68	A5	68.3
2003	55	A2	59.975
2004	64	A4	64.95
2005	63	A3	66.45
2006	68	A5	86.3
2007	65	A4	59.975
2008	72	A6	66.45
2009	78	A9	78.75
2010	76	A8	76.25
2011	75	A7	76.25
2012	84	A10	85
2013	77	A8	76.25
2014	78	A9	76.25

We use the mean square error (MSE) to measure the performance of the forecasting methods, where the mean square error is calculated as follows: sum of the squared differences between actual enrollments for year *i*, and forecasted enrollments of year *i*, divided by the total number of observations used in calculation. From Table 4, we calculate the forecasting results of the proposed method with that of the actual data. A graphical representation in Fig.1 also indicates the performance of the proposed method clearly.
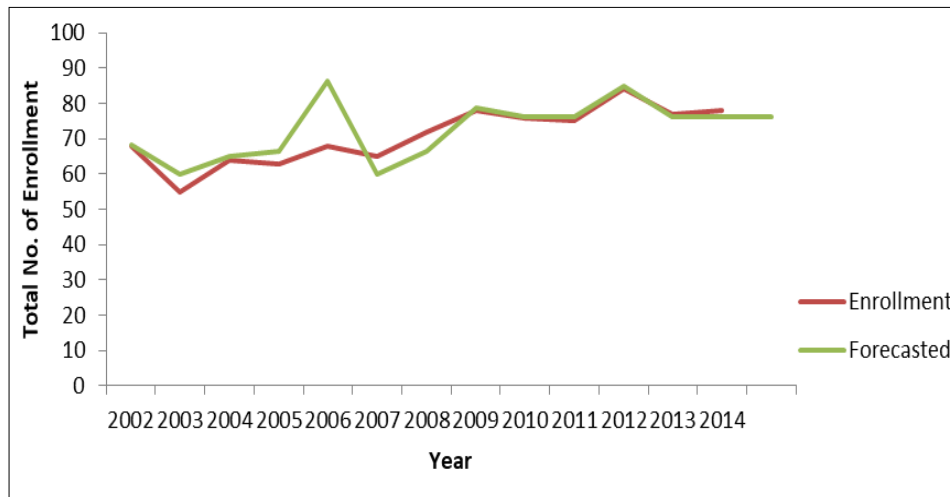
Figure 1. Predictive Performance of Proposed Model for Student Enrollment

Figure 1 indicates that, difference between actual enrollment and forecasted enrollment values are marginal except the year 2006. Result of MSE indicates that, forecasted values are less than the threshold value of 10%.

5. Conclusion

This study presents Chen's modified fuzzy method to forecast student enrolment based on fuzzy time series, where the data are collected from philosophy department at Jahangirnagar University. Mean square error (MSE) has been used as a performance measure to illustrate and test the forecasting processes and method. From the illustrative example, we can see that the proposed method can make good forecasts of enrollments data series with a performance criteria MSE which is less than the threshold value of 10%. Findings of this study are critical for the university authority in adopting appropriate forecasting technique and thereby formulating apposite policy making for future.

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