# A Hybrid Algorithm to Forecast Enrolment Based on Genetic Algorithms and Fuzzy Time Series

Haneen Al-Wazan[1], Kais Ibraheem[2], and Abdul-Ghafoor Salim[1]
[1]Department of Mathematics, Mosul University, Iraq
[2]Department of Computers Sciences, Mosul University, Iraq

**Abstract:** *In this paper, we proposed a hybrid algorithm to forecast enrolment based on fuzzy time series and genetic algorithms, the proposed algorithms presents a good forecasting result with higher accuracy rate. Historical enrolment of the University of Alabama from year 1948 to 2010 are used in this study to illustrate the forecasting process.*

**Keywords:** *Fuzzy time series forecasting, genetic algorithms prediction.*

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## 1. Introduction

Forecasting is one of the important activities in business, enrolment, finance, etc., that helps in decision making. There are different models out of which researches had shown that genetic algorithms with fuzzy logic is one of the most powerful non-linear models for forecasting for any time series, The classical time series methods can not deal with forecasting problems in which the values of time series are linguistic terms represented by fuzzy sets.

Chena and Hsu [4] proposed a new method to forecast enrolments using fuzzy time series. Timma [13] studied forecasting using neural networks and genetic algorithms. Sah and Degtiarev [10] presented a novel improvement of forecasting approach based on using time-invariant fuzzy time series. Chen and Chung [5] investigated the forecasting enrolments of students by using fuzzy time series and genetic algorithms. They presented a new method to deal with forecasting problems based on fuzzy time series and genetic algorithms. Tahseen *et al.* [2] presented multivariate high order fuzzy time series. Jilani *et al.* [12] studied multivariate high order fuzzy time series forecasting for car road accidents. Mandal *et al.* [8] studied soft computing approach in prediction of time series data. Lee *et al.* [7] proposed the adoption of the weighted and the difference between actual data toward midpoint interval based on fuzzy time series, by using the enrolment of the University of Alabama and University Technology Malaysia (UTM). Zaharim *et al.* [15] proposed Genetic algorithm in time series fatigue analysis. Aydin *et al.* [3] studied the prediction algorithm based on fuzzy logic using time series data mining method. Memmedli and Ozdemir [9] investigated an application of fuzzy time series to improve ISE forecasting. Alina and Elena [1] presented a hybrid approach for modeling financial time series. Haneen *et al.* [12] proposed a novel algorithm to forecast enrolment based on fuzzy time series. In this paper we proposed a hybrid algorithm to forecast enrolment based on fuzzy time series and genetic algorithms. We used the Historical data of the University of Alabama to apply the algorithm on it.

## 2. Basics of Fuzzy Time Series

In This section we briefly summarizes basic fuzzy and fuzzy time series concepts. The main difference of fuzzy time series and traditional time series is that the values of fuzzy time series are represented by fuzzy sets rather than real values. Let $U$ be the universe of discourse, where $U = \{u_1, u_2, \ldots, u_n\}$. A fuzzy set defined in the universe of discourse $U$ can be represented by equation 1:

$$A = f_A(u_1)/u_1 + f_A(u_2)/u_2 + \ldots\ldots + f_A(u_n)/u_n \quad (1)$$

Where $f_A$ denotes the membership function of the fuzzy set $A$, $f_A: U \rightarrow [0,1]$, and $f_A(u_i)$ denotes the degree of membership of $u_i$ belonging to the fuzzy set $A$, and $f_A(u_i) \in [0,1]$ and $1 \le i \le n$.

- *Definition 1:* Assume $Y(t) \subset R$ (real line), $t = \ldots, 0, 1, 2, \ldots, n$ to be a universe of discourse defined by the fuzzy set $f_i(t)$. $F(t)$ consisting of $f_i(t)$, $i = 1, 2, \ldots, n$ is defined as a fuzzy time series on $Y(t)$. At that, $F(t)$ can be understood as a linguistic variable, whereas $f_i(t)$, $i = 1, 2, \ldots, n$, are possible linguistic values of $F(t)$ [5, 9].
- *Definition 2:* If $F(t)$ is caused by $F(t-1)$, denoted by $F(t-1) \rightarrow F(t)$, then this relationship can be represented by $F(t) = F(t-1) \circ R(t,t-1)$, where the symbol "∘" is an operator; $R(t,t-1)$ is a fuzzy relation between $F(t)$ and $F(t-1)$ and is called the first-order model of $F(t)$ [4, 14].

- *Definition 3:* Denoting $F(t-1)$ by $A_i$ and $F(t)$ by $A_j$ the relationship between $F(t-1)$ and $F(t)$ can be defined by a logical relationship $A_i \rightarrow A_j$ [2, 9, 14].
- *Definition 4:* Let $R(t,t-1)$ be a first-order model of $F(t)$. If for any $t$, $R(t,t-1)=R(t-1,t-2)$, then $F(t)$ is called a time-invariant fuzzy time series. Otherwise, it is called a time-variant fuzzy time series [5].
- *Definition 5:* Fuzzy logical relationships, which have the same left-hand sides, can be grouped together into fuzzy logical relationship groups. For example, for the identical left-hand side $A_i$ such grouping can be depicted using equation 2 [9]:

$$\left.\begin{array}{l} A_i \rightarrow A_{j1} \\ A_i \rightarrow A_{j2} \\ . \\ . \end{array}\right\} \Rightarrow A_i \rightarrow A_{j1}, A_{j2}, \ldots \quad (2)$$

## 3. Basics of Genetic Algorithms

Genetic algorithms (Gas) based on the principles of natural evolution. Due to its ease of applicability, numerous application of genetic algorithms are found in the area of business, scenic, engineering, and forecasting problems. Now we will mention some basics of genetic algorithms.

- *Chromosome*

All living organisms consist of cells. In each cell there is the same set of chromosomes. Chromosomes are strings of DNA and serves as a model for the whole organisms. In genetic algorithms terminology these are the point in the search space and represented by string of coded genes [13].

- *Population*

A population a collection of chromosomes. A population consists of number of chromosomes being tested. The two important aspects of population used in genetic algorithms are:

1. The initial population generation.
2. The population size [11].

- *Fitness Function*

The fitness of a chromosome in genetic algorithms is the value of an objective function. The fitness not only indicates how good the solution is, but also corresponds to how close the chromosome is to the optimal one. There is several types of fitness function but in time series forecasting mean square error, absolute error, root mean square error average error etc., are good convergence criterions to be used in the forecasting process [11].

- *Genetic Algorithms Operators*

A genetic algorithms is composed of three operators:

1. Initialize population.
2. Encoding.
3. Reproduction/Selection.
4. Cross over.
5. Mutation [11].

- *Best Chromosome*

A best chromosome is the one with the minimum fitness [11].

## 4. A Hybrid Algorithm to Forecast Enrolment Based on Fuzzy Time Series and Genetic Algorithms

In this section we proposed a hybrid algorithm to forecast enrolment of the University of Alabama based on fuzzy time series and genetic algorithms .The forecasting method consists of two ways, the first way is used to determined the best interval with less fitness function we use in this way only steps1-7. The second way forecasting is the find the final forecasting results we use in this steps 4, 5 and step 8 with the 3 rules. The steps of the algorithm are given below:

- *Step 1:* Collect the data.
- *Step 2:* Determine the maximum and the minimum of the interval $U = [D_{min} - D_1, D_{max} + D_2]$ where $D_1$ and $D_2$ are constant to define the universe of discourse $U = [a, b]$.
- *Step 3:* Divide the universe of discourse $U$ into m intervals, $u_1, u_2, \ldots, u_m$ where $u_1 = [a,x_1], \ldots, u_m = [x_{m-1}, b]$. Where $x_1, \ldots, x_{m-1}$ are integer constant and $x_1 < \ldots < x_{m-1}$ as follows:
  Define each chromosome consisting of $m-1$ genes as shown below: $x_1, x_2, \ldots, x_{m-1}$.
  Initially, the values of $x_1, x_2, \ldots, x_{m-1}$ of each chromosome are randomly generated by the system, and the system generates $N$ chromosomes as an initial population. Where $N$ is the numbers of chromosomes.
- *Step 4:* Fuzzify the historical enrolments with the chromosomes in the population. Determine the fuzzy logical sets by using equation 3:

$$A_i = \left(d_{i-1}, d_i, d_{i+1} d_{i+2}\right) \quad (3)$$

  Starting by $A_1 = (d_0, d_1, d_2, d_3)$ and ending by $A_m = (d_{m-1}, d_m, d_{m+1}, d_{m+2})$.
  Where $d_0 = D_{min}-100$, $d_{m+2} = D_{max}$ and fuzzify the historical enrolments shown in Table 1, where the fuzzy set $A_i$ denotes a linguistic value of the enrolments represented by a fuzzy set, and $1 \leq i \leq m$.
- *Step 5:* Determine the fuzzy logical relations as: $A_j \rightarrow A_i$ and find the fuzzy logical groups.
- *Step 6:* Select two chromosomes randomly from the population to perform the crossover and mutation operations. To perform the mutation operation we need to compare the value of genes $i$ and $i+1$; $i = 1, 2, \ldots, m-1$ if $(gene(i+1)-gene(i))>100$ *or*

(*gene*(*i*+*1*)-*gene*(*i*))<*200* then regenerate the *gene*(*i*), after the mutation operations, if the chromosomes are not sorted by the values of genes, then the system will sort the values of genes in the chromosomes in an ascending sequence.

- *Step 7:* Based on the corresponding intervals of each chromosome in the generated population the forecasted value at time *t* is determined by the following rules:

  a. If the fuzzy logical relationship group $A_j$ is empty $A_j \rightarrow \phi$ then by equation 4:

$$F_{vt} = A_j / 2 \tag{4}$$

  b. If the fuzzy logical relationship group $A_j$ is one to one $A_j \rightarrow A_k$ then the interval that contain the forecasted value is $A_k$ then by equation 5:

$$F_{vt} = A_k / 2 \tag{5}$$

  c. If the fuzzy logical relationship group $A_j$ one to many $A_j \rightarrow A_{k1}, A_{k2}, \ldots, A_{kp}$ then the interval that contain the forecasted value represented by equation 6:

$$F_{vt} = \frac{(A_{k1} + A_{k2} + \ldots + A_{kp}) / p}{2} \tag{6}$$

- *Step 8:* The best chromosome will be selected by computing the fitness function which is the Mean Square Error (MSE) for each chromosome the best chromosome is the one that have less men square error and it will be the initial interval to find the new forecasting value we will repeat the steps 4, 5. And we will compute the final forecasting value as follows:

  Based on the corresponding intervals of the best chromosome the forecasted value at time *t* is determined by the following rules:

  a. If the fuzzy logical relationship group $A_j$ is empty $A_j \rightarrow \phi$ then by equation 7:

$$F_{vt} = A_j / 2 \tag{7}$$

  b. If the fuzzy logical relationship group $A_j$ is one to one $A_j \rightarrow A_k$ then the interval that contain the forecasted value is $A_k$ then:

  Assume that the fuzzy logical relationship is $A_i \rightarrow A_j$, where $A_i$ denotes the fuzzified enrolment of year n-1 and $A_j$ denotes the fuzzified enrolment of year *n*. Compute *Y* as follows:

  *Y= [(enrolment of year* (*n*) *- enrolment of year* (*n - 1*)) - (*enrolment of year* (*n - 1*) *- enrolment of year* (*n - 2*))*]* then compare the value of Y with zero and apply the following:

  1. *If j >i, and Y >0*
     *then the trend of the forecasting will go up, and we use the following Rule 2 to forecast the enrolments.*
  2. *If j >i, and Y <0*
     *then the trend of the forecasting will go down, andwe use the following Rule 3 to forecast the enrolments.*
  3. *If j <i, and Y >0*
     *then the trend of the forecasting will go up, and we use the following Rule 2 to forecast the enrolments.*
  4. *If j <i, and Y <0*
     *then the trend of the forecasting will go down, and we use the following Rule 3 to forecast the enrolments.*
  5. *If j =i, and Y >0*
     *then the trend of the forecasting will go up, and we use the following Rule 2 to forecast the enrolments.*
  6. *If j =i, and Y <0*
     *then the trend of the forecasting will go down, and we use the following Rule 3 to forecast the enrolments.*

  c. If the fuzzy logical relationship group $A_j$ one to many $A_j \rightarrow A_{k1}, A_{k2}, \ldots, A_{kp}$ then the interval that contain the forecasted value is can be determined as follows:

  1. If the difference between any two of *k1, k2, ..., kp≤2* then the interval that contain the forecasted value is calculated using equation 8:

$$IF_{vt} = \frac{A_{k1} + A_{k2} + \ldots + A_{kp}}{p} \tag{8}$$

  and the forecasting is the middle of this interval.

  2. If the difference between any two of *k1, k2, ..., kp>2* then the forecasted value is the middle of the interval calculated using equation 9:

$$IF_{vt} = \frac{A_{k1} + A_{k2} + \ldots + A_{ki-1} + A_{ki+1} + \ldots + A_{kp}}{p}$$
$$= \left( \frac{d_{k1-1} + \ldots + d_{(ki-1)-1} + d_{(ki+1)-1} + \ldots + d_{kp-1}}{p}, \frac{d_{k1} + \ldots + d_{(ki-1)} + d_{(ki+1)} + \ldots + d_{kp}}{p}, \frac{d_{k1+1} + \ldots + d_{(ki-1)+1} + d_{(ki+1)+1} + \ldots + d_{kp+1}}{p}, \frac{d_{k1+2} + \ldots + d_{(ki-1)+2} + d_{(ki+1)+2} + \ldots + d_{kp+2}}{p} \right) \tag{9}$$

Where $A_{ki}$ is the intervals that have deference >*2*, *i = 1, 2, ..., p* and the forecasting of the fuzzy sets $A_{ki}$ is calculated as one to one fuzzy logical relationship by applying step 8-b.

The rules 1, 2 and 3 used in the algorithm are shown as follows:

- *Rule 1:* When forecasting the enrolment of year 1950, there are no data before the enrolments of year 1947, therefore we are not able to calculate equation 10:

$$Z = ((enrollment(1949) - enrollment(1948)) - enrollment(1948) - enrollment(1947))) \tag{10}$$

  Therefore if $|En(1949) - En(1948)|/2 > \frac{A_j}{2}$ – then the trend of the forecasting of this interval will be upward and calculate using equation 11:

$$F_n = 0.75 \text{ of } A_j \tag{11}$$

If $|En(1949) - En(1948)|/2 = \frac{A_j}{2}$ then the forecasting enrolment falls at the middle value of this interval.

If $|En(1949) - En(1948)|/2 < \frac{A_j}{2}$ then the trend of the forecasting of this interval will be downward, and $F_n = 0.25 \text{ of } A_j$; where *En=enrolment*.

- *Rule 2*: If $x=|Y|*2+En(n-1) \in A_j$ or $x=En(n-1)-|Y|*2 \in A_j$ then the trend of the forecasting of this interval will be upward and by using equation 12 we find:

$$\begin{aligned} & F_n = 0.75 \text{ of } A_j \\ & \text{If } x = \frac{|Y|}{2} + En(n-1) \in A_j \\ & \text{or } x = En(n-1) - \frac{|Y|}{2} \in A_j \end{aligned} \tag{12}$$

Then the trend of the forecasting of this interval will be downward, and calculate by equation 13:

$$F_n = 0.25 \text{ of } A_j \tag{13}$$

If neither is the case, then the forecasting enrolment be the middle value of the interval $A_j$.

- *Rule 3:* If $x = \frac{|Y|}{2} + En(n-1) \in A_j$ or $x = En(n-1) - \frac{|Y|}{2} \in A_j$ then the trend of the forecasting of this interval will be downward, and we will calculate it using equation 14:

$$\begin{aligned} & F_n = 0.25 \text{ of } A_j \\ & \text{If } x = |Y| * 2 + En(n-1) \in A_j \\ & \text{If } x = |Y| * 2 + En(n-1) \in A_j \\ & \text{or } x = En(n-1) - |Y| * 2 \in A_j \end{aligned} \tag{14}$$

Then the trend of the forecasting of this interval will be upward, and $F_n = 0.75 \text{ of } A_j$. If neither is the case, then we let the forecasting enrolment be the middle value of the interval $A_j$ [5].

## 5. Results

We will apply the proposed algorithm to forecast the historical enrolments of the University of Alabama that shown in Table 8. The universe set is $U = [5172-172, 27052 + 948]$ i.e., $U = [5000, 28900]$:

1. We will apply our algorithm firstly on enrolment from year 1971 to 1992 so we can compare our method with others, As a start we will divide the universe of discourse $U = [13000, 20000]$ into 11 intervals so each chromosome consisting of 10 genes, the values of each chromosome are randomly generated by the system, and the system will generates 50 chromosomes as an initial population as shown in Table 1.
2. Fuzzify the historical enrolments with the chromosomes in the population. For example for the first chromosome shown in Table 1 we can see that the subintervals of the universe interval $U = [13000, 20000]$ are $u_1, ..., u_{11}$, where $u_1 = [13000, 13180]$, $u_2 = [13180, 13226]$, $u_3 = [13226, 13353]$, $u_4 = [13353, 14497]$, $u_5 = [14497, 15177]$, $u_6 = [15177, 15250]$, $u_7 = [15250, 15750]$, $u_8 = [1570, 16434]$, $u_9 = [16434, 18198]$, $u_{10} = [18198, 18210]$, $u_{11} = [18210, 20000]$. The fuzzified enrolment are shown in Table 2.
3. Select two chromosomes randomly for the crossover and mutation operations, we choose single point crossover, after the mutation operations, if the chromosomes are not sorted by the values of genes in an ascending sequence, then the system will sort the values of genes in the chromosomes in an ascending sequence. The mutation and crossover operations for the chromosomes are shown in Table 3.
4. The first step forecasting is to determine the best chromosome which is the one with less fitness value. The fitness function used in this paper is the Mean Square Error (MSE) that is given below:
$$MSE = \frac{\sum_{i=1}^{n} \left( Actual\,Enrollment_i - Forecasted\,Enrollment_i \right)^2}{n}.$$
5. From 4, we determined the best initial interval for our second step forecasting. The chromosome no.36 is the best with $MSE = 166033$ will be used to find the final forecasting results.
6. In order to get better results we can increase the number of chromosomes genes to 130 genes (i. e., 130 subintervals) this can be shown in Table 4. Table 5 showed that the results will be better by increasing the size of population to 100 chromosomes. Table 6 showed that the proposed algorithm presents better results than the exist methods.
7. In this step we applied the proposed method on the data from 1948 to 2010 as given in Table 7. To do this we needed to generate randomly an initial population consisted of 100 chromosomes and each chromosome contained 365 genes (i. e., each chromosome consisted of 366 subintervals), then the crossover and mutation operators have been done, and we fuzzified enrolment. Then the forecasted enrolment is shown in Table 7.
8. In order to get better results we can increase the number of chromosomes genes to 130 genes (i. e., 130 subintervals) this can be shown in Table 4. Table 5 showed that the results will be better by increasing the size of population to 100 chromosomes. Table 6 showed that the proposed algorithm presents better results than the exist methods.
9. In this step we applied the proposed method on the data from 1948 to 2010 as given in Table 7. To do this we needed to generate randomly an initial population consisted of 100 chromosomes and each chromosome contained 365 genes (i. e., each

chromosome consisted of 366 subintervals), then the crossover and mutation operators have been done, and we fuzzified enrolment. Then the forecasted enrolment is shown in Table 7.

Table 1. Randomly generated chromosomes.

| $x_i$ Chrom No. | Genes Value | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ | $x_7$ | $x_8$ | $x_9$ | $x_{10}$ |
| **Chrom 1** | 13108 | 13226 | 13353 | 14497 | 15177 | 15250 | 15750 | 16434 | 18198 | 18210 |
| **Chrom 2** | 13201 | 13797 | 14492 | 16295 | 16849 | 17056 | 17703 | 19300 | 19615 | 19858 |
| **Chrom 3** | 16037 | 17016 | 17194 | 17857 | 17983 | 18095 | 18563 | 18917 | 18949 | 19130 |
| **Chrom 4** | 13870 | 15178 | 16429 | 16537 | 17400 | 17482 | 17486 | 17848 | 18625 | 19684 |
| **Chrom 5** | 13747 | 14054 | 15057 | 16144 | 16303 | 16536 | 16807 | 17390 | 17490 | 18219 |
| **Chrom 6** | 13916 | 13994 | 14275 | 15029 | 16300 | 16864 | 17923 | 18746 | 19735 | 19900 |
| **Chrom 7** | 13946 | 14697 | 15953 | 16046 | 16428 | 16877 | 17105 | 18772 | 19500 | 19571 |
| **Chrom 8** | 13049 | 13103 | 13381 | 16477 | 16628 | 16658 | 17954 | 18437 | 18601 | 18692 |
| **Chrom 9** | 13296 | 15744 | 15867 | 16848 | 17124 | 17278 | 17876 | 18292 | 18744 | 18957 |
| **Chrom 10** | 13669 | 13738 | 13986 | 14036 | 15788 | 16144 | 17012 | 17274 | 18624 | 19221 |
| **Chrom 11** | 13058 | 14718 | 14905 | 15079 | 15644 | 15733 | 15860 | 15957 | 16896 | 17371 |
| **Chrom 12** | 13938 | 15118 | 15494 | 15934 | 16602 | 17536 | 17805 | 18036 | 18992 | 19043 |
| **Chrom 13** | 14205 | 14284 | 14461 | 14884 | 16109 | 16276 | 17937 | 18070 | 18585 | 19732 |
| **Chrom 14** | 13396 | 13606 | 14291 | 15369 | 16727 | 17213 | 18135 | 18345 | 18524 | 18596 |
| **Chrom 15** | 13246 | 13907 | 14575 | 15098 | 16216 | 16448 | 16688 | 16957 | 17632 | 19531 |
| **Chrom 16** | 13206 | 13327 | 14276 | 14736 | 16261 | 16677 | 16870 | 16925 | 17424 | 19300 |
| **Chrom 17** | 15012 | 15102 | 15590 | 17393 | 17484 | 17882 | 17980 | 18193 | 18511 | 19623 |
| **Chrom 18** | 14443 | 15441 | 15560 | 17518 | 17563 | 17806 | 18025 | 18430 | 18810 | 19310 |
| **Chrom 19** | 13247 | 13891 | 14537 | 15630 | 15969 | 16583 | 17778 | 17951 | 19415 | 19455 |
| **Chrom 20** | 13246 | 14661 | 15417 | 15939 | 16384 | 17822 | 17939 | 18142 | 18433 | 19173 |
| **Chrom 21** | 13032 | 14248 | 14455 | 14656 | 14658 | 15226 | 16382 | 16640 | 18099 | 18688 |
| **Chrom 22** | 14960 | 15368 | 15697 | 15912 | 16424 | 17519 | 19281 | 19756 | 19818 | 19821 |
| **Chrom 23** | 14509 | 16148 | 16447 | 16711 | 16746 | 17528 | 18214 | 19266 | 19347 | 19504 |
| **Chrom 24** | 14099 | 14530 | 15093 | 15703 | 15775 | 16051 | 17336 | 17628 | 18199 | 18276 |
| **Chrom 25** | 14051 | 14470 | 14926 | 15052 | 16362 | 16639 | 17017 | 17325 | 19101 | 19401 |
| **Chrom 26** | 14261 | 14535 | 14679 | 15151 | 15836 | 16731 | 16737 | 17156 | 17378 | 19496 |
| **Chrom 27** | 13454 | 14878 | 15690 | 15782 | 15812 | 16198 | 16368 | 16976 | 17995 | 19358 |
| **Chrom 28** | 14946 | 16312 | 16862 | 17211 | 17219 | 17579 | 18325 | 18646 | 19139 | 19145 |
| **Chrom 29** | 13535 | 13902 | 14317 | 14643 | 16432 | 17505 | 17949 | 18489 | 19242 | 19698 |
| **Chrom 30** | 14700 | 14986 | 15165 | 15558 | 15995 | 16147 | 17100 | 17328 | 19169 | 19787 |
| **Chrom 31** | 13908 | 15300 | 15618 | 15777 | 15916 | 16028 | 16071 | 16288 | 16482 | 17096 |
| **Chrom 32** | 13523 | 14866 | 15952 | 16080 | 16112 | 16264 | 16612 | 17151 | 18846 | 19563 |
| **Chrom 33** | 13013 | 13347 | 13381 | 14196 | 17456 | 17816 | 18099 | 18254 | 18407 | 19165 |
| **Chrom 34** | 14445 | 14470 | 15061 | 15313 | 16422 | 17593 | 18152 | 18633 | 18708 | 18781 |
| **Chrom 35** | 13016 | 14094 | 14600 | 14692 | 14860 | 15981 | 16911 | 18372 | 18813 | 19653 |
| **Chrom 36** | 13560 | 13734 | 14238 | 14378 | 14518 | 15895 | 16041 | 16991 | 17559 | 18143 |
| **Chrom 37** | 14533 | 15362 | 16100 | 16193 | 16423 | 16601 | 16849 | 17483 | 18658 | 19208 |
| **Chrom 38** | 13986 | 14637 | 15162 | 15426 | 17244 | 17993 | 18238 | 18440 | 18512 | 19349 |
| **Chrom 39** | 13265 | 15289 | 16707 | 17205 | 17602 | 17822 | 18584 | 19243 | 19416 | 19786 |
| **Chrom 40** | 13188 | 13425 | 13535 | 13996 | 14710 | 15234 | 15896 | 16334 | 16869 | 16872 |
| **Chrom 41** | 13596 | 13874 | 14450 | 15475 | 16549 | 17490 | 17677 | 18898 | 19108 | 19112 |
| **Chrom 42** | 13417 | 13513 | 16054 | 16733 | 17206 | 17968 | 17987 | 18517 | 18972 | 19311 |
| **Chrom 43** | 14308 | 14570 | 15056 | 15376 | 16314 | 16877 | 18261 | 18364 | 19002 | 19794 |
| **Chrom 44** | 14508 | 15340 | 15429 | 15765 | 15998 | 16400 | 17558 | 18211 | 18390 | 19062 |
| **Chrom 45** | 14845 | 16576 | 17290 | 17411 | 17416 | 17753 | 17908 | 18139 | 19398 | 19686 |
| **Chrom 46** | 13657 | 13949 | 14504 | 15915 | 16341 | 17705 | 18058 | 18406 | 18845 | 19283 |
| **Chrom 47** | 14005 | 14141 | 14478 | 14835 | 15424 | 15673 | 16201 | 17392 | 18545 | 19486 |
| **Chrom 48** | 13220 | 13829 | 15675 | 15936 | 16049 | 16119 | 18838 | 19241 | 19548 | 19562 |
| **Chrom 49** | 13225 | 13977 | 14518 | 15304 | 15674 | 16288 | 17681 | 17804 | 18772 | 19433 |
| **Chrom 50** | 13366 | 13453 | 13904 | 14362 | 15565 | 15623 | 15836 | 16341 | 16364 | 18409 |

Table 2. Fuzzified enrolment from 1971 to 1992.

| Year | Act. En. | Fuz. En. | Year | Act. En. | Fuz. En. | Year | Act. En. | Fuz. En. | Year | Act. En. | Fuz. En. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1971 | 13055 | $A_1$ | 1977 | 15603 | $A_7$ | 1983 | 15497 | $A_7$ | 1989 | 18970 | $A_{11}$ |
| 1972 | 13563 | $A_4$ | 1978 | 15861 | $A_8$ | 1984 | 15145 | $A_5$ | 1990 | 19328 | $A_{11}$ |
| 1973 | 13867 | $A_4$ | 1979 | 16807 | $A_9$ | 1985 | 15163 | $A_5$ | 1991 | 19337 | $A_{11}$ |
| 1974 | 14696 | $A_5$ | 1980 | 16919 | $A_9$ | 1986 | 15984 | $A_8$ | 1992 | 18876 | $A_{11}$ |
| 1975 | 15460 | $A_7$ | 1981 | 16388 | $A_8$ | 1987 | 16859 | $A_9$ | | | |
| 1976 | 15311 | $A_7$ | 1982 | 15433 | $A_7$ | 1988 | 18150 | $A_9$ | | | |

Table 3. The chromosomes after the crossover and mutation operations and calculating MSE.

| $x_i$ Chrom No. | Genes Value | | | | | | | | | | MSE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $x_{10}$ | $x_{10}$ | $x_{10}$ | $x_{10}$ | $x_{10}$ | $x_{10}$ | $x_{10}$ | $x_{10}$ | $x_{10}$ | $x_{10}$ | |
| Chrom **1 | 13038 | 13187 | 13201 | 14217 | 16162 | 16623 | 16815 | 17054 | 17760 | 19144 | 411417 |
| Chrom **2 | 13108 | 13692 | 14219 | 14857 | 15866 | 17375 | 18613 | 18618 | 18904 | 19408 | 344707 |
| Chrom **3 | 13035 | 13687 | 13870 | 14223 | 15950 | 16374 | 16616 | 18680 | 19243 | 19352 | 534125 |
| Chrom **4 | 13848 | 14709 | 15178 | 16566 | 17244 | 17914 | 18935 | 19434 | 19465 | 19698 | 293851 |
| Chrom **5 | 13916 | 14946 | 15663 | 16188 | 16320 | 17024 | 17814 | 17819 | 18277 | 18402 | 274286 |
| Chrom **6 | 13698 | 13747 | 14281 | 15736 | 16524 | 17358 | 17577 | 18976 | 19450 | 19470 | 238009 |
| Chrom **7 | 13049 | 14250 | 16695 | 16749 | 17369 | 17451 | 18285 | 19103 | 19108 | 19221 | 492943 |
| Chrom **8 | 13103 | 13866 | 15117 | 15670 | 16045 | 16050 | 16153 | 16492 | 16912 | 18242 | 292888 |
| Chrom **9 | 13669 | 14383 | 14761 | 14999 | 17007 | 17552 | 18436 | 18557 | 19313 | 19625 | 994932 |
| Chrom **10 | 13296 | 13945 | 13946 | 14272 | 14432 | 16601 | 16957 | 17519 | 18771 | 19385 | 385769 |
| Chrom **11 | 13122 | 13279 | 13938 | 15082 | 16921 | 16938 | 17582 | 18255 | 19023 | 19408 | 977408 |
| Chrom **12 | 13058 | 13885 | 14440 | 14511 | 14683 | 16377 | 18426 | 18793 | 18862 | 18866 | 809108 |
| Chrom **13 | 13396 | 14031 | 14666 | 14763 | 17160 | 18204 | 18440 | 18462 | 18651 | 19282 | 825731 |
| Chrom **14 | 13001 | 13160 | 13606 | 13682 | 14478 | 15130 | 17827 | 18246 | 18486 | 19261 | 261064 |
| Chrom **15 | 13206 | 13972 | 14369 | 14536 | 14846 | 15770 | 16641 | 17376 | 18076 | 19081 | 330278 |
| Chrom **16 | 13063 | 13246 | 13400 | 13510 | 13984 | 14603 | 16554 | 16935 | 18412 | 18850 | 41620 3 |
| Chrom **17 | 13611 | 13752 | 14443 | 15358 | 16151 | 17243 | 18385 | 18755 | 19223 | 19619 | 359639 |
| Chrom **18 | 13632 | 14015 | 15012 | 15491 | 15550 | 15592 | 16034 | 16259 | 17723 | 18860 | 282464 |
| Chrom **19 | 13246 | 13977 | 15337 | 15908 | 16145 | 17043 | 17430 | 18078 | 18732 | 19005 | 292395 |
| Chrom **20 | 13247 | 13346 | 13458 | 13567 | 15101 | 15916 | 17626 | 18391 | 18723 | 19514 | 403797 |
| Chrom **21 | 13366 | 14248 | 14750 | 15849 | 16681 | 18238 | 18352 | 19067 | 19198 | 19620 | 34466 |
| Chrom **22 | 13012 | 13032 | 13051 | 13134 | 14150 | 15007 | 17870 | 17898 | 18813 | 19371 | 592839 |
| Chrom **23 | 13283 | 13329 | 14099 | 14162 | 14202 | 16077 | 16847 | 17820 | 18750 | 19054 | 459396 |
| Chrom **24 | 13840 | 13931 | 14509 | 16910 | 17429 | 17722 | 17926 | 18075 | 18730 | 19163 | 1312138 |
| Chrom **25 | 14261 | 14295 | 16096 | 17891 | 18209 | 18303 | 18650 | 19051 | 19098 | 19121 | 458451 |
| Chrom **26 | 13417 | 14051 | 14587 | 15446 | 15665 | 16694 | 17116 | 17429 | 19146 | 19146 | 247655 |
| Chrom **27 | 13692 | 14468 | 14878 | 14893 | 15314 | 17027 | 17202 | 18149 | 18573 | 18908 | 496517 |
| Chrom **28 | 13454 | 13740 | 14497 | 15087 | 15121 | 15680 | 18514 | 18695 | 19194 | 19313 | 607678 |
| Chrom **29 | 13022 | 13042 | 13131 | 13902 | 13922 | 15799 | 17212 | 18800 | 19096 | 19248 | 183544 |
| Chrom **30 | 13340 | 13535 | 13557 | 14777 | 15465 | 16246 | 16880 | 18813 | 19170 | 19337 | 571821 |
| Chrom **31 | 13523 | 13762 | 14749 | 15639 | 16646 | 17065 | 17498 | 17960 | 18175 | 19124 | 244177 |
| Chrom **32 | 13753 | 13908 | 14812 | 15243 | 17308 | 17443 | 18191 | 18532 | 19163 | 19208 | 49658 |
| Chrom **33 | 13318 | 13347 | 13348 | 13624 | 15476 | 15480 | 16364 | 16428 | 17910 | 18715 | 314741 |
| Chrom **34 | 13005 | 13013 | 13948 | 14071 | 14687 | 15381 | 15897 | 16440 | 16755 | 18331 | 453904 |
| Chrom **35 | 13317 | 13337 | 13560 | 17115 | 17704 | 18471 | 18557 | 18909 | 19303 | 19314 | 1508675 |
| Chrom **36 | **13179** | **13928** | **14339** | **14774** | **15695** | **16260** | **16560** | **17795** | **18707** | **19540** | **166033** |
| Chrom **37 | 13270 | 13783 | 13986 | 14207 | 14624 | 15714 | 16814 | 18293 | 18858 | 18979 | 319689 |
| Chrom **38 | 14335 | 14493 | 14533 | 14831 | 15139 | 15841 | 16423 | 18435 | 18569 | 18899 | 370970 |
| Chrom **39 | 13188 | 13295 | 13833 | 14148 | 15079 | 15823 | 18264 | 19270 | 19406 | 19436 | 602690 |
| Chrom **40 | 13027 | 13265 | 14688 | 15642 | 15932 | 16079 | 16422 | 18297 | 18300 | 18687 | 307608 |
| Chrom **41 | 13398 | 13417 | 14336 | 15409 | 16503 | 18153 | 18762 | 18971 | 19363 | 19675 | 412638 |
| Chrom **42 | 13513 | 15415 | 15493 | 16490 | 16565 | 16692 | 16696 | 16927 | 18861 | 19505 | 427158 |
| Chrom **43 | 13574 | 13672 | 13831 | 14508 | 16151 | 16355 | 17224 | 19444 | 19479 | 19530 | 540702 |
| Chrom **44 | 13585 | 13677 | 14308 | 17065 | 17913 | 18004 | 18418 | 18636 | 18662 | 19100 | 1077178 |
| Chrom **45 | 13252 | 13657 | 13980 | 14876 | 15985 | 18440 | 18882 | 19336 | 19394 | 19739 | 665869 |
| Chrom **46 | 13154 | 13289 | 13949 | 15185 | 15314 | 15805 | 15981 | 18357 | 18883 | 19342 | 475012 |
| Chrom **47 | 13220 | 15599 | 16260 | 16422 | 16906 | 17086 | 17487 | 18026 | 18578 | 19036 | 307787 |
| Chrom **48 | 13829 | 14920 | 15328 | 15519 | 16238 | 17016 | 17135 | 17879 | 19212 | 19319 | 283241 |
| Chrom **49 | 13083 | 13366 | 13832 | 15156 | 15959 | 16779 | 18993 | 19027 | 19099 | 19133 | 581187 |
| Chrom **50 | 13225 | 13262 | 14650 | 16308 | 16442 | 16537 | 17670 | 17959 | 18910 | 19834 | 444079 |

Table 4. Forecasted enrolment with population size=50 chromosome and different no. of intervals.

| Year | Actual Enrolment | Forecasted Enrolment with Different Numbers of Intervals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 20 | 40 | 50 | 70 | 90 | 100 | 130 |
| 1971 | 13055 | ------- | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 1672 | 13563 | 13554 | 13710 | 13480 | 13481 | 13399 | 13573 | 13594 | 13612 |
| 1973 | 13867 | 13554 | 13856 | 13840 | 13836 | 13600 | 14014 | 13859 | 13937 |
| 1974 | 14696 | 14707 | 15173 | 15206 | 14640 | 14872 | 14976 | 14623 | 14949 |
| 1975 | 15460 | 15335 | 15444 | 15399 | 15175 | 15444 | 15616 | 15472 | 15567 |
| 1976 | 15311 | 15335 | 15389 | 15399 | 15175 | 15406 | 15491 | 15290 | 15289 |
| 1977 | 15603 | 15711 | 15606 | 15444 | 15175 | 15570 | 15730 | 15602 | 15750 |
| 1978 | 15861 | 15711 | 15903 | 15516 | 15841 | 15722 | 16000 | 15876 | 15838 |
| 1979 | 16807 | 17178 | 16703 | 16657 | 16872 | 16789 | 16790 | 16830 | 16787 |
| 1980 | 16919 | 16869 | 16703 | 16849 | 16872 | 16789 | 16813 | 16898 | 16832 |
| 1981 | 16388 | 16310 | 16266 | 16466 | 16367 | 16350 | 16252 | 16445 | 16357 |
| 1982 | 15433 | 15335 | 15444 | 15399 | 15175 | 15444 | 15534 | 15472 | 15483 |
| 1983 | 15497 | 15335 | 15444 | 15399 | 15175 | 15526 | 15578 | 15472 | 15567 |
| 1984 | 15145 | 15335 | 15173 | 15206 | 15041 | 15319 | 15412 | 15110 | 15233 |
| 1985 | 15163 | 15204 | 15173 | 15123 | 15041 | 15444 | 15412 | 15110 | 15233 |
| 1986 | 15984 | 15944 | 16266 | 15700 | 15915 | 16265 | 16054 | 16026 | 15851 |
| 1987 | 16859 | 17486 | 16703 | 16849 | 16872 | 16789 | 16813 | 16861 | 16797 |
| 1988 | 18150 | 18251 | 18461 | 17882 | 18057 | 18451 | 17911 | 18253 | 17968 |
| 1989 | 18970 | 19332 | 19238 | 18810 | 18954 | 18866 | 18975 | 19003 | 19022 |
| 1990 | 19328 | 18915 | 19325 | 19195 | 19343 | 19330 | 19345 | 19337 | 19343 |
| 1991 | 19337 | 19124 | 19325 | 19264 | 19343 | 19330 | 19345 | 19337 | 19343 |
| 1992 | 18876 | 18915 | 19238 | 18762 | 18832 | 18803 | 18924 | 18890 | 18995 |
| **MSE** | | 53420 | 35102 | 32726 | 24428 | 22780 | 20914 | 14908 | 9816 |

Table 5. Forecasted enrolment with population size=100 chromosome and 130 intervals.

| Year | Act. | Forec. | Year | Act. | Forec. | Year | Act. | Forec. | Year | Act. | Forec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1971 | 13055 | | 1977 | 15603 | 15626 | 1983 | 15497 | 15498 | 1989 | 18970 | 18958 |
| 1972 | 13563 | 13568 | 1978 | 15861 | 15849 | 1984 | 15145 | 15125 | 1990 | 19328 | 19306 |
| 1973 | 13867 | 13869 | 1979 | 16807 | 16796 | 1985 | 15163 | 15160 | 1991 | 19366 | 19356 |
| 1974 | 14696 | 14686 | 1980 | 16919 | 16953 | 1986 | 15984 | 15988 | 1992 | 18804 | 18903 |
| 1975 | 15460 | 15463 | 1981 | 16388 | 16395 | 1987 | 16859 | 16859 | | | |
| 1976 | 15311 | 15297 | 1982 | 15433 | 15416 | 1988 | 18150 | 18130 | MSE | 246 | |

Table 6. A comparison of the MSE of the forecasted enrolment for different forecasting methods.

| Method | MSE |
|---|---|
| Chen and Hsu [4] | 5353 |
| Lee *et al.* [7] | 16248.7 |
| Chen and Chung [5] | 35324 |
| Huarng [4] | 226611 |
| Jilani *et al.* [6] | 41426 |
| The proposed method | 246 |

Table 7. Forecasted enrolments of the University of Alabama from year 1948 to 2010.

| Year | Actual Enrolment | Forecasted Enrolment | Year | Actual Enrolment | Forecasted Enrolment |
|---|---|---|---|---|---|
| 1948 | 8916 | ----- | 1980 | 16919 | 16923.00 |
| 1949 | 7974 | 7979.00 | 1981 | 16388 | 16394.00 |
| 1950 | 6293 | 6260.00 | 1982 | 15433 | 15425.00 |
| 1951 | 5269 | 5260.00 | 1983 | 15497 | 15518.00 |
| 1952 | 5172 | 5165.00 | 1984 | 15145 | 15120.00 |
| 1953 | 5652 | 5618.00 | 1985 | 15163 | 15178.00 |
| 1954 | 6111 | 6068.00 | 1986 | 15984 | 16014.00 |
| 1955 | 7038 | 7040.00 | 1987 | 16859 | 16869.00 |
| 1956 | 7112 | 7106.00 | 1988 | 18150 | 18146.00 |
| 1957 | 7032 | 7040.00 | 1989 | 18970 | 18947.00 |
| 1958 | 7089 | 7090.00 | 1990 | 19328 | 19318.00 |
| 1959 | 7407 | 7424.00 | 1991 | 19366 | 19352.00 |
| 1960 | 7848 | 7816.00 | 1992 | 18804 | 18886.00 |
| 1961 | 8257 | 8267.00 | 1993 | 18909 | 18886.00 |
| 1962 | 8560 | 8569.00 | 1994 | 18707 | 18713.00 |
| 1963 | 8879 | 8859.00 | 1995 | 18561 | 18583.00 |
| 1964 | 9724 | 9717.00 | 1996 | 17572 | 17573.00 |
| 1965 | 10938 | 10933.00 | 1997 | 17877 | 17866.00 |
| 1966 | 11975 | 11974.00 | 1998 | 17929 | 17935.00 |
| 1967 | 12251 | 12255.00 | 1999 | 18267 | 18653.00 |
| 1968 | 12816 | 12836.00 | 2000 | 18859 | 18840.00 |
| 1969 | 13035 | 13057.00 | 2001 | 18735 | 18713.00 |
| 1970 | 13017 | 13057.00 | 2002 | 19181 | 19167.00 |
| 1971 | 13055 | 13057.00 | 2003 | 19828 | 19846.00 |
| 1972 | 13563 | 13548.00 | 2004 | 20512 | 20533.00 |
| 1973 | 13867 | 13863.00 | 2005 | 20969 | 20948.00 |
| 1974 | 14696 | 14668.00 | 2006 | 21835 | 21842.00 |
| 1975 | 15460 | 15468.00 | 2007 | 23878 | 23867.00 |
| 1976 | 15311 | 15307.00 | 2008 | 25580 | 25586.00 |
| 1977 | 15603 | 15574.00 | 2009 | 27052 | 27055.00 |
| 1978 | 15861 | 15824.00 | 2010 | 28807 | 28818.00 |
| 1979 | 16807 | 16798.00 | MSE | 323.3 | |

## 6. Conclusions

In this paper we presented a hybrid algorithm to forecast enrolment based on fuzzy time series and genetic algorithms. Historical enrolments of the University of Alabama are used in this study to illustrate the forecasting process. From Table 5 we can see that when the number of intervals is bigger, then the accuracy rate will be higher, From Tables 5 and 6 we can see that the other effective element is the population size, when the population size was 50 the MSE=9816 but when the population size was 100 the MSE=246, with the same number of intervals. Figure 1 shows a comparison between actual and forecasted enrolment, We also compare our method with other methods, Table 7 shows that our method presents better forecasting results and can get a higher forecasting accuracy rate than the existing methods.

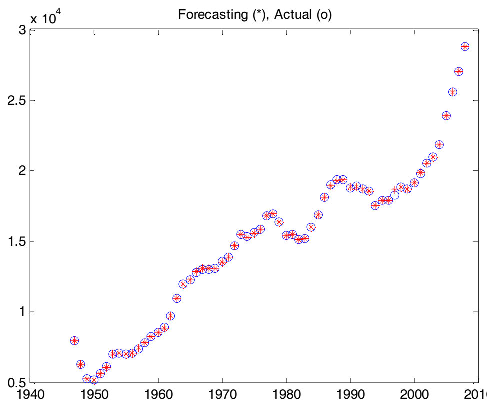


Figure 1. A comparison between actual and forecasted enrolment.

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**Haneen Al-Wazan** received her BSc degree in mathematics from the Department of Mathematics, College of Computers Sciences and Mathematics, Mosul University, Iraq 2005. Her MSc degree in numerical analysis from the Department of mathematics, College of Computers Sciences and Mathematics, Mosul University, Iraq 2008 and she is a PhD student in the research stage in time series analysis and forecasting using artificial intelligence techniques in the College of Computers Sciences and Mathematics, Mosul University, Iraq. Her research interests include numerical analysis, time series analysis and forecasting, fuzzy time series forecasting and forecasting using neural network. She is author of 7 research articles.

**Kais Ibraheem** received his MSc degrees in applied mathematics and PhD degrees in electrical engineering from Gadjah Mada University, Indonesia, in 1998 and 2003, respectively. He is currently a head of department of computer sciences faculty of education, Mosul University, Iraq. His research interests include artificial intelligence, wavelet, and numerical analysis.

**Abdul-Ghafoor Salim** received his BSc degree in mathematics from the Department of Mathematics, College of Sciences Mosul University, Iraq, 1984. His MSc degree in time series from the Department of Mathematics, College of Sciences Mosul University, Iraq, 1989. His PhD degree in time series from the Department of Mathematics, College of Sciences Mosul University, Iraq, 1996. His research interests include time series analysis, and forecasting. He is the author of over 30 research articles. He is the supervisor of 9 MSc thesis, and 5 PhD thesis. He participanted at many conferences inside and outside the country.