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RAINFALL PREDICTION ANALYSIS USING FUZZY TIME SERIES IN NAGAPATTINAM

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ABSTRACT. Rainfall is caused by a variety of meteorological conditions and the mathematical model for it is nonlinear. Forecasting is the process of predicting future outcomes, by which decision makers analyse the related data and graphs to decide and take the best decisions for the future. Multiple methods have been proposed to forecast the rainfall distribution but the accurateness is still a concern. Length of intervals greatly affects forecasting results in fuzzy time series (FTS). Hence, an effective length of intervals can significantly improve the forecasting results. The aim of the study is to compare the performance among fuzzy time series methods. In this study 10 years of rainfall data of Nagapattinam region is analysed using the statistical tools Root Mean Squared Error (RMSE) and Average Forecasting Error Rate (AFER).As a result, it is shown that, comparatively, improved Hwang and Chen method is best suited.

1. INTRODUCTION

Making decisions on forecasting is a complicated process. Due to the complexity of meteorological phenomena, accurate prediction of rainfall is challenging one. To plan our day-to-day activities accurate weather predictions are important. Farmers need information about the weather to plan for planting and harvesting their crops. Weather forecasting helps to keep us out of danger. Fuzzy

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logic is the most powerful linear model for forecasting of any time series. In 1993, Song and Chissom presented the theory of fuzzy time series. Fuzzy time series model deal with the both linguistic and numerical values. This paper is organised as follows: In section 2, the basic concept of fuzzy time series has been discussed. In section 3, review of related works is described in brief. In section 4, areas under study have been discussed. In section 5, fuzzy forecasting models are descried in brief.In section 6, we have compared the forecasting results. The conclusion is given section 7. Further references are [1, 9].

2. Basic Concept of Fuzzy Time Series

A time series represents a collection of values of certain events or tasks which are obtained with respect to time. Future prediction of time series events has been attracted people from its beginning. Song and Chissom developed a model, based on uncertainty and imprecise knowledge contained in time series data. They initially used the fuzzy sets concept to represent or manage all these uncertainties and referred this concept as Fuzzy Time Series (FTS). Researchers have developed numerous models based on the FTS concept to deal with the forecasting problems of short term as well as long term events. The following are some definitions related with fuzzy time series.

Definition 2.1. *(Time Series)*
A time series is a sequence of observations collected at regular time intervals when there is correlation among successive observations.

Definition 2.2. *(Fuzzy Time series) Let* $X(t)(t = \cdots, 0, 1, 2, \cdots)$*, a subset of real numbers, be the universe of discourse on which fuzzy sets* $f_i(t)(i = 1, 2, \cdots)$ *are defined. If*$F(t)$ *is a collection of*$f_1(t), f_2(t), \cdots$*, then* $F(t)$ *is called a fuzzy time series of* $X(t)$*.*

Definition 2.3. *(Fuzzy Relationship) Suppose* $F(t)$ *is implied by F(t-1) only, that is*$F(t-1) \rightarrow F(t)$*, then this relationship can be expressed as* $F(t) = F(t-1) \times R(t, t-1)$*) where* $R(t, t-1)$ *is the fuzzy relation between* $F(t-1)$ *and* $F(t)$ *and* $F(t) = F(t-1) \times R(t, t-1)$ *is called the first order model of* $F(t)$*.*

Definition 2.4. *(Invariant Fuzzy Time series) Let* $R(t, t-1)$ *be a first order model of* $F(t)$*. If for any t,* $R(t, t-1) = R(t-1, t-2), F(t)$ *is called a time invariant fuzzy time series. Otherwise, it is called variant time series.*

Definition 2.5. *(n-order Fuzzy time series) Let $F(t)$ be a fuzzy time series. If $F(t)$ is caused by $F(t-1), F(t-2), .F(t-n)$, then this fuzzy relationship is represented by $F(t_n), ., F(t-2), F(t-1) \rightarrow F(t)$ and is called an n- order fuzzy time series.*

Definition 2.6. *(AFER (Average Forecasting Error)) The formula for AFER is*

$$AFER = \frac{1}{n} \sum \frac{|R_i - f_i|}{R_i} \times 100\%,$$

where R_i and F_i are respectively the actual rainfall data and forecasting data in the i^{th} year.

Definition 2.7. *(RMSE(Root Mean Square Error)) The RMSE can be defined as*

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(R_i - F_i)^2}{n}},$$

where R_i and F_i are respectively the actual rainfall data and forecasting data in the i^{th} year.

3. Review Of Related Works

Song and Chissom [10, 11] first introduced the method of fuzzy time series for forecasting humidity and rainfall. In 1994, they proposed a model for forecasting enrollments using fuzzy time series. Later, Chen [2] presented a new method for forecasting university enrollment, which is more efficient than the method proposed by Song and Chissom. Hwang [5] proposed a new method on fuzzification to revise Song and Chissom's method. The result got a better forecasting error.In 2014, a modified method of forecasting enrollments based on fuzzy time series was developed by HaoFeng and Hongxuwang [3] based on the method proposed by Saxena, Sharma and Easo [8].

4. Data And Area Of Study

Nagapattinam is a coastal district situated on the eastern side of Tamil Nadu. Nagapattinam district was carved out by bifurcating the erstwhile composite Thanjavur district on October 19, 1991. The town of Nagapattinam is the district headquarters. The district lies on the east coast to the south of Cuddalore district and another part of the Nagapattinam district lies to the south of Karaikkal and Tiruvarur districts. The average maximum temperature of the district as

a whole is about 32°C and the average minimum temperature is 24.6°C. The Southwest winds sets in during April, it is the strongest in June and continues till September. Northeast monsoon starts during the month of October and blow till January. Cyclonic storm with varying wind velocity affects once in 3 or 4 years during the months of November-December. The storms affect the plantation crop. During Southwest monsoon the air is calm and undisturbed. The Northeast monsoon which starts in October and ends in December contributes about 60% of the total annual rainfall. The southwest monsoon rains occur from June to September. The average normal and actual rainfall is 265.2 and 250.6 mm respectively during south west monsoon while it is 908.8 and 969.2 mm respectively during north east monsoon during 2007-2008. The rainfall data set provided by the statistical department of Nagapattinam is given in Figure-2. It contains the annual rainfall (in mm) from 2008 to 2017.

5. Fuzzy Time Series Forecasting Model

First, we tested the model [2] with rainfall data to forecast the distribution. Then we applied the methods of [6], [3] and [4].

Steps for finding forecasting fuzzy time series (Chen's Method)
Chen [2] proposed a simple method to forecast the enrollment in fuzzy time series.
The six steps involved in the method is given below:
Step 1: Define the universe of discourse and partition it into equally lengthy intervals.
Step 2: Define fuzzy sets on the universe of discourse.
Step 3: Fuzzify historical data.
Step 4: Identify fuzzy logical relationship (FLR's).
Step 5: Establish fuzzy logical relationship groups (FLRG's).
Step 6: Establish fuzzy logical relationship groups (FLRG's).

Steps for finding forecasting fuzzy time series (Zhang and Wan's Method)
They proposed a modified method from Saxena and Easo's method. In this method the percentage change arrange in increasing order as the universe of discourse and established inverse fuzzy number of consecutive years. The steps followed are given below:
Step 1: List the historical data.

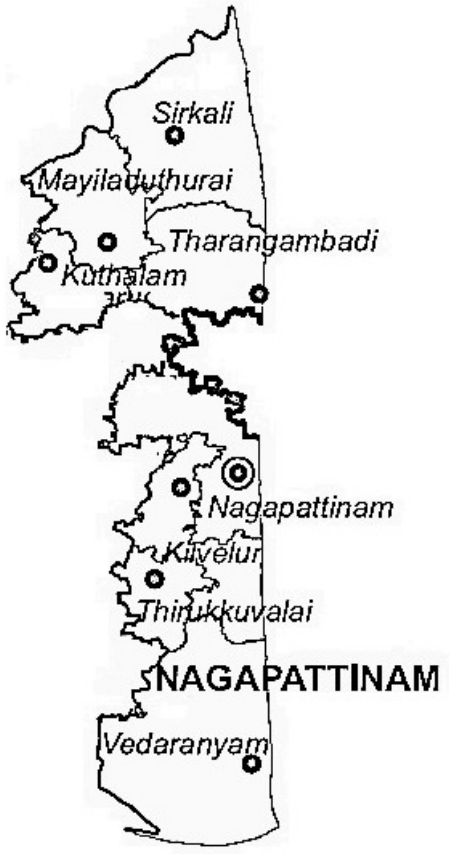

FIGURE 1. Map of Nagapattinam.

Step 2: Calculate the percentage change.
Step 3: Construct the discrete domain.
Step 4: Establish inverse fuzzy number.
Step 5: Defuzzify the forecasted output.

Steps for finding forecasting fuzzy time series (Modified Saxena and Easo's Method)

In [3], they proposed a modified method from [7]. In this method [3], the percentage change is used as universe of discourse and established inverse fuzzy number of consecutive years. The steps followed are given below:

Step 1: List the historical data.
Step 2: Calculate the percentage change.
Step 3: Establish discrete universe of discourse.

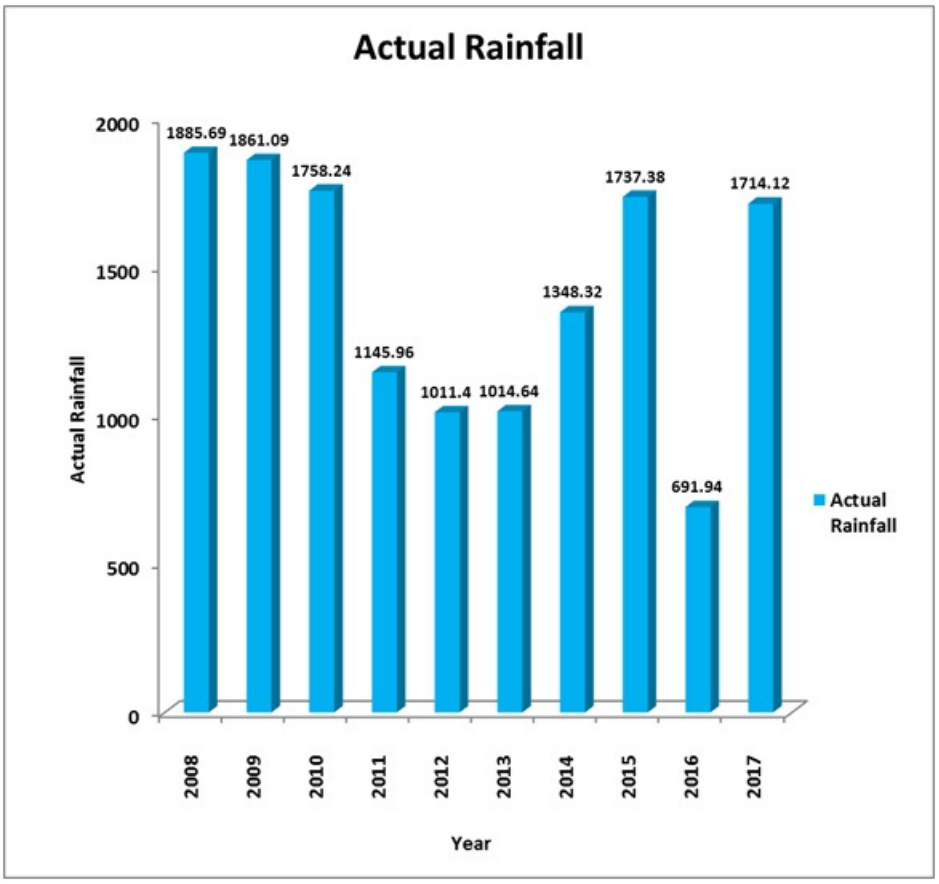

FIGURE 2. Annual rainfall year wise (2008-2017) in Nagapattinam.

Step 4: Establish inverse fuzzy number.
Step 5: Defuzzify the forecasted output.

Steps for finding forecasting fuzzy time series (Improved Hwang and Chen and Lee)

In this model, finding a domain of interval and change of percentage for historical data are not necessary. But greater adjustment in fuzzy inverse formula is used.

Step 1: List the historical data of annual rainfall.
Step 2: Find the yearly difference of actual rainfall data.
Step 3: Establish inverse fuzzy number.
Step 4: Establish a forecasting formula to forecast.

6. Comparison Of Different Forecasting Models

Forecasting values are obtained using Chen,Zhang and Wang, Modified Saxena and Easo andImproved Hwang and Chenmethods. Moreover, their RMSE and AFER are compared. The results are shown in Table-1.

TABLE 1. it can be seen the small value of RMSE and AFER, this confirms the goodness of forecasting model.

Year	Actual rainfall	Chen	Zhang and Wang method	Modified method of Saxena	Improved method of Hwang Chen
2008	1885.69				
2009	1861.09	1800	1739.43	1861.09	1861.09
2010	1758.24	1800	1769.	1758.29	1758.25
2011	1145.96	900	1186.09	1146.84	1146.40
2012	1011.40	1200	1014.16	1011.26	1010.81
2013	1014.64	1200	1015.01	1014.64	1014.64
2014	1348.32	1200	1375.62	1341.67	1344.96
2015	1737.38	1700	1425.46	1737.51	1737.43
2016	691.94	900	726.92	690.96	691.35
2017	1714.12	1100	1568.42	1714.83	1714.22
RMSE		240.7750	117.0600	2.1580	1.1045
AFER		14.3080%	4.4510%	0.0776%	0.0430%

7. Conclusion

Song and Chissom proposed the first forecasting model of fuzzy time series in 1993. In 1994, they proposed a model for forecasting enrollments using fuzzy time series. Later, Chen [1996] presented a new method for forecasting university enrollment, which is more efficient than the method proposed by Song and Chissom, as the proposed method uses simplified arithmetic operation rather than the complicated Max-Min composition operation.Up to now, many literatures and researchers research and develop this theory. In this paper, we calculated and compared the forecasted values of the rainfall data of kanyakumari district using the forecasting models, namely Chen, modified Saxena and

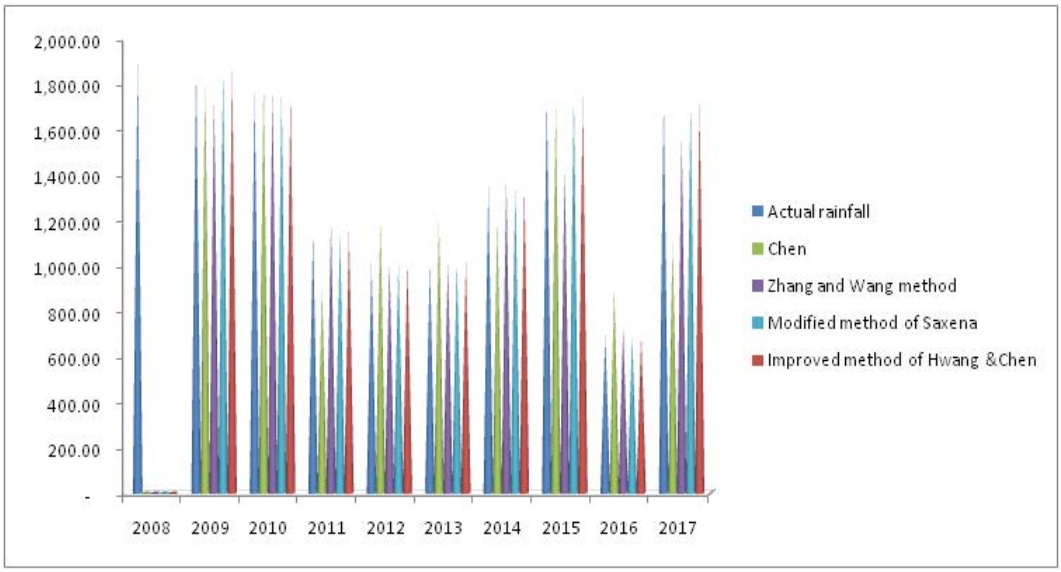

FIGURE 3. forecasting observation.

Easo and improved Hwang and Chen and Lee. From Table 1, we see that AFER and RMSE values are less in improved Hwang and Chen and Lee.

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