Rainfall Prediction In Nagapattinam Using Fuzzy Logic

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Abstract

Rainfall plays a vital role in human life rather than other weather events. As the variations are unpredictable, it difficult to predict rainfall over a region, so that rainfall forecasting carried out by the metrological department has been most crucial and demanding one. Fuzzy logic models have been proposed to perform forecasting, and its prime operations are fuzzification and defuzzification. These models are simple to employ but offer better results than statistical models. The present study explores the strength of forecasting models based on fuzzy logic rules. Furthermore, predicted results are compared with the actual rainfall data.

Keywords: Defuzzification, Fuzzification, Fuzzy logic, Rainfall, Temperature, Weather Forecast, Wind Speed.

1. Introduction

Agriculture in India relies on weather and climate conditions. Weather forecasts are key for the selection of crop choice, crop variety, etc. But it is a challenging task due to drastic climate variations. Weather data comprises different atmospheric traits such as temperature, wind speed, humidity, pressure, etc. Rainfall is a complex atmospheric process, which depends upon many weather related features. Timely and accurate forecasting of rainfall will be helpful in planning the water resources management, issuance of early flood warnings, construction activities, etc.

Time-series data analysis is one of the key features of modern researchers in the domain of knowledge discovery. Time-series data is collected over a specific period of time such as hourly, daily, weekly, monthly, quarterly or yearly. The application of fuzzy set theory has rapidly increased in many areas of the scientific world because it provides efficient methods to deal with uncertainties. In fuzzy logic approach, we can express crisp intervals in terms of linguistic variables like low, medium, high, good, moderate, poor etc. In this research work, the focus is on the development of a fuzzy logic model for predicting rainfall in the Nagapattinam district. The model uses a data set with input parameters wind speed and temperature.

2. Literature review

Halide and Ridd (2002) proposed fuzzy logic model to predict local rainfall data, Brown-Brandle et al (2003), have shown by means of comparison that fuzzy inference models provide better results than multiple regression models. In a similar research by Wong et al (2003), they have compared the results of fuzzy rule-based rainfall prediction with an established method which uses radial basis function networks and orographic effect.

According to Carrano et al. (2004), fuzzy models are most suitable when subjective and qualitative data are utilized and the numbers of pragmatic observations are limited. Thus, it is necessary to address the problems on the statistical models and the fuzzy rule-based models are the most appropriate alternative.
3. Area and data of study

Nagapattinam District was carved out of erstwhile Thanjavur District on October 18, 1991. Subsequently it was bifurcated in 1997 as Nagapattinam and Tiruvarur Districts. It is a very small district with a total geographical area of 2715.83 Sq. Kms. This constitutes just 2.09 % of the area of the State. Nagapattinam, on the east coast of Tamil Nadu in India has occupied a very important place in the medieval and subsequent periods in the history of Tamil Nadu, and was well known in all South-East Asian Countries.

The district shares borders with Thanjavur district, Tiruvarur district, Cuddalore district and Karaikal district of the union territory Puducherry. This district lies south of Cuddalore district and another part of the Nagapattinam district lies to the south of Karaikkal and Tiruvarur districts. Nagapattinam lies between Northern Latitude 10.7906 degrees and 79.8428 degrees’ Eastern longitude. Temperature, in the district, varies between 24.6 °C to 32.0 °C. The normal rainfall in this district is 1367.4 mm against the state average of 974.6 mm. This high rainfall supplements the Cauvery water for the high water requirements of paddy, which is the main crop of this district.
4. Methodology

This technique consists of two input variables and one output variable. The wind speed and the temperature at a given time are the input variables and the amount of precipitation estimated will be the output. The values of the input variables (temperature and wind speed) are divided into five linguistic variable terms, which are very low, low, normal, high, very high.

| SL.No | Linguistic variables | Representations |
|-------|----------------------|-----------------|
| 1.    | Very Low             | VL              |
| 2.    | Low                  | LW              |
| 3.    | Normal               | NR              |
| 4.    | High                 | HG              |
| 5.    | Very high            | VH              |

Table 1

Temperature Equation

The temperature series from 20°C - 40°C. The membership value of the temperature is defined as follows:

$$\mu_{VL}(T) = \begin{cases} -0.2T + 5 & \text{if } 20 \leq T \leq 25 \\ 0 & \text{if } T > 25 \end{cases}$$

$$\mu_{LW}(T) = \begin{cases} 0.2T - 4 & \text{if } 20 \leq T \leq 25 \\ -0.2T + 6 & \text{if } 25 \leq T \leq 30 \\ 0 & \text{if } T > 30 \end{cases}$$

$$\mu_{NR}(T) = \begin{cases} 0.2T - 5 & \text{if } 25 \leq T \leq 30 \\ -0.2T + 6 & \text{if } 30 \leq T \leq 35 \\ 0 & \text{if } T > 35 \end{cases}$$
\[ \mu_{HG}(T) = \begin{cases} 0.2T - 6 & \text{if } 30 \leq T \leq 35 \\ -0.2T + 6 & \text{if } 35 \leq T \leq 40 \\ 0 & \text{if } T < 30 \end{cases} \]

\[ \mu_{VH}(T) = \begin{cases} 0.2T - 7 & \text{if } 35 \leq T \leq 40 \\ 0 & \text{if } T < 35 \end{cases} \]

**Wind Speed Equation**

The temperature series from 0 Km/hr - 24 Km/hr. The membership value of the wind speed is defined as follows:

\[ \mu_{VL}(W) = \begin{cases} -0.2W + 1 & \text{if } 0 \leq W \leq 6 \\ 0 & \text{if } W > 6 \end{cases} \]

\[ \mu_{LW}(W) = \begin{cases} 0.2W & \text{if } 0 \leq W \leq 6 \\ -0.2W + 2.2 & \text{if } 6 \leq W \leq 12 \\ 0 & \text{if } W > 12 \end{cases} \]

\[ \mu_{HR}(W) = \begin{cases} 0.2W - 1.4 & \text{if } 6 \leq W \leq 12 \\ -0.2W + 3.4 & \text{if } 12 \leq W \leq 18 \\ 0 & \text{if } W > 18 \end{cases} \]

\[ \mu_{BH}(W) = \begin{cases} 0.2W - 2.6 & \text{if } 12 \leq W \leq 18 \\ -0.2W + 4.6 & \text{if } 18 \leq W \leq 24 \\ 0 & \text{if } W < 12 \end{cases} \]

\[ \mu_{VH}(W) = \begin{cases} 0.2W - 3.8 & \text{if } 18 \leq W \leq 24 \\ 0 & \text{if } W < 18 \end{cases} \]

5. **Result and discussion**

The restrictions used for the prediction of rainfall are temperature and wind speed. The output variable value is collected into five linguistic variables which are very low, low, normal, high, very high.

**For very low Rainfall:**

\[ R = \frac{M-1}{-0.02} \text{ if } 0 \leq R \leq 50 \]

**For low Rainfall:**
\[ R = \frac{M}{0.02} \text{ if } 0 \leq R \leq 50 \]
\[ R = \frac{M-2}{-0.02} \text{ if } 50 \leq R \leq 100 \]

For normal Rainfall:
\[ R = \frac{M+1}{0.02} \text{ if } 50 \leq R \leq 100 \]
\[ R = \frac{M-3}{-0.02} \text{ if } 100 \leq R \leq 150 \]

For high Rainfall:
\[ R = \frac{M+2}{0.02} \text{ if } 100 \leq R \leq 150 \]
\[ R = \frac{M-4}{-0.02} \text{ if } 150 \leq R \leq 200 \]

For very high Rainfall:
\[ R = \frac{M+3}{0.02} \text{ if } 150 \leq R \leq 200 \]

The table given below displays how the two input and the output values are correlated. The table is erected using a data derive from United States Department of Agriculture (USDA). The data involve of predictable amount of rainfall for a specific month and the values of temperature and wind speed. These archives were further standardized and fuzzified to be used to make the rules used for prediction by the fuzzy logic system.

| TP  | WS | VL  | LW  | NR  | HG  | VH  |
|-----|----|-----|-----|-----|-----|-----|
| VL  | VL | VL  | LW  | LW  | NR  |     |
| LW  | VL | VL  | LW  | NR  | NR  |     |
| NR  | LW | LW  | NR  | NR  | HG  |     |
| HG  | LW | NR  | NR  | HG  | HG  |     |
| VH  | NR | NR  | HG  | HG  | VH  |     |

Table 2  Relationship between Temperature, Wind Speed and amount of Rainfall

If (temperature is VL and Wind speed is VL) then Rainfall is VL.
If (temperature is LW and Wind speed is HG) then Rainfall is NR.
If (temperature is LW and Wind speed is NR) then Rainfall is L.W.
If (temperature is VH and Wind speed is HG) then Rainfall is HG.

The formula for predicting the rainfall is given by
\[ R = \frac{\mu(V_k) \cdot V}{\sum \mu(V_k)} \]  \text{ where } k = 1, 2, \ldots n \text{ and } V_k \text{ is the value of the variable and } \mu(V_k) \text{ is the membership of the variable.}
Fig. 3 Rainfall prediction

| Actual Rainfall | Predicted Rainfall | RMSE (Root mean square Error) | AFER (Average forecasting Error) |
|-----------------|---------------------|-------------------------------|----------------------------------|
| 694.52          | 993.32              | 60.02821                      | 32.12708                         |

6. Conclusion

In the present study, we have explored the potential of the fuzzy inference system model in forecasting. From Fig. 3 it is evident that there are few deviations between the predicted rainfall data and the actual rainfall data. Further, the study shows that the forecasting model is reliable and efficient and can be used for rainfall prediction.

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