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Prediction of rainfall using fuzzy logic

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ABSTRACT

Information on rainfall prediction has great significance in agricultural fields where most of the crop's irrigation depends on the rain water. Thus, rainfall prediction is a mandatory and an important process recently. Classical logic is further extended into fuzzy logic. Fuzzy logic has many advantages over classical logic. Two types of connotations of Fuzzy logic are: In narrow sense, Fuzzy Logic is a logical system, which is an extension of multivalued logic. The expert system of fuzzy consists of linguistics rules concerning the input variable of the fuzzy membership functions to the output variable of the fuzzy membership function. Fuzzy production rule IF-THEN statements relate the input variables of each other to define the result. Predicate logic operators such as AND operator is used to relate input and output variable. This paper proposed the prediction of rainfall using expert system model based fuzzy logic system for the demanding operational responsibilities needed by the meteorological department in the nation.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Newer Trends and Innovation in Mechanical Engineering: Materials Science.

1. Introduction

Prediction is trendy to be used as a source to carry out indispensable awareness for a forthcoming event. In the earlier days forecasting was in advance aimed to support human against the unlikable natural catastrophes. All over the world weather forecasting is the major essential also challenging functional responsibilities approved by meteorological facilities. By predicting weather conditions factors in the antecedent (IF) and consequent (THEN) parts that display an imprecision and uncertainty are being treated with reason and effective algorithms [1].

Forecasting of Rainfall is an essential and significant method now a days. Every year, many people were died and banished due to heavy rain and floods. Diverse reproductions are cast-off for prediction of rainfall with a statement that the course under examination is an inactive one and is rendering to the use of self-determining variables recitation events of rainfall [2]. Process of rainfall is associated approximately to forerunners from supplementary constraints such as, surface pressure for weekly to longer than daily time scale, sea surface temperature for seasonal time scales and other atmospheric parameters. Limited additional atmospheric restrictions embrace temperature, relative humidity, dew point and wind.

Rainfall is a stochastic procedure whose forthcoming event be contingent on some predecessors from other constraints such as the sea surface temperature for monthly to seasonal time scales, the surface pressure for weekly to daily time scale and other atmospheric constraints for daily to hourly time scale. Unpredictability of weather and climatic aspects, particularly those atmospheric constraints will be the major force for daily precipitation event. If unpredictability pattern could be documented and used for future path, feasibility of daily rainfall prediction is very much possible [3].

The concept of fuzzy logic is an analogous to the perception of emotions of human being and interpretation processes. Contrasting the classical controller approach, which is a point-to-point control system, fuzzy logic control system is a range-to-point or range-to-range control system. Fuzzy logic system concept was introduced by Zadeh in the year 1965 [4]. Fuzzy logic is intended at a reinforcement of methods of reasoning which are estimated rather than meticulous. Mamdani et al., [5] applied the fuzzy logic in a practical application to control an automatic steam engine in the year 1974 which is almost after ten years the theory of fuzzy logic was recognized. Bai et al [6] proposed the following steps that have

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to require implementing real time applications using fuzzy logic techniques.

1) Fuzzification – to renovate classical data or crisp data into fuzzy data or membership functions (MFs).
2) Fuzzy Inference Process –membership functions are combined with the control rules to send the fuzzy productivity.
3) Defuzzification – use dissimilar procedures to calculate the related output individually.

The rest of the paper is prearranged as follows. Section 2 analyses around the related work on rainfall prediction and fuzzy based systems. Section 3 designates about fuzzy logic modeling for rainfall prediction and section 4 details the results. Lastly, conclusion is given in section 5.

2. Related work

In this section, first we review the previous work on the modeling for predicting rainfall using various methodologies. The work related to fuzzy based system for various applications is discussed. A prototypical for forecasting rainfall using fuzzy set theory is discussed with USDA scan data for the year 2004 [1]. Temperature and wind speed parameters alone are used in the antecedent part of the production rules to predict rainfall. The percentage of error is high when compared to the calculated amount of actual rainfall. Pejman et al [2] estimated an adaptive neural fuzzy inference system for rainfall measures. The consequences are in high concord with the documented data through the station growing figures near the actual time rainfall measures. Agboola et al [7] studied the capability of fuzzy rules in modeling rainfall with two practical components such as knowledge base and fuzzy reasoning. The mold is flexible and able to model inaccurate connection among input and output variables. The reason could be improved with Artificial Neural Network (ANN) with improved Fuzzy Inference System (FIS). Gholam et al [8] discussed the yearly predicting of rainfall by Mamdani FIS to forecast rainfall in the historical data from December to May. The administrative belief of soft computing to adventure acceptance for fuzziness, vagueness, forcefulness, unfinished truth to accomplish manageability and recovering understanding with realism is used. To improve the model, we need to be provided more training data. Jing et al [9] proposed a weather conditions forecast prototypical built on neural network and FIS. The model simulates sequential relations among fuzzy sets using artificial neural network and neural FIS.

The system is modeled with backward neural networks, which can be modeled with another type of neural network to get better predictive results. AL-Matarneh et al [10] developed a temperature-based weather conditions forecasting models using Neural Networks and fuzzy logic to predict the temperature daily. The model uses only two procedures; discrepancy accounted and means of absolute error for predicting the forecast. For water saving in an irrigation system a fuzzy based system is presented in [11]. The system was developed using low cost Fuzzy Logic Controller (FLC) based automatic irrigation system to irrigate the crop professionally by saving water. The irrigation system saves the water usage and other nutrients to progress the yield of the crop. Yung-Hsiang et al [12] studied to transform a train correspondent's proficiency into a beneficial knowledge rule. Fuzzy Petri Net is adopted to devise the decision rules of train dispatchers in case of irregularity as the basis for outlook expansion of a transmitting choice sustenance system. The experiment discourses the anomalous situations, together with unified traffic control system failure, automatic train protection failure, and engine failure. Somia et al [13] applied rule-based reasoning and fuzzy logic with 5 constraints such as relative humidity, total cloud cover, wind direction, temperature and surface pressure using three membership functions for Cairo airport station and for Mersa Matruh station. Two skill scores such as Brier score and Friction score were used to analyze the results. Jimoh et al [14] discussed the effect of natural disaster such as flooding, heavy rainfall, scarcity etc. be prohibited with active planning and suggested that the forecast of forthcoming happening is a vital. Fuzzy logic system [15–18] model is proposed to predict the rainfall based on the given temperature of a particular geographical location.

3. Fuzzy logic modeling for rainfall prediction

Usage of fuzzy logic modeling is appropriate with ambiguous, imprecise and qualitative expression of the classification. Fuzzy rule sets have objects with similar properties. The distinguishing value for an object to a particular fuzzy rule set is considered as 1 and the value is outside the fuzzy rule set then it is considered as 0 [1]. An object with function value 1 be in the right place to set without any hesitation and values with membership function 0 unconditionally don't be in the right place to set. An object with transitional membership functions partially be in the right place to set.

Fuzzy sets are the group of objects with the similar characteristics, and in crisp sets the objects whichever belongs to the set or do not [1]. The function indicates the degree of truth as an addition to assessment. Degrees are perplexed with probabilities, and are abstractly distinct. Fig. 1 show the steps implicated in a fuzzy based system. The system functional components can be classified into two function. First, the fuzzy rule base to describe the membership functions of the fuzzy sets to be used in the fuzzy rules. Second, the decision-making section that perform the inference procedures on the rules.

If the data is available, then fuzzification is made to associate the input variables with the membership functions on the evidence fragment to attain the membership values from the evidence fragment to attain the membership values of each linguistic fuzzy set.

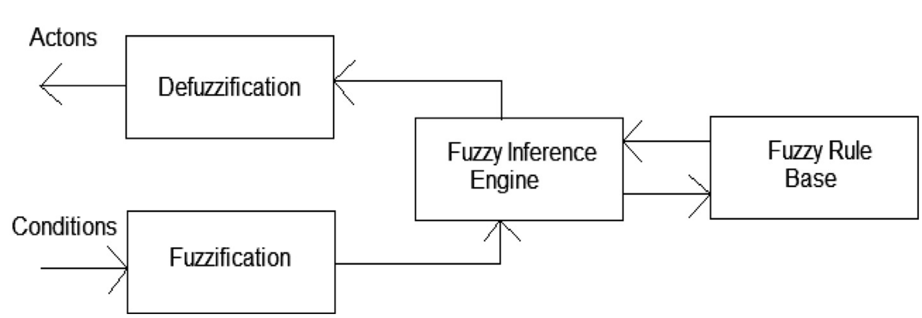

Fig. 1. Fuzzy base system.

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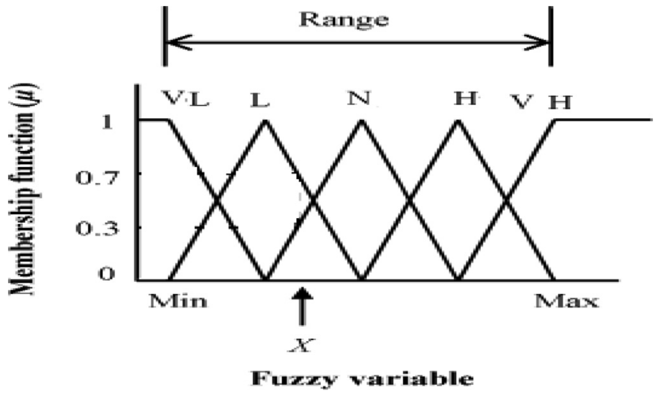

Fig. 2. Fuzzy variable.

The values are combined using min operator to obtain satisfied consequent of each rule based on the strong point. Then defuzzification is made to cumulative the qualified consequents to get the exact output.

The system has a range between least and most extreme value of any fuzzy variable. The value is alienated into appropriate number to characterize in ascending order beginning from the minimum to maximum value of the fuzzy set. The range is divided into five fuzzy levels as Very Low (VL), Low (L), Normal (N), High (H), and Very High (VH) as shown in Fig. 2. The fuzzy variable X intersects between two levels with membership function value (μ).

Table 1 shows the ranges for the linguistic fuzzy values. To calculate the rainfall prediction, we considered the following constraints are used to predict the rainfall forecasting: temperature, pressure, humidity, and wind speed. The linguistic expressions for various fuzzy levels are as follows:

$$var(x)=\begin{cases} VLif\,var(x)<0.25 \\ Lif\,0.0<var(x)<0.5 \\ Nif\,0.25<var(x)<0.75 \\ Hif\,0.5<var(x)<1.0 \\ VHif\,0.75<var(x)<1.0 \end{cases}$$

The corresponding membership function is obtained from the triangular membership function with a lower limit p, an upper limit q and a value m between p and q.

$$\mu_A(x)=\begin{cases} 0x\le p \\ \frac{x-p}{m-p}p<x\le m \\ 1x\ge q \end{cases}$$

The fuzzy variable X and the given membership function, $\mu \rightarrow [0, 1]$. The fuzzy set is defined as,

$$A=\{x,\mu A(x)|x\in X\}$$

The membership function $\mu_{A(x)}$ grasps decent for the efficient values,

$$\mu A(x)\geqslant 0, \upsilon x\in X$$

Table 1
Values with ranges.

Values	Ranges
(VL) Very Low	[0.00, 0.25]
(L) Low	[0.00, 0.50]
(N) Normal	[0.25, 0.75]
(H) High	[0.50, 1.00]
(VH) Very High	[0.75, 1.00]

The method of fuzzification involves to find the values of input variables, obtain the interconnecting points from the armaments of triangles to compute the levels in fuzzy, and to attain the corresponding membership function μ. The actual membership functions of various fuzzy levels are as follows:

$$VL(x)=\begin{cases} 0ifx\le 0 \\ \frac{x}{0.25}if0<x\le 0.25 \\ 1ifx\ge 0.25 \end{cases}$$

$$L(x)=\begin{cases} 0ifx<0 \\ \frac{x}{0.50}if0<x\le 0.50 \\ 1ifx\ge 0.50 \end{cases}$$

$$N(x)=\begin{cases} 0ifx<0.25 \\ \frac{x-0.25}{0.50}if0.25\le x<0.75 \\ 1ifx\ge 0.75 \end{cases}$$

$$H(x)=\begin{cases} 0ifx<0.50 \\ \frac{x-0.50}{0.50}if0.50\le x<0.1 \\ 1ifx\ge 1 \end{cases}$$

$$\mu_A(x)=\begin{cases} 0ifx\le 0.75 \\ \frac{x-0.75}{0.25}if0.75<x\le 1.0 \\ 1ifx\ge 1.0 \end{cases}$$

4. Results and discussion

Some of the parameters consider to influence the amount of rainfall is given in the Tables 2 and 3. Consider the Table 4 showing the regional meteorological data in various places of Tamil Nadu State for a period from March-May 2017 (Source – Regional Meteorological Centre, Chennai). Few aspects mainly consider to inspiration the volume of rainfall like wind speed, temperature, humidity, weather condition, etc., Fuzzy Production Rule IF-THEN statements [15–18] relate the input variables to each other to describe the result. AND operator ($\bigwedge$) and OR operator ($\bigvee$) is used in predicate logic to narrate the input and output variable [16–17].

Examples of Fuzzy Production Rules (FPRs) is given below for the rainfall prediction:

1. IF (WS is VL) $\bigwedge$ (TP is VL) THEN (RF is VL)
2. IF (WS is L) $\bigwedge$ (TP is L) THEN (RF is VL)
3. IF (WS is VH) $\bigwedge$ (TP is VH) THEN (RF is VH)

Table 2
Parameters.

Parameters	Minimum	Maximum	Average
Wind speed m/s	0.7	3.1	3.0
Rainfall	0.2	9.1	3.5
Temperature C	20.4	41.2	27.3

Table 3
Fuzzy variable.

Parameters	Fuzzy variable	Linguistic variable
Wind speed	WS	Very High WS, High WS, Normal WS, Low WS, Very Low WS
Rainfall	RF	Very High RF, High RF, Normal RF, Low RF, Very Low RF
Temperature	TP	Very High TP, High TP, Normal TP, Low TP, Very Low TP

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Table 4
Rainfall data.

Places	Actual(mm)	Predicted(mm)	Levels
Ariyalur	43.7	101.8	Low (L)
Chennai	1.8	58.5	Very Low (VL)
Coimbatore	170.5	150.3	Normal (N)
Cuddalore	23.3	81.7	Very Low (VL)
Dharmapuri	241.0	160.4	High (H)
Dindigul	151.4	168.0	Normal (N)
Erode	258.4	142.4	Very High (VH)
Kancheepuram	14.3	66.0	Very Low (VL)
Kanyakumari	152.4	288.3	Low (L)
Karaikal	205.3	66.6	Very High
Karur	127.7	109.2	Normal (N)
Krishnagiri	285.1	151.6	Very High (VH)
Madurai	177.3	144.8	High (H)
Nagapattinam	51.4	80.5	Low (L)
Namakkal	141.7	148.6	Normal (N)
Nilgiris	329.2	235.3	High (H)
Perambalur	122.1	108.9	Normal (N)
Pudukottai	54.4	97.5	Low (L)
Ramanathapuram	69.3	115.5	Low (L)
Salem	167.8	170.8	Normal (N)
Sivaganga	107.3	121.2	Normal (N)
Thanjavur	60.4	102.1	Low (L)
Theni	147.0	168.3	Normal (N)
Tirunelveli	178.0	166.2	Normal (N)
Tiruppur	106.2	135.1	Low (L)
Tiruvallur	15.9	67.2	Very Low (VL)
Tiruvannamalai	57.5	98.9	Low (L)
Tiruvarur	30.5	97.7	Very Low (VL)
Toothukudi	36.7	111.6	Very Low (VL)
Tiruchirapalli	107.8	109.9	Normal (N)
Vellore	106.9	106.5	Normal (N)
Villupuram	49.8	76.0	Low (L)
Virudhunagar	144.8	161.5	Normal (N)

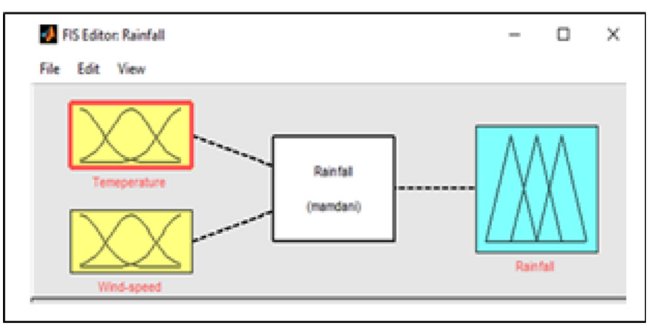

Fig. 3. FIS editor rainfall.

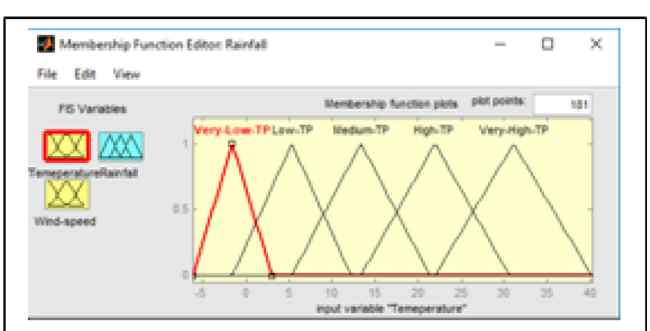

Fig. 4. Membership function editor.

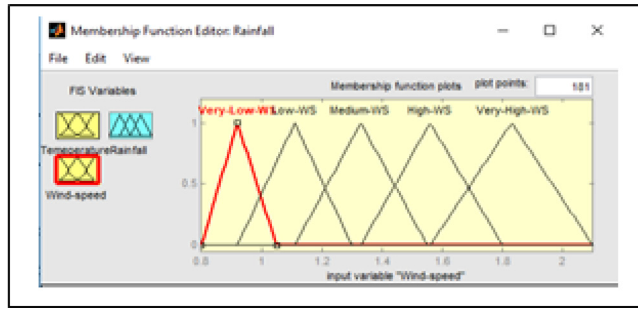

Fig. 5. Input membership function.

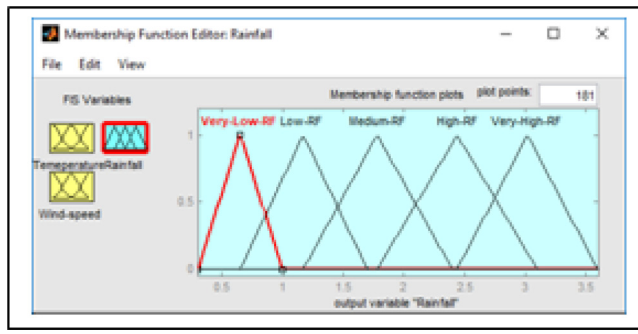

Fig. 6. Output membership function.

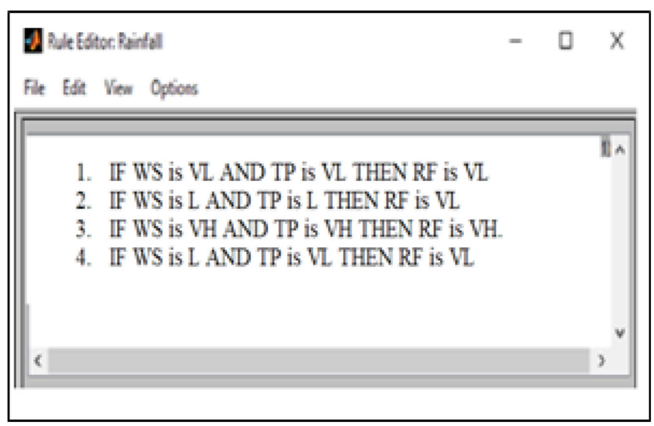

Fig. 7. Rules editor.

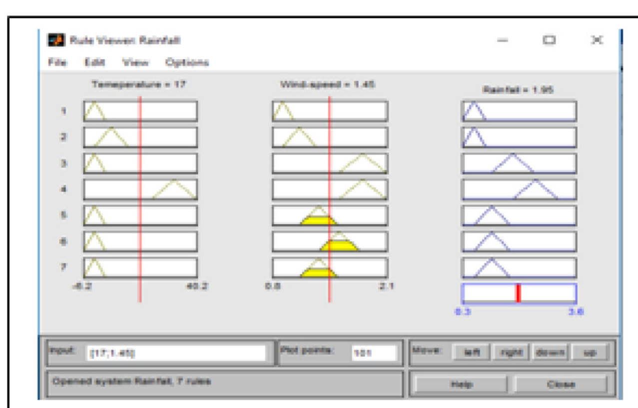

Fig. 8. Rule viewer.

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22. IF WS is H ⋀ TP is VH THEN RF is H.
23. IF WS is VH ⋀ TP is M THEN RF is H.

The fuzzy membership function (MF) of the given rainfall data can be shown as a triangular MF for input and output MF's. Base on the fuzzy production rule, Fuzzy Inference System (FIS) [15–17] is shown from Figs. 3–8.

5. Conclusion

This paper discussed an intelligent fuzzy model for rainfall events prediction. In the Fuzzy Production Rule, the Antecedent (IF part) and Consequent (THEN part) statements relate the input (Antecedent side) variable to each other to define the results. Predicate logic operators such as AND operator is used to narrate input (Antecedent side) and output (Consequent side) variable. Identifying the parameters and the fuzzy variables are used in the fuzzy logic that the values temperature (TP), Wind Speed (WS) was an effort to calculate amount of rainfall (RF). FIS is the most significant modeling tool created on fuzzy set theory.

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