PREDICTION OF MONSOON RAINFALL DISPERSION WITH FUZZY EXPERT SYSTEM

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ABSTRACT

Seasonal weather forecasting has the potential to play a significant role in enhancing end users' resilience to the impacts of climate change and variability. The Fuzzy Membership tool allows you to transform continuous input data based on a series of specific functions that are common to the Traiangular fuzzification process. Conjunction logical operator for the implication a fuzzy rule will have several antecedents that are used in conjunction to build our fuzzy rule. Defuzzification is the final step in a fuzzy system algorithm. Based on the output of a fuzzy system one has to give an estimate of the crisp quantity (a representative crisp element) for the output value of the SISO and MISO fuzzy system. A combination of satellite imagery and ground-based observations are used and using aircraft or satellites, and remote sensing (RS) collects data on distant objects or locations. In this paper, we used Tamil nadu weather data with fuzzy expert system for predicting Monsoon Rainfall dispersion.

Keywords: Conjunction, Fuzzification, Defuzzification, Rainfall

1.INTRODUCTION

Seasonal weather forecasting has potential to play a significant role in enhancing end users' resilience to the impacts of climate change and variability. Smallholder farmers, for example, are vital to the economies and food security within the majority of the developing world, yet they are confronted with increasingly scarce resources, changing weather patterns, and extreme events that pose significant threats to the stability of both production and income. Monthly forecasts can provide this key stakeholder group with information to support their decision making regarding which crops they should plant, when to plant and harvest, and when to apply fertilizer and other inputs to maximize their yields and mitigate their losses. Kyada(2) defined about that Seasonal rainfall forecasts can have significant value for Water resources planning and management e.g., reservoir operations, agricultural practices, town planning and flood emergency responses.

2.Mathematical Form of Fuzzy Compositonal Rule Based Expert System

Definition 1: Mamdani-Assilian defined the fuzzy rule base as,

If x is A then y is B.

as a fuzzy relation as follows

(i) Mamdani rule:

$$R_M\ (x, y) = A(x) \wedge B(y);$$

(ii) Larsen rule:

$$R_L\ (x, y) = A(x) \cdot B(y);$$

(iii) t-norm rule:

$$R_T\ (x, y) = A(x)T\ B(y), \text{ with T being an arbitrary t-norm.}$$

(iv) G¨odel rule:

$$R_G\ (x, y) = A(x) \rightarrow B(y),$$

with → being G¨odel implication;

(v) G¨odel residual rule:

$$R_R(x, y) = A(x) \rightarrow T\ B(y)$$

with →T being a residual implication with a given t-norm.

Definition 2: Fuzzy Composition

R is a set containing ordered pairs (x,y) for x ∈ A, y ∈ B. Let R and S be two relation defined on sets A, B and C. T is said to be composition of R and S.

$$R \subseteq A\ X\ B, S\ \subseteq B\ X\ C$$

$$T = S \cdot R\ \subseteq A\ X\ C$$

$$T = \{\ (x,z)\ /\ x \in A,\ y \in B,\ z \in c\ ;\ (x,y)\ \in R\ ,\ (y, z) \in S\}$$

Let R be a relation characterizing the set A. The composition of R and R is written as $R\ \cdot R$ (OR) R^2.

2.1 Triangular Membership function

This is specified by three parameters (a, b, c) with (a <b<c) determining the x Coordinates of the three angles. Variable x is the crisp value that its membership function is to be determined Within the Universe of discourse. Triangular members function can be represented mathematically by either of these two mathematical models

$$\text{(i)Triangle (x: a,b,c) = Max (Min} \left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0$$

$$\text{(ii) Triangle (x: a,b,c)} = \begin{cases} 0, x \leq a \\ \frac{x-a}{b-a}, a \leq x \leq b \\ \frac{c-x}{c-b}, b \leq x \leq c \\ 0, X \geq C \end{cases}$$

--------------------- (1)

Theorem 1:

For implication operator, For 1 singleton input, result C' is obtained from C and matching degree α_i

When a fuzzy rule R_1 and singleton input u_0 are given.

R_1 : If u is A Then w is C,

Or $R_1 : A \rightarrow C$

The inference result C' is defined by the membership function μ_c(w)

μ_c(w) = $\alpha_1 \wedge\ \mu_c$(w) (Mamdani implication)

μ_c(w) = $\alpha_1 . \mu_c$(w) (Larsen implication)

Where $\alpha_1\ = \mu_A(u_0)$

Proof

μ_{R1}(u,w) = μ_A(u) → μ_C(w)

By the compositional rule of inference

C’ = A’ ∘ R (A → C) = A’ ∘ R_1

In this case, A’ = u_0

μ_c(w) = $\mu_0 \circ (\mu_A(u) \rightarrow \mu_c\ (w))$

= $(\mu_A(u_0) \rightarrow \mu_c\ (w))$

If we apply min operator for the implication

$\mu_{C'}$(w) = min $[\mu_A(u_0) \rightarrow \mu_c\ (w))\ ]$

= $\alpha_1 \wedge (\mu_c\ (w))$ ---------------------(4)

(4) is consider to be MMIS method.

Similarly, if we use conjunction logical operator(1) for the implication a fuzzy rule will have several antecedents that are used in conjunction to build our fuzzy rule. For example a more complex fuzzy rule can be considered. in this case the antecedents are combined into a fuzzy relation A_i(u)∧ B_i(v). Then the Mamdani Assilian rule will be

If u is A_i and v is B_i then w is C_i, i = 1, ..., n.

$\mu_{C'}$(w) = $[(\mu_A(u_0) \wedge\ (\mu_B\ (v_0)) \rightarrow \mu_c\ (w]$

= $\alpha_1 \wedge (\mu_c\ (w))$

Where, α_1= $(\mu_A(u_0) \wedge \mu_B\ (v_0))$ -------------(5)

(5) is consider to be MACIS method in our thesis.

Between the antecedents we can use a general fuzzy conjunction (t-norm) but we do not have usually an implication between the antecedents since they are not in a cause effect relation with each-other.

Similarly, if we use Larsen product operator for the implication

$\mu_{C'}$(w) = $(\mu_A(u_0) \rightarrow \mu_c\ (w))$

= $(\mu_A(u_0)\ \cdot\ \mu_c\ (w))$

= = $\alpha_1 \cdot (\mu_c\ (w))$

α_1= $(\mu_A(u_0))$ --------------- (6)

(6) is consider to be LPOIS method in our thesis.

2.2**Defuzzification**

Defuzzification is the final step in a fuzzy system algorithm. Based on the output of a fuzzy system one has to give an estimate of the crisp quantity (a representative crisp element) for the output value of the SISO and MISO fuzzy system. In this case one has to use a defuzzification. There are many different defuzzification methods and based on the given application that we are working on, we can select a suitable defuzzification. With the help of center of average defuzzification, we found the definition MCOA and CCOA.

Definition 3 :

Min center of average (MCOA) for mamdani implication model. Here, we use SISO Method (i.e) Single input for Single output.

$$Z_{MCOA} = \frac{u_0 * \mu_A(u_0) + w * \mu_c(w)}{\mu_A(u_0) + \mu_c(w)} \quad \ldots\ldots\ldots\ldots (7)$$

$$Z'_{MCOA} = \frac{1}{2}\sum_{I=1}^{2} u_o * \mu_A(u_0) \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Definition 4 :

Conjuction center of average (CCOA) for mamdani Assilian implication model. Here, we use MISO method (i.e) multiple inputs are given for single output

$$Z_{CCOA} = \frac{u_0 * \mu_A(u_0) + u_0 * \mu_B(v_0) + w * \mu_c(w)}{\mu_A(u_0) + \mu_c(w)} \text{------------------}(9)$$

$$Z'_{CCOA} = \frac{1}{2}\sum_{I=1}^{5} u_o * \mu_A(u_0) \text{----------------}(10)$$

3.Applications for seasonal rainfall forecasting.

3.1 Data

Here we taken, 2021 Tamil Nadu, India weather data for predicting seasonal rainfall. Consider the set $\widetilde{M} = \{ \widetilde{M}_1, \widetilde{M}_2, \widetilde{M}_3 \ldots \ldots \ldots \ldots . \widetilde{M}_{12} \}$ as a universal sets where $\widetilde{M}_1, \widetilde{M}_2, \widetilde{M}_3 \ldots \ldots \ldots \ldots . \widetilde{M}_{12}$ represent the month from January to December for the Year 2021.

3.2 ALGOROITHM

STEP 1: List out the Input and Output weather parameters , for rainfall rediction in seasonal forecasting, which is detailed in Table (1)

S.no	Lingustic variable	Function	Membership function
1	Temperature $(\tilde{x}_1)$	Input	Triangular M F
2	Wind Speed $(\widetilde{x_2})$	Input	Triangular M F
3	Humidity $(\widetilde{x_3})$	Input	Triangular M F
4	Pressure $(\tilde{x}_4)$	Input	Triangular M F
5	Rainfall$(\tilde{x}_5{}')$	output	Triangular M F

Table 1: List of Parameter as I/O with M.F

$$\widetilde{W} = \{ (\widetilde{M}_1 \tilde{x}_1), (\widetilde{M}_1 \tilde{x}_2), (\widetilde{M}_1 \tilde{x}_3), (\widetilde{M}_1 \tilde{x}_4), (\widetilde{M}_1 \tilde{x}_5) \}$$

= { (22.85), (2.27), (86.88), (97.86), (100.2)}

STEP 2:

If we found the I/O weather parameters ranges are split it into Low, Moderate and High for all parameters, which is given in table (2)

S.no	Fuzzy set		
	Low	Moderate	High
Temperature	0 - 25	25 - 35	35 - 55
Wind speed	1 – 19	20 - 30	31 - 38
Humidity	40 – 62	63 - 79	80 - 96
Pressure	9601 - 9810	1011 - 1015	1016 - 1020
Rainfall	0 – 105	106 - 200	201 - 505

Table 2 : Ranges of Parameter

STEP 3:

Apply the real time data values in equ (1), we get

When $\widetilde{M}_1\tilde{x}_1 = 22.85$

$$\mu_{Low}(\widetilde{M}_1\tilde{x}_1) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_1 \geq 25 \\ 1 & \widetilde{M}_1\tilde{x}_1 = 0 \\ \dfrac{(25 - \widetilde{M}_1\tilde{x}_1)}{(25 - 0)} & 0 < \widetilde{M}_1\tilde{x}_1 < 25 \end{cases}$$

$$= 0.086$$

$$\mu_{Moderate}(\widetilde{M}_1\tilde{x}_1) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_1 \leq 26 \, or \, \widetilde{M}_1\tilde{x}_1 \geq 42 \\ \dfrac{(\widetilde{M}_1\tilde{x}_1 - 26)}{(35 - 26)} & 26 < \widetilde{M}_1\tilde{x}_1 < 35 \\ 1 & \widetilde{M}_1\tilde{x}_1 = 35 \\ \dfrac{(42 - \widetilde{M}_1\tilde{x}_1)}{(42 - 35)} & 35 < \widetilde{M}_1\tilde{x}_1 < 42 \end{cases}$$

$$\mu_{High}(\widetilde{M}_1\tilde{x}_1) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_1 \leq 43 \\ 1 & \widetilde{M}_1\tilde{x}_1 = 50 \\ \dfrac{(\widetilde{M}_1\tilde{x}_1 - 43)}{(50 - 41)} & 43 < \widetilde{M}_1\tilde{x}_1 < 50 \end{cases}$$

When $\widetilde{M}_1\tilde{x}_2 = 2.27$

$$\mu_{Low}(\widetilde{M}_1\tilde{x}_2) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_2 \geq 19 \\ 1 & \widetilde{M}_1\tilde{x}_2 = 1 \\ \dfrac{(19-\widetilde{M}_1\tilde{x}_2)}{(19-1)} & 1 < \widetilde{M}_1\tilde{x}_2 < 19 \end{cases}$$

=0.9294

$$\mu_{Moderate}(\widetilde{M}_1\tilde{x}_2) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_2 \leq 20 \; or \widetilde{M}_1\tilde{x}_2 \geq 28 \\ \dfrac{(\widetilde{M}_1\tilde{x}_2 - 20)}{(24-20)} & 20 < \widetilde{M}_1\tilde{x}_2 < 24 \\ 1 & \widetilde{M}_1\tilde{x}_2 = 24 \\ \dfrac{(33-\widetilde{M}_1\tilde{x}_2)}{(33-24)} & 24 < \widetilde{M}_1\tilde{x}_2 < 33 \end{cases}$$

$$\mu_{High}(\widetilde{M}_1\tilde{x}_2) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_2 \leq 34 \\ 1 & \widetilde{M}_1\tilde{x}_2 = 38 \\ \dfrac{(\widetilde{M}_1\tilde{x}_2 - 34)}{(38-34)} & 34 < \widetilde{M}_1\tilde{x}_2 < 38 \end{cases}$$

When $\widetilde{M}_1\tilde{x}_3 = 86.88$

$$\mu_{Low}(\widetilde{M}_1\tilde{x}_3) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_3 \geq 62 \\ 1 & \widetilde{M}_1\tilde{x}_3 = 40 \\ \dfrac{(62-\widetilde{M}_1\tilde{x}_3)}{(62-40)} & 40 < \widetilde{M}_1\tilde{x}_3 < 62 \end{cases}$$

$$\mu_{Moderate}(\widetilde{M}_1\tilde{x}_3) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_3 \leq 63 \; or \widetilde{M}_1\tilde{x}_3 \geq 79 \\ \dfrac{(\widetilde{M}_1\tilde{x}_3 - 63)}{(72-63)} & 63 < \widetilde{M}_1\tilde{x}_3 < 72 \\ 1 & \widetilde{M}_1\tilde{x}_3 = 72 \\ \dfrac{(79-\widetilde{M}_1\tilde{x}_3)}{(79-72)} & 72 < \widetilde{M}_1\tilde{x}_3 < 79 \end{cases}$$

$$\mu_{High}(\tilde{M}_1\tilde{x}_3) = \begin{cases} 0 & \tilde{M}_1\tilde{x}_3 \leq 80 \\ 1 & \tilde{M}_1\tilde{x}_3 = 96 \\ \dfrac{(\tilde{M}_1\tilde{x}_3 - 80)}{(96-80)} & 80 < \tilde{M}_1\tilde{x}_3 < 96 \end{cases}$$

$= 0.43$

When $\tilde{M}_1\tilde{x}_4 = 97.86$

$$\mu_{Low}(\tilde{M}_1\tilde{x}_4) = \begin{cases} 0 & \tilde{M}_1\tilde{x}_4 \geq 98.10 \\ 1 & \tilde{M}_1\tilde{x}_4 = 96.01 \\ \dfrac{(98.10 - \tilde{M}_1\tilde{x}_4)}{(98.10-96.01)} & 96.01 < \tilde{M}_1\tilde{x}_4 < 98.10 \end{cases}$$

$= 0.11$

$$\mu_{Moderate}(\tilde{M}_1\tilde{x}_4) = \begin{cases} 0 & \tilde{M}_1\tilde{x}_4 \leq 98.11\ or \tilde{M}_1\tilde{x}_4 \geq 105.5 \\ \dfrac{(\tilde{M}_1\tilde{x}_4 - 98.11)}{(99.13-101.5)} & 98.11 < \tilde{M}_1\tilde{x}_4 < 99.13 \\ 1 & \tilde{M}_1\tilde{x}_4 = 105.5 \\ \dfrac{(101.5 - \tilde{M}_1\tilde{x}_4)}{(101.5-99.13)} & 101.5 < \tilde{M}_1\tilde{x}_4 < 105.5 \end{cases}$$

$$\mu_{High}(\tilde{M}_1\tilde{x}_4) = \begin{cases} 0 & \tilde{M}_1\tilde{x}_4 \leq 105.6 \\ 1 & \tilde{M}_1\tilde{x}_4 = 120.0 \\ \dfrac{(\tilde{M}_1\tilde{x}_4 - 105.6)}{(120.0-105.6)} & 105.6 < \tilde{M}_1\tilde{x}_4 < 120.0 \end{cases}$$

When $\tilde{M}_1\tilde{x}_5 = 100.2$

$$\mu_{Low}(\tilde{M}_1\tilde{x}_5) = \begin{cases} 0 & \tilde{M}_1\tilde{x}_5 \geq 105 \\ 1 & \tilde{M}_1\tilde{x}_5 = 0 \\ \dfrac{(105 - \tilde{M}_1\tilde{x}_5)}{(100- \ 0)} & 0 < \tilde{M}_1\tilde{x}_5 < 105 \end{cases}$$

$= 0.0457$

$$\mu_{Moderate}(\tilde{M}_1\tilde{x}_5) = \begin{cases} 0 & \tilde{M}_1\tilde{x}_5 \leq 106\ or \tilde{M}_1\tilde{x}_5 \geq 300 \\ \dfrac{(\tilde{M}_1\tilde{x}_5 - 106)}{(150-106)} & 106 < \tilde{M}_1\tilde{x}_5 < 150 \\ 1 & \tilde{M}_1\tilde{x}_5 = 150 \\ \dfrac{(300 - \tilde{M}_1\tilde{x}_5)}{(300-150)} & 150 < \tilde{M}_1\tilde{x}_5 < 300 \end{cases}$$

$$\mu_{High}(\widetilde{M}_1\tilde{x}_5) = \begin{cases} 0 & \widetilde{M}_1\tilde{x}_5 \le 301 \\ 1 & \widetilde{M}_1\tilde{x}_5 = 650 \\ \dfrac{(\widetilde{M}_1\tilde{x}_5 - 301)}{(650-301)} & 301 < \widetilde{M}_1\tilde{x}_5 < 650 \end{cases}$$

STEP 4 : MMIS Method

Step 4.1 : we found the membership values for $\widetilde{M}_1$ to $\widetilde{M}_{12}$ by the equ (1)

Step 4.2 :

R: If Temperature is (Low (or) Moderate (or) High) Then Rainfall is (Low (or) Moderate (or) High)

Now we have to find the inference value with above rule. we get,

$$\widetilde{W}_1 = \mu_{Low}(\widetilde{M}_1\tilde{x}_1) \wedge \mu_{Low}(\widetilde{M}_1\tilde{x}_5)$$

= (0.0475 , 0.086)

Step 4.3 : By using MCOA equ (7 and 8) , the above values becomes,

$$Z_{MCOA} = \frac{0.0457 \text{ X } 100.2+0.086 \text{ X } 22.85}{0.0457+0.086} = 49.69\ \%.$$

(i.e) Z_{MCOA} found the rainfall percentage as 49.69 % for January month.

$$z'_{MCOA} = \frac{0.0457 \text{ X } 100.2+0.086 \text{ X } 22.85}{2} = 3.27\%$$

(i.e) z'_{MCOA}found the rainfall percentage as 3.27 % for January month.

STEP 5: MACIS Method

Step 5.1 : we found the fuzzy value with triangular membership function of equ (1)

Step 5.2 :

R: If Temperature is (Low (or) Moderate (or) High) and Wind speed is (Low (or) Moderate (or) High) and Humidity is (Low (or) Moderate (or) High) and Pressure is (Low (or) Moderate (or) High)

Then Rainfall is (Low (or) Moderate (or) High)

For system of rules - be jointly satisfied, the rules are connected by "and" connectives. Here, the aggregated output, $\widetilde{W}$is determined by the fuzzy intersection of all individual rule consequents, $\widetilde{W}$where i=1, 2,…n as

$$\widetilde{W}'_1 = \mu_{Low}(\widetilde{M}_1\tilde{x}_1) \wedge \mu_{Low}(\widetilde{M}_1\tilde{x}_2) \wedge \mu_{High}(\widetilde{M}_1\tilde{x}_3) \wedge \mu_{Low}(\widetilde{M}_1\tilde{x}_4) \wedge \mu_{Low}(\widetilde{M}_1\tilde{x}_5)$$

= ((0.0475) , (0.086) , (0.9294) ,(0.43) , (0.11))

Step 5.3: By

using CCOA Equation (9 and 10), the above values becomes,

$$Z_{CCOA} = \frac{0.086 \text{ X } 22.85+0.9294 \text{ X } 2.27+0.43 \text{ X } 86.88+0.11 \text{ X } 97.86+0.0457 \text{ X } 100.2}{0.086+0.9294+0.43+0.11+0.0457}$$

= 35.46 %

(i.e) Z_{CCOA} found the rainfall percentage as 35.46 % for January month.

$$Z'_{CCOA} = \frac{0.086 \text{ X } 22.85+0.9294 \text{ X } 2.27+0.43 \text{ X } 86.88+0.11 \text{ X } 97.86+0.0457 \text{ X } 100.2}{2}$$

$$= 28.38\ \%$$

(i.e) Z'_{CCOA} found the rainfall percentage as 28.38 % for January month.

Repeat the above process from Step 1 to Step 3 and Step 5 for MACIS method for remaining months, which are detailed given in the table. (3)

3.3 RESULT

Month	Seasonal	Actual Rainfall values	Forecasted Rainfall Values			
			Z_{MCOA}	Z_{CCOA}	Z'_{MCOA}	Z'_{CCOA}
January	Winter	100.2	49.69	35.46	3.27	28.38
February		15.82	16.21	30.29	7.24	40.24
March	Summer	0	11.35	6.44	-	14.01
April		39.62	35.72	29.85	23.26	38.55
May		142.2	98.55	72.99	66.65	95.09
June	South West monsoon	56.77	46.43	40.44	18.32	49.47
July		147	130.41	76.35	70.55	111.0
August		117.61	78.45	52.05	17.37	67.37
September		160.69	114.94	73.42	80.96	99.87
October	North east monsoon	208.33	195.18	82.58	64.25	94.51
November		404.2	351.44	93.99	60.32	106.58

December		232.14	192.56	78.24	53.68	76.61

Table 3: Prediction of Seasonal Rainfall values with fuzzy expert system.

4.CONCLUSION:

When we compare above four methods Z_{MCOA} are highly efficient for finding summer, south west monsoon and north east monsoon with fuzzy expert system.In this effort, Pressure, Temperature, Humidity, wind speed and Rainfall of Month wise are taken as an important parameter for predicting monthly outlook – Rainfall forecasting based on fuzzy expert system with product conjunction. This proposed method is used - determination of founding distribution of seasonal rainfall for monthly outlook as whether the month got Rainfall .

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