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AN ANALYSIS OF THE SHORTCOMINGS OF WEATHER FORECAST BY IMD OVER DEVELOPED COUNTRIES USING NEUTROSOPHIC FUZZY WEIGHTED MULTI EXPERT ARTIFICIAL NEURAL NETWORK SYSTEM

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Abstract:
The Indian Meteorological Department (IMD) plays a vital role in forecasting weather. Since India, basically an agricultural nation which purely depends on monsoons, the prediction of future happenings such as rainfall, extreme coolness, hotness, disasters such as flood, storm, strong wind blow and so on are very much important in long term planning. But the prediction of weather fails many a times in India which makes us to compare with the developed countries such as USA, Japan and other western nations where the accuracy of weather prediction is very high. The factors contributing to the shortcomings of IMD must be analyzed for suggesting better ideas and tactics for which, this research article is a step towards it. In this paper Neutrosophic Fuzzy weighted multi expert artificial neural network system is employed which is an inventive and distinct approach from the earlier ones.

Key Words: IMD, Weather, Prediction, Neutrosophic, Fuzzy Weighted, Multi Expert, Artificial Neural Network System & Trapezoidal Fuzzy Number.

1. Introduction:

Agriculture is the backbone of India's economy which is solely a rain-fed one. The entire set of activities of the process depends mainly on many natural factors whose occurrences are highly indeterministic, but they are predictable. The intimation of these natural happenings to the farmers is done by national meteorological agencies. The calendar year is segmented into four seasons namely winter (Jan, Feb), pre monsoon (Mar, Apr, May), south west monsoon (June, July, Aug, Sep), post monsoon (Oct, Nov, Dec). The pre steps of forecasting are monitoring and preparation of climatology and the forecasting types are now, short range, medium range and long range. The theory behind predictions and the forecasting techniques such as statistical and synoptic methods employed are compatible, inspite of it; the accuracy is low which creates a feel of inconsistency. But the weather prediction of developed nations is good and reliable. The reason for taking such efforts by these developed nations in accurate weather forecast is that the people are very cautious and they plan their daily activities in accordance to it. Though Indian technologies are upgraded and improvised, still there are shortcomings. With regard to this the Indian meteorology experts state that there are many physical hurdles with respect to climate and monsoons. In other hand, the deficit of atmospheric models encompassing many features also contributes to it. Several researchers are working in this area in theoretical aspect but not in scientific perspective. To explore these reasons in a more insightful manner a mathematical inference making tool is used in this paper. Artificial Neural Networks are predominantly used in decision making which is the resultant of inference making and analysis [4, 5]. The functioning mechanisms of these networks are the replica of biological neural systems. These ANN have three layers such as input, hidden and output. The inputs are activated using activation functions. In this research work the opinion of the experts with the bias as -1 are considered as inputs, and the inputs are obtained as the defuzzified values of the concepts expressed as trapezoidal linguistic values. In the earlier works the experts give their feedback on each concepts in terms of numerical values from [0, 1], but in this paper the feedback is given in terms of fuzzy linguistic variables. The paper is structured as follows: section 2 contains the preliminaries; section 3 confers the factors contributing to the shortcomings of IMD; section 4 consists of the methodology; section 5 discusses the results and section 6 concludes the paper.

2. Preliminaries:

The elementary concepts that are used in this paper are listed below [7,11].

The bias is the value of the aggregate of weights of inputs around which the output of the neuron is highly sensitive to get altered in the sum. In case of neural networks the bias is -1.

The sigmoid function or sigmoidal curve or logistic function is the function $S_\beta = \frac{1}{1+e^{-x}}$

A fuzzy set $\tilde{A}$ is defined by $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) : x \in X, \mu_{\tilde{A}}(x) \in [0, 1]\}$. In the pair $\{(x, \mu_{\tilde{A}}(x))\}$, the first element x belong to the classical set A, the second element $\mu_{\tilde{A}}(x)$, belong to the interval [0, 1], called membership function or grade of membership.

The membership function is also a degree of compatibility or a degree of truth of x in $\tilde{A}$.

A fuzzy number is any fuzzy subset of the real line R, whose membership function satisfies the following conditions, is a generalized fuzzy number $\mu_{\tilde{A}}(x)$ is a continuous mapping from R to the closed interval [0, 1].

$\mu_{\tilde{A}}(x) = 0, -\infty < x \le a_1,$

$\mu_{\tilde{A}}(x) = L(x)$ is strictly increasing on $[a_1, a_2]$,

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$\mu_{\tilde{A}}(x) = 1, a_2 \le x \le a_3,$

$\mu_{\tilde{A}}(x) = R(x)$ is strictly decreasing on $[a_3, a_4]$,

$\mu_{\tilde{A}}(x) = 0, a_4 \le x < \infty$, where a_1, a_2, a_3 and a_4 are real numbers.

A **Trapezoidal Fuzzy Number:** The fuzzy number $\tilde{A}(a_1, a_2, a_3, a_4)$ where $a_1 < a_2 < a_3 < a_4$ and defined on R is called the trapezoidal fuzzy number, its membership function $\tilde{A}$ is given by

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a_1 \text{ or } x > a_4 \\ \dfrac{x - a_1}{a_2 - a_1}, & a_1 \le x < a_2 \\ 1, & a_2 \le x < a_3 \\ \dfrac{x - a_4}{a_3 - a_4}, & a_3 \le x \le a_4 \end{cases}$$

Defuzzification of Trapezoidal Fuzzy Number: The trapezoidal fuzzy number is defuzzfied by median method where $A = (a_1 + a_2 + a_3 + a_4) / 4$

Contributing Factors of the Shortcomings of IMD:

The factors that lead to the low accuracy of weather prediction are as follows

- ✓ Geographical location
- ✓ Complex monsoon Climate
- ✓ Deficit of advanced atmospheric models
- ✓ Need of better technologies
- ✓ Demand of Human Resource
- ✓ Disinterest of people in knowing about the day's weather.
- ✓ Indian Nation is not disaster prone one
- ✓ Much weather forecast provisions are not encouraged

Geographical Location: The latitude and longitude location of our nation is 28^0 38' N and 77^0 13' E respectively. The varied topography and vast geographical scale makes the generalization highly difficult.

Complex Monsoon Climate: The tropical climate is prevailing in our nation. The seasonal change in the wind direction is monsoon. The characteristics of this climate are complex and highly dependent on monsoons.

Deficit of Advanced Atmospheric Models: The modeling of atmospheric changes is very much important in weather forecasting. The problem in devising suitable models without many assumptions and encompassing of several factors is highly difficult.

Need of Better Technologies: The technologies used by our IMD are good but still the need of better technologies for better expected weather prediction with high degree of accuracy exists.

Demand of Human Resource: Human resource is needed for the execution of any type of activity. Ranging from top executive level to labour category the demand of human power is required. The necessity of efficient people at decision making and policy formation cadre is still prevailing.

Disinterest of People in Knowing about the Day's Weather: The people of India are not much interested in knowing each day's weather. They do not plan according to the weather report, rather they manage with the fluctuating weather. In brief they are bothered about long range forecast rather than short range forecast.

Indian Nation is Not Disaster Prone One: Our nation is not prone any sort of disaster, it means the occurrence of major calamities are not as frequent as in America, Japan and other nations.

Much Weather Forecast Provisions are not Encouraged: In western nations separate channels are telecasted for weather forecast but in our nation the weather report concludes the news telecasted in our channels. This indicates that several weather forecast provisions lack encouragement.

3. Methodology:

The factors discussed in the last section are considered for study which are labeled as follows

Trz C1	Geographical location
Trz C2	Complex monsoon Climate
Trz C3	Deficit of advanced atmospheric models
Trz C4	Need of better technologies
Trz C5	Demand of Human Resource
Trz C6	Disinterest of people in knowing about the day's weather.
Trz C7	Indian Nation is not disaster prone one
Trz C8	Much weather forecast provisions are not encouraged

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These are considered as inputs as follows

X1 Geographical location
X2 Complex monsoon Climate
X3 Deficit of advanced atmospheric models
X4 Need of better technologies
X5 Demand of Human Resource
X6 Disinterest of people in knowing about the day's weather.
X7 Indian Nation is not disaster prone one
X8 Much weather forecast provisions are not encouraged

Five expert's opinion are obtained in terms of linguistic variables which are tabulated as follows

Expert	X0	X1	X2	X3	X4	X5	X6	X7	X8
E1	H	VH	H	MH	M	H	L	L	VL
E 2	M	VH	VH	H	H	MH	ML	M	L
E 3	VH	H	H	H	H	M	ML	M	L
E 4	H	VH	VH	VH	H	H	M	L	ML
E 5	MH	H	H	MH	MH	M	L	L	L

The quantification of the linguistic variables in terms of the triangular fuzzy number is

Very Low (VL)	(0,0.05,0.1,0.2)
Low (L)	(0.05,0.1,0.2,0.3)
Medium Low/Lower Intermediate (ML)	(0.1,0.2,0.3,0.4)
Medium (M)	(0.2,0.3,0.4,0.5)
Medium High/Higher Intermediate (MH)	(0.3,0.4,0.5,0.6)
High (H)	(0.6,0.6,0.7,0.8)
Very High (VH)	(0.8,0.9,1,1)

Expert	X0	X1	X2	X3	X4	X5	X6	X7	X8
E1	(0.6,0.6, 0.7,0.8)	(0.8,0.9, 1,1)	(0.6,0.6,0. 7,0.8)	(0.3,.4,0.5 ,0.6)	(0.2,0.3,0. 4,0.5)	(0.6,0.6,0. 7,0.8)	(0.05,0.1,0 .2,0.3)	(0.05,0.1,0 .2,0.3)	(0,0.05,0.1 ,0.2)
E 2	(0.2,0.3, 0.4,0.5)	(0.8,0.9, 1,1)	(0.8,0.9,1, 1)	(0.6,0.6,0. 7,0.8)	(0.6,0.6,0. 7,0.8)	(0.3,.4,0.5 ,0.6)	(0.1,0.2,0. 3,0.4)	(0.2,0.3,0. 4,0.5)	(0.05,0.1,0 .2,0.3)
E 3	(0.8,0.9, 1,1)	(0.6,0.6, 0.7,0.8)	(0.6,0.6,0. 7,0.8)	(0.6,0.6,0. 7,0.8)	(0.6,0.6,0. 7,0.8)	(0.2,0.3,0. 4,0.5)	(0.1,0.2,0. 3,0.4)	(0.2,0.3,0. 4,0.5)	(0.05,0.1,0 .2,0.3)
E 4	(0.6,0.6, 0.7,0.8)	(0.8,0.9, 1,1)	(0.8,0.9,1, 1)	(0.8,0.9,1, 1)	(0.6,0.6,0. 7,0.8)	(0.6,0.6,0. 7,0.8)	(0.2,0.3,0. 4,0.5)	(0.05,0.1,0 .2,0.3)	(0.1,0.2,0. 3,0.4)
E 5	(0.3,0.4, 0.5,0.6)	(0.5,0.6, 0.7,0.8)	(0.6,0.6,0. 7,0.8)	(0.3,.4,0.5 ,0.6)	(0.3,.4,0.5 ,0.6)	(0.2,0.3,0. 4,0.5)	(0.05,0.1,0 .2,0.3)	(0.05,0.1,0 .2,0.3)	(0.05,0.1,0 .2,0.3)

The defuzzified tabulated values are

Expert	X0	X1	X2	X3	X4	X5	X6	X7	X8
E1	0.68	0.925	0.68	0.45	0.35	0.68	0.163	0.163	0.09
E 2	0.35	0.925	0.925	0.68	0.68	0.45	0.25	0.35	0.163
E 3	0.925	0.68	0.68	0.68	0.68	0.35	0.25	0.35	0.163
E 4	0.68	0.925	0.925	0.925	0.68	0.68	0.35	0.163	0.25
E 5	0.45	0.68	0.68	0.45	0.45	0.35	0.163	0.163	0.163

The average of the weightage given by the experts is

E1	E2	E3	E4	E5
0.51	0.58	0.57	0.67	0.42

The input is taken as the average of the weightage given by the experts together with the bias -1 as in neural network.

X0	X1	X2	X3	X4	X5	X6	X7	X8
-1	0.62	0.83	0.78	0.64	0.57	0.5	0.24	0.23

The corresponding output is given by

$Y_i = S_\beta \left(\sum_{i=0}^{5} W_i \; X_i \right)$ where W_i is the weight given by the experts.

$S_\beta(a) = (1 + \exp(-\beta a))^{-1}$

The tabulation of the output Yi is as follows

Y1	Y2	Y3	Y4	Y5
0.83	0.92	0.81	0.92	0.82

The altogether opinion of the experts pertaining to the factors causing hurdles in weather prediction happens to be > 0.1 To make an inference the following fuzzy set along with the membership function is defined.

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$\mu : E \rightarrow [0,1]$, where E = { E1,E2,E3,E4,E5}

$$\mu(E) = \begin{cases} 0 & \text{if } Ei < 0.40 \\ 0.91 & \text{if } 0.40 \leq Ei < 0.50 \\ 0.94 & \text{if } 0.50 \leq Ei < 0.55 \\ 0.97 & \text{if } 0.55 \leq Ei < 0.60 \\ 1 & \text{if } 0.60 \leq Ei < 1 \end{cases}$$

A comparison table is formulated for decision making.

Expert	Average Weight	Weighted Multi Expert Neural Network System	μ (E)	Difference
E1	0.51	0.83	0.94	0.11
E 2	0.58	0.92	0.97	0.05
E 3	0.57	0.81	0.97	0.16
E 4	0.67	0.92	1	0.08
E 5	0.42	0.82	0.91	0.09

4. Discussion:

The comparison table reveals that the expert's opinion are considered for study whose corresponding differences are less than 0.1 and ignore the feedback of others. The reasons that highly contribute for the shortcomings are geographical location, complex monsoon climate, lack of technologies and deficit of suitable atmospheric models act as main hurdles for enhancing high degree of accuracy of weather prediction. The predictions of IMD cannot be blamed as the tropical climate prevailing in our nation is quite a natural phenomenon and explicating beyond it is always a nightmare. Since today all our mobile phones have inbuilt weather forecast tool, which itself gives us prior information of weather. On comparative analysis with the past years the predictions seems to be appropriate and to further enhance it better technologies can be hired and practiced, in addition to it many weather adaptative and smart climate services can be promoted.

5. Conclusion:

This research work consists of an innovative approach in discussing the shortcomings of IMD. The assignment of feedback in terms of linguistic variables makes these techniques distinct from that of others. This paper also pave way for suggesting measures to overcome the shortcomings. This work can be extended or modified by quantifying the linguistic input with other type of fuzzy numbers.

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