APPLICATION OF FUZZY LOGIC BASED TECHNIQUES IN WEATHER PREDICTION

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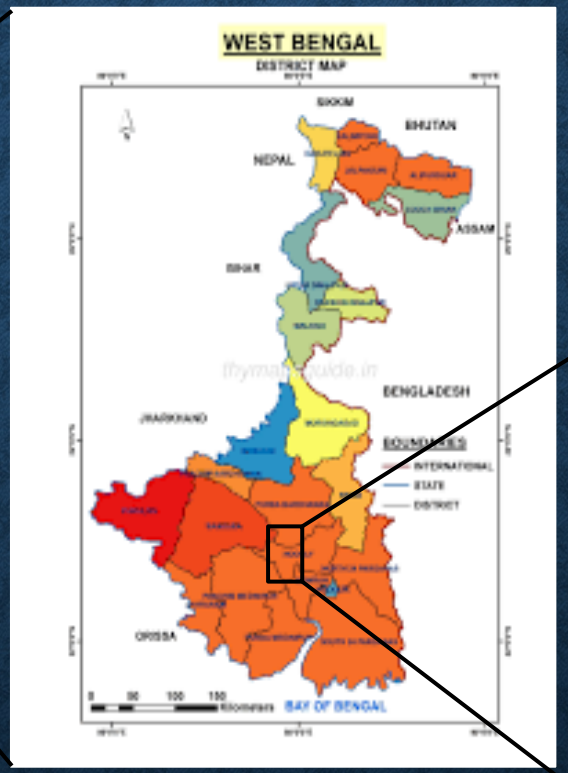
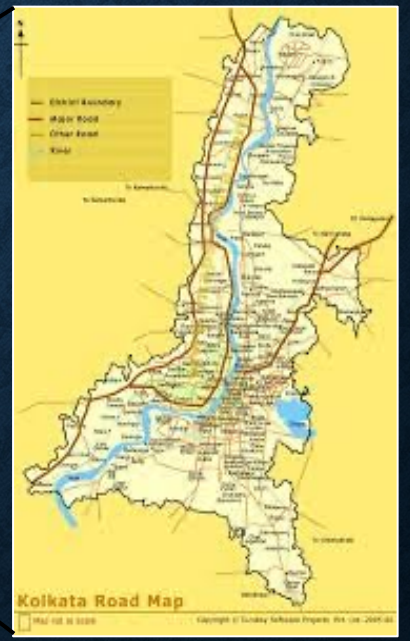
AREA OF THE STUDY





HAZARDOUS EFFECT OF PRE-MONSOON RAIN IN KOLKATA , INDIA

OBJECTIVE OF THE STUDY

- Application of non-classical logic (FUZZY) in predicting precipitation / non-precipitation during pre-monsoon season in a metro city of India (Kolkata).
- Mainly the following tools are used in the study:

(1) Fuzzy Joint Membership Degree

(2) Fuzzy If-Then Rule

(3) Defuzzification (Weighted Average Method)

INTRODUCTION

- **Convective development** is associated with **thunderstorm** during the **pre-monsoon season (March-May)** every year , which is a severe weather phenomenon accompanied by strong winds, lightning, thunder, rainfall and sometime hail.
- Rainfall is a stochastic process, whose upcoming event depends on some precursors from other parameters such as sea surface temperature for monthly to seasonal time scales, the surface pressure for weekly to daily time scales and other atmospheric parameters (such as, temperatures, relative humidity, wind speed etc.) for daily to hourly time scales.

FUZZY LOGIC

- DEFINITION: Fuzzy Logic is an approach to computing based on " degrees of truth" rather than the usual " true or false" (i.e., 1 or 0 in Boolean Logic).
- Intelligent system approaches for data analysis, interpretation, verification etc. may be used since plethora of data is available now. **Fuzzy logic** is one of such intelligent or expert systems, the goal of which is to perform at the level of a human expert by leveraging knowledge and experience gained over time. Not only that soft computational techniques are cost effective too.

RESEARCH GAP AND QUESTION

- Most of popular statistical techniques are mainly based on **bi-valued** logic and they are **linear** in nature , whereas any **atmospheric phenomenon** is inherently **nonlinear** in nature.
- The statistical methods usually do not address the **numeric imprecision** of the quantified physical parameters , i.e. the overlapping values of the parameters in two different situation (which is very common in atmospheric science) , whereas the essence of **Fuzzy Logic** is to address that .

DATA

- The upper air RS/RW (Radio Sonde/Radio Wind) data, namely surface temperature, surface wind speed and relative humidity of Kolkata (22.53°N, 88.33°E) at 0000 UTC and 1200 UTC are collected from the Department of Atmospheric Science, Wyoming University (http://weather.uwyo.edu/upperair/sounding.html), during pre-monsoon season (March–May) of 1984–2002 out of which the period of training dataset consists of one set as 1985-1996 and the other set as1984-1998. Similarly for test data one set is considered from 1997-1999 and the other as 1999-2002.
- The ranges of low precipitation (1mm-7.5mm) and medium precipitation (7.6mm-35.5mm) considered for the study are taken from IITM, Pune, India. The results are obtained using programming in C and Microsoft Excel, 2013.
- During the pre-monsoon season the precipitation is usually considered as thunderstorm precipitation. The precipitation recorded by IMD, Alipore , Kolkata on a particular day represents the precipitation from 8 a.m. of the previous day to 8 a.m. on that day. Hence to predict the precipitation of a day, say , 14th April, the data of 1200 UTC of 12th April is used here. It is assumed that these data may predict the precipitation from 8 a.m. of 13th April to 8 a.m. of 14th April.

METHODOLOGY: CHOICE OF MEMBERSHIP FUNCTION

- There is no such standard methods are available yet to construct membership function though some standard membership functions are available in the books.
- Gaussian membership functions are **continuously differentiable** as well as **parameterizable**.
- Gaussian membership functions are **factorizable so that a joint membership function is the product of individual membership functions.**

METHODOLOGY : MEMBERSHIP DEGREE FOR PRECIPITABLE DAY

- The membership degrees of the parameters (temperature, wind speed and relative humidity) to belong to a precipitable day (P) and non-precipitable day (NP) are computed as follows:

$$\mu_{PT_i} = \exp\left[\frac{-(T_i - T_{pmean})^2}{T_{pvar}}\right], \quad i=1(1)n$$

$$\mu_{PW_i} = \exp\left[-(W_i - W_{pmean})^2 / W_{pvar}\right], \quad i=1(1)n$$

$$\mu_{PH_i} = \exp\left[-(H_i - H_{pmean})^2 / H_{pvar}\right], \quad i=1(1)n$$

where , T_i, , W_i and H_i respectively denote the temperature, wind speed and relative humidity of the i^{th} precipitable day; T_{pmean} , W_{pmean} and H_{pmean} are the averages of temperature , wind speed and relative humidity respectively for precipitable days ; T_{pvar} , W_{pvar} and H_{pvar} are the corresponding variances.

METHODOLOGY : MEMBERSHIP DEGREE FOR NON-PRECIPITABLE DAY

μ_{NPT_j} = exp [-(T_j- T_{npmean})^2 / T_{npvar}] , j=1(1)n

μ_{NPW_j} = exp [-(W_j- W_{npmean})^2 / W_{npvar}] , j=1(1)n

μ_{NPH_j} = exp [-(H_j- H_{npmean})^2 / H_{npvar}] , j=1(1)n

where , T_j , W_j and H_j respectively denote the temperature, wind speed and relative humidity of the jth non-precipitable day; T_{npmean} , W_{npmean} and H_{npmean} are the averages of temperature , wind speed and relative humidity respectively for non-precipitable days ; T_{npvar} , W_{npvar} and H_{npvar} are the corresponding variances.

METHODOLOGY : JOINT MEMBERSHIP DEGREE

- The joint membership degrees of the abovementioned parameters to belong to a day with precipitation (DP) and a day with no precipitation (NDP) using product norm are as follows:
- $\mu_{DPi} = \mu_{PT_i} * \mu_{PW_i} * \mu_{PH_i}$ for the i^{th} precipitable day , i=1(1)n
- $\mu_{NDPj} = \mu_{NPT_j} * \mu_{NPW_j} * \mu_{NPH_j}$ for the j^{th} non-precipitable day , j= 1(1)n

FUZZY MEMBERSHIP DEGREE FOR A PARTICULAR DAY TO BE PREDICTED

$\mu_{DPT} = \exp\left[\frac{-(T - T_{pmean})^2}{T_{pvar}}\right]$, $\mu_{NDPT} = \exp\left[\frac{-(T - T_{npmean})^2}{T_{npvar}}\right]$

$\mu_{DPW} = \exp\left[-(W - W_{pmean})^2 / W_{pvar}\right]$, $\mu_{NDPW} = \exp\left[-(W - W_{npmean})^2 / W_{npar}\right]$

$\mu_{DPH} = \exp\left[-(H - H_{pmean})^2 / H_{pvar}\right]$, $\mu_{NDPH} = \exp\left[-(H - H_{npmean})^2 / H_{npvar}\right]$

- $\mu_{DP} = \mu_{DPT} * \mu_{DPW} * \mu_{DPH}$, $\mu_{NDP} = \mu_{NDPT} * \mu_{NDPW} * \mu_{NDPH}$

- where T, W and H denote Temperature, Windspeed and Relative Humidity respectively of that day.
- It is to be noted that the membership degrees are dimensionless.

FUZZY IF-THEN RULE IN FORECASTING PRECIPITABLE DAYS WITH AMOUNT OF PRECIPITATION DURING PREMONSOON SEASON IN KOLKATA, INDIA

- Prediction of the days with low and medium range precipitation during the pre-monsoon season (March, April and May) in Kolkata (22.53° N,88.33° E), India depending on temperature, wind speed and relative humidity for the next 24 hours from the time of observation using Fuzzy If-Then Rule.
- Prediction of the amount of expected precipitation (low or medium) for next 24 hours from the time of observation using defuzzification (Weighted Average Method).

METHODOLOGY : FUZZY IF-THEN RULE

- If , for a particular day, a < T < b and c < W < d and p < H < q then compute μ_{DP} and μ_{NDP}.
- Here the ranges (a , b) , (c , d) and (p , q) for temperature , windspeed and relative humidity are determined on the basis of the given data set.
- If $\mu_{DP} > \mu_{NDP}$ then the day belongs to DP else the day belongs to NDP. If the day is DP then the output is treated as YES otherwise NO.
- If μ_{DP} and μ_{NDP} differ by a small amount then also the methodology works.
- If, however, $\mu_{DP} = \mu_{NDP}$, then no specific conclusion may be drawn so far this methodology is concerned. Those cases are yet to be explored.

METHODOLOGY: DEFUZZIFICATION AND RESIDUAL PLOTS

- The weighted average method used for defuzzification is as follows:

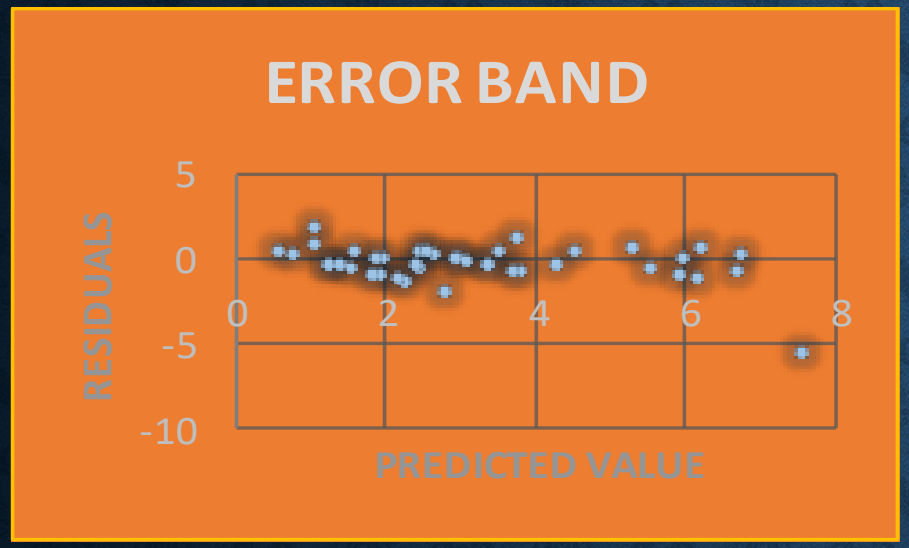
$P/i^{th\ day}$

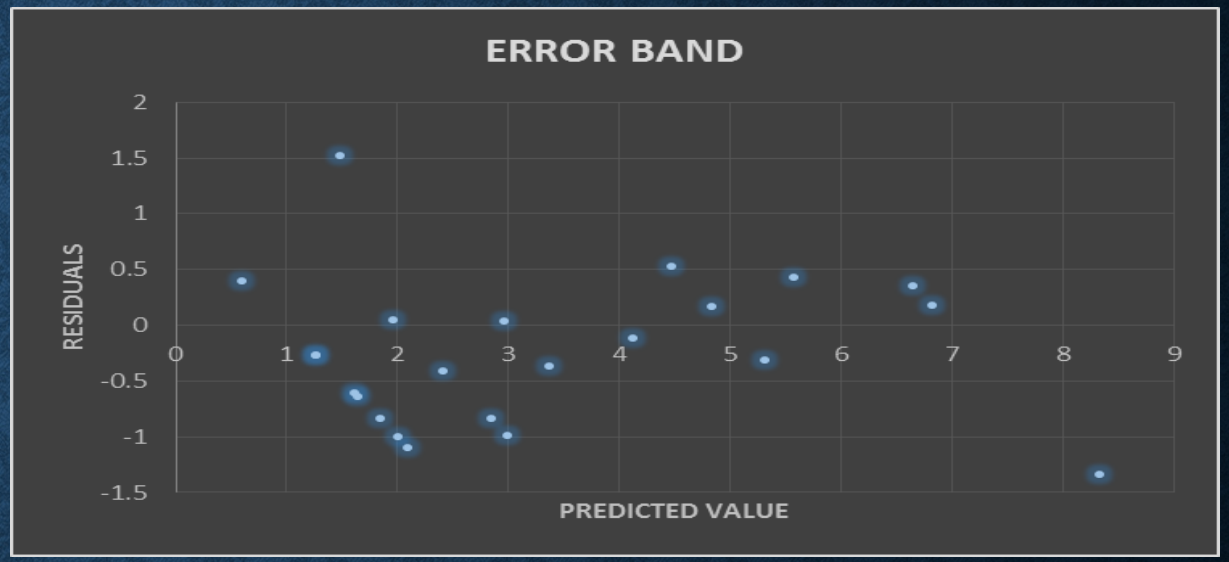
$= [\ \mu_{DP}(T_i) * T_i + \mu_{DP}(W_i) * W_i + \mu_{DP}(H_i) * H_i\ ] / [\mu_{DP}(T_i) + \mu_{DP}(W_i) + \mu_{DP}(H_i)\ ]$

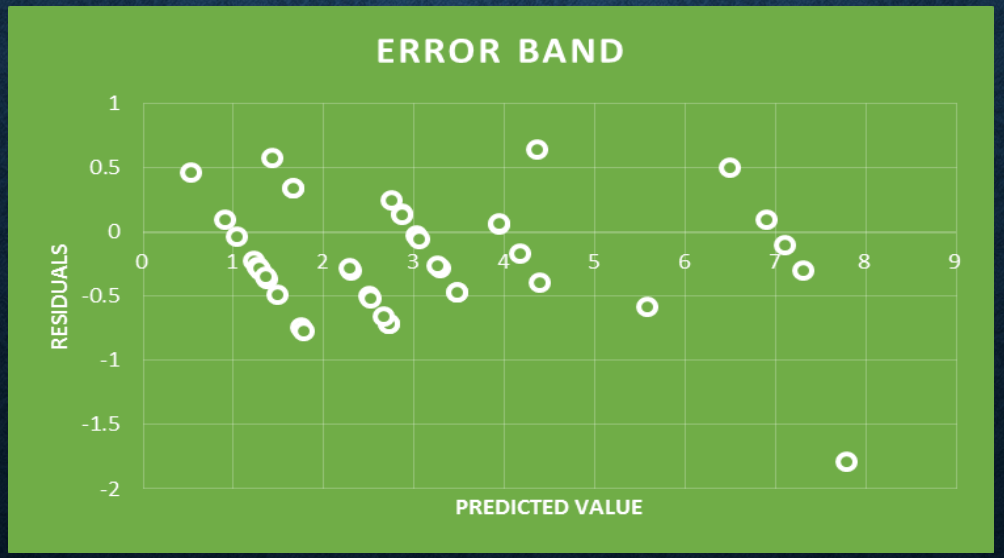
where $P/i^{th\ day}$ denotes the amount of precipitation on the i^{th} day with precipitation and all the parameters being normalized.

- The residual plots are drawn to detect if there is any such error present in the methodology. The outliers which are the values lying outside a specific range are also noted and they are treated as exceptions.

RESIDUAL PLOTS :MARCH , APRIL, MAY







METHODOLOGY:

The present study considers separately the following situations

- Prediction of low range precipitations from data of 0000 UTC (Morning MLP)
- Prediction of No precipitation from the data of 0000 UTC (Morning MNP)
- Prediction of medium range precipitation from data of 0000 UTC (Morning MMP)
- Prediction of Low precipitation from data of 1200 UTC (Evening ELP)
- Prediction of No precipitation from data of 1200 UTC (Evening ENP)
- Prediction of Medium precipitation from data of 1200 UTC (Evening EMP)

FINDINGS: PERCENTAGE OF CORRECT PREDICTION

MARCH			
	LOW		MEDIUM
MORNING	80		60
EVENING	76.7		76
APRIL			
	LOW		MEDIUM
MORNING	70		66.7
EVENING	76.7		73.3
MAY			
	LOW		MEDIUM
MORNING	75.7		76
EVENING	67.5		52

PRECIPITATION AMOUNT FOR LOW PRECIPITATION USING DEFUZZIFICATION

PREDICTED	ACTUAL	ERROR
1.559872	2	-0.44013
5.737546	1	4.737546
5.552167	5	0.552167
7.572613	2	5.572613
2.987884	3	-0.01212
1.916884	1	0.916884
2.446241	2	0.446241
3.785818	3	0.785818
0.552167	1	-0.44783
3.36307	3	0.36307
7.876165	1	6.876165
3.677456	3	0.677456
1.525436	1	0.525436
9.722418	7	2.722418
3.758841	1	2.758841
3.488366	4	-0.51163
7.790941	2	5.790941
14.23268	1	13.23268
4.520743	5	-0.47926
2.382518	2	0.382518
0.748669	1	-0.25133
1.044877	3	-1.95512
6.142381	5	1.142381
4.294456	4	0.294456
2.2295	1	1.2295
2.46408	3	-0.53592
5.925124	5	0.925124
5.947166	6	-0.05283
6.694179	6	0.694179
1.21971	1	0.21971
4.999023	1	3.999023
3.0494	3	0.0494
6.214847	7	-0.78515
1.796378	1	0.796378
1.361061	1	0.361061
2.929631	3	-0.07037
7.355841	1	6.355841
1.2504	1	0.2504
2.614018	3	-0.38598
1.981872	2	-0.01813
3.36307	1	2.36307
1.876165	2	-0.12384
4.677456	1	3.677456
3.525436	1	2.525436
3.722418	1	2.722418
3.758841	5	-1.24116
3.488366	1	2.488366
2.790941	1	1.790941
4.23268	1	3.23268
5.553148	1	4.553148
2.520743	3	-0.47926
3.382518	3	0.382518
6.748669	7	-0.25133
1.044877	2	-0.95512
2.142381	1	1.142381
5.294456	6	-0.70554
4.472589	5	-0.52741
8.332009	7	1.332009
2.408275	2	0.408275
1.835112	1	0.835112
5.31379	5	0.31379
4.835112	5	-0.16489
1.263326	1	0.263326
0.60047	1	-0.39953
2.985941	2	0.985941
1.637342	1	0.637342
2.839607	2	0.839607
1.606769	1	0.606769
5.568246	6	-0.43175
2.960647	3	-0.03935
1.998172	1	0.998172
6.821402	7	-0.1786
3.368194	3	0.368194
6.642976	7	-0.35702
1.951866	2	-0.04813
4.116944	4	0.116944
1.475797	3	-1.5242
2.095286	1	1.095286
1.263326	1	0.263326
1.416076	2	-0.58392
3.932366	4	-0.06763
1.085368	1	0.085368
1.828883	1	0.828883
6.489536	7	-0.51046
1.268249	1	0.268249
3.276422	3	0.276422
1.71223	1	0.71223
1.246018	1	0.246018
1.432688	1	0.432688
1.63001	1	0.63001
0.971768	1	-0.02823
1.964124	1	0.964124
1.692819	1	0.692819
1.42601	1	0.42601
1.121273	1	0.121273
4.350068	5	-0.64993
6.894181	7	-0.10582
2.492118	2	0.492118
0.894181	1	-0.10582
2.705786	2	0.705786
1.646546	2	-0.35345
1.888739	1	0.888739
3.017449	3	0.017449
0.852581	1	-0.14742
7.682195	7	0.682195
2.853424	3	-0.14658
8.219329	7	1.219329
2.705674	2	0.705674
4.384775	4	0.384775
3.050929	3	0.050929
1.384775	1	0.384775
1.693594	1	0.693594
0.851303	1	-0.1487
1.651237	2	-0.34876
4.164896	4	0.164896
1.296069	1	0.296069
1.359171	1	0.359171

CONCLUSION

- Weather prediction is a global demand of human civilization now - a - days . India is famous for its varied geographical atmosphere and it is already accepted that the possibility of occurrence or maturity of thunderstorms differ from place to place throughout India . As thunderstorm is a mesoscale phenomenon , so a particular region (Kolkata) of Eastern India is selected for the present study.
- Fuzzy logic -based techniques are chosen to analyze and predict the Pre-monsoon weather of Kolkata regarding precipitation. Any atmospheric phenomenon is necessarily multivariate , complex and non - linear in nature. That is why the joint membership degree is applied, which is necessarily multivariate and non-linear.
- It is to be noted that the present technique partly addresses the numeric imprecision of the quantified physical parameters too.

- The fuzzy if-then rule and defuzzification method are applied to predict a precipitable day with the amount of precipitation . It is found that most of the predictions are very close to the actual ones, the error lying between -5 mm to + 5 mm. Only a few crosses this range of error. These cases are yet to be explored.

- It may be concluded that the methodology introduced here provides with correct predictions in and around 65 % cases , so far the present dataset is concerned.

Acknowledgments

I am thankful to my graduate student Ms. Sweta Chakraborty for her help.

Some important References

- Chatterjee S . , Ghosh S., and De U . K . , 2009 Reduction of number of parameters and forecasting convective developments at Kolkata (22 . 53° N . 88 . 33° E) , India during pre monsoon season : An application of multivariate techniques , *Indian Journal of Radio and Space Physics* , 38 , 275 - 282.

- Dhanya C . T . and Nagesh Kumar D ., 2009 Data Mining for Evolving Fuzzy Association Rules for Predicting Monsoon Rainfall of India , *Journal of Intelligent Systems* ,18 ,193- 209 .

- Ma Yimin. , Huang X ., Mills G . A . and Parkyn K . ,2009 Verification of mesoscale NWP forecasts of abrupt cold frontal wind change , *Wea . Forecasting* ,25 ,93 - 112 .

- Hubbert J. C., M. Dixon and S. M. Ellis, 2009. Weather radar ground clutter, Part II: Real-time identification and filtering. J. Atmos. Ocean. Technol. 26, 1181-1197.

- Ghosh S., Chatterjee S., De U.K. , 2011. Comparison between LDA technique and fuzzy membership roster method for pre-monsoon weather forecasting, *Atmosféra* Vol. 24, 385-396

- Ghosh S., Chatterjee S., De U.K. , 2012. A soft computational technique for identification of significant atmospheric layer for premonsoon weather prediction of Kolkata, India *Bull. Cal.Math .Doc.,* 104, 203-210.

THANK YOU