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Fuzzy Reliability Analysis of Heating Fans Using Mediative Fuzzy Logic

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Abstract: Fuzzy logic deals with reasoning that is approximate rather than fixed and exact. Fuzzy logic deals the situations with the help of its membership grades. But due to the informational uncertainty and imperfect knowledge fuzzy logic is not adequate enough to deal such situations. Intuitionistic fuzzy logic (IFL) may role over the fuzzy logic due to its non-membership grade. But confliction in the hesitation part due to membership and non-membership grades in intuitionistic fuzzy logic is unable to describe all the characteristic of the system and exactness of its functioning. In the present paper we have used the mediative fuzzy logic (MFL). The Mediative fuzzy logic refers to the contradiction in hesitation part in intuitionistic fuzzy logic and gives birth to the contradiction fuzzy set. The contradiction fuzzy set gives a firing level on the contradiction of membership, non-membership and the hesitation part. In the present paper we have studied agreement and disagreement in the expert's decision and developed an inference system based on mediative fuzzy logic. Using this technique, we have improved "**Intuitionistic fuzzy logic control for heater fans", (M. Akram2013 Mathematics in Computer Science)** and have shown that results obtained by our technique are better.

Keywords: Fuzzy Logic, Intuitionistic Fuzzy Logic (IFL), Mediative Fuzzy Logic (MFL), Fuzzy Inference Engine, Sugeno's Defuzzification.
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I. INTRODUCTION

Zadeh (1965) introduced the concept of fuzzy logic thereafter fuzzy logic was applied in the the analysis of systems performance. Fuzzy systems are suitable for uncertain or approximate reasoning, especially for the system with a mathematical model that is difficult to derive and uncertainty affects all decision making and appears in a number of different forms. The concept of information and uncertainty are fully correlated to each other. The fundamental aspect of this correlation involves problem solving stage that may cause information deficiency, which may be incomplete, imprecise, fragmentary, not fully reliable, vague, contradictory, or deficient in some other way [1]. Such type of problems can be evaluated by using Fuzzy Logic [2, 3] or Intuitionistic Fuzzy Logic [4,5].

In fuzzy set only the membership degree is considered. In reality it may be difficult to evaluate of membership values, there may be some hesitation degree between membership and non-membership. Intuitionistic fuzzy set (IFS) introduced by Atanassov (1986), is characterized by three functions expressing the membership, non-membership and the degree of hesitation [4].

In [6] an optimized method to reduce the number points in order to identify a person using fuzzy fingerprints was presented. In [7]the model for intuitionistic fuzzy logic controller for heater fans using intuitionistic fuzzy systems was presented. In [8] a model using intuitionistic fuzzy logic controller to determine washing time of a washing machine was presented. In [9] an intelligent method for transport system using intuitionistic fuzzy logic was presented as the conventional traffic controller model is unable to solve the problems (congestion at the crossings). In [10] a method was developed for type-1 intuitionistic fuzzy inference to handle more uncertainty than type-1 fuzzy inference system and which performs faster than a type-2 fuzzy inference system. The results proved that the intuitionistic fuzzy inference system performs better than other methods and an improvement has been shown in the construction of control systems. In [11] a method was presented to develop the membership and non-membership functions of the fuzzy reliability using time-dependent intuitionistic fuzzy sets and in [12] an graphically representation of intuitionistic fuzzy sets for their use in Mamdani fuzzy inference systems was described and showed the importance of IFS.

Mediative fuzzy logic, was presented first time by Montie et al. [13], which is good option to deal with kind of inconsistent information and also provide a common solution when contradiction exists; this is a mediate solution. Mediative fuzzy logic can be reduced to intuitionistic and traditional fuzzy logic, depending on how the membership functions (agreement or non-agreement) are established. Using mediative fuzzy logic, many problems have proved the benefits of its use. Also mediative fuzzy logic results were compared with intuitionistic fuzzy logic and traditional fuzzy logic and the result showed that mediative fuzzy logic is able to solve contradictory knowledge and it can gives improved results when hesitation and contradiction fuzzy sets occurred [14]. In [15] mediative fuzzy logic was used to construct the human evolutionary for solving nonlinear optimization problems avoiding the problem of cycling In [16] mediative fuzzy logic was used to present a new method for controlling population size in evolutionary algorithms. In [17] a method for heart disease diagnosis using mediative fuzzy logic was proposed. In [18] a new fuzzy inference method working with membership and non-membership was presented.

In the present paper we have used the mediative fuzzy logic (MFL). The Mediative fuzzy logic refers to the contradiction in hesitation part in intuitionstic fuzzy logic and gives birth to the contradiction fuzzy set. The contradiction fuzzy set gives a firing level on the contradiction of membership, non-membership and the hesitation part. The paper is divided into eight sections. Section two contains the basic definitions which will be used in the analysis. In section three a small description related to mediative fuzzy logic has been discussed. An algorithm for our technique has been proposed in section four of the research paper. In section five fuzzy inference systems has been proposed based on the fuzzy rule base system. Defuzzification based on membership, non-membership and contradiction fuzzy sets has been discussed in section six of the paper. Numerical computation and result have been analyzed in section seven of the research paper. In last section conclusion of the research paper has been discussed. Using this technique, we have improved "Intuitionistic fuzzy logic control for heater fans", (M. Akram 2013 Mathematics in Computer Science) and have shown that result obtained by our technique are better.

II. BASIC DEFINITIONS

A traditional fuzzy set in X is given as a set A= $\{(x, \mu_A(x)/x \in X\}$ [2]. The intuitionistic fuzzy set introduced by Atanassov [5] as follows:

2.1Definition 1. An intuitionistic fuzzy set A in X is defined as

$A = \{(x, \mu_A(x), \nu_A(x))/x \in X\}$, where $\mu_A, \nu_A : X \rightarrow [0, 1]$ satisfy the condition

$0 \le \mu_A(x) + \nu_A(x) \le 1 \ \forall \ x \in X$.

The numbers $\mu_A(x)$ and $\nu_A(x)$ denote the degree of membership and non-membership of x to A, respectively. Obviously, a fuzzy set A corresponds to the following intuitionistic fuzzy set

$A= \{(x, \mu_A(x), 1-\mu_A(x)), x \in X\}$. For each intuitionistic fuzzy set A in X, $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ is called the intuitionistic fuzzy index of x in A; it is a hesitancy degree of x to A [4, 5] and satisfies the inequality $0 \le \pi_A(x) \le 1 \ \forall \ x \in X$.

Therefore, if we want to describe an intuitionistic fuzzy set we must use any two functions from the triplet: (membership function, non-membership function, intuitionistic fuzzy index).

2.2 Definition 2. An intuitionistic fuzzy number denoted as

$A = \{(x, \mu_A(x), \nu_A(x))/x \in X\}$ is given by

$$\mu_A(x) = \begin{cases} 0, & if\ x < a_1 \\ \dfrac{x-a_1}{a_2-a_1}, & if\ a_1 \le x \le a_2 \\ 1 & if\ a_2 \le x \le a_3 \\ \dfrac{x-a_4}{a_3-a_4}, & if\ a_3 \le x \le a_4 \\ 0, & for a_4 < x \end{cases} \qquad \nu_A(x) = \begin{cases} 1 & if\ x < b_1 \\ \dfrac{x-b_2}{b_1-b_2}, & if\ b_1 \le x \le b_2 \\ 0 & if\ b_2 \le x \le b_3 \\ \dfrac{x-b_3}{b_4-b_3}, & if\ b_3 \le x \le b_4 \\ 1, & for b_4 < x \end{cases}$$

Where $b_1, a_1, b_2, a_2, a_3, b_3, a_4, b_4 \in R$ and $b_1 \le a_1 \le b_2 \le a_2 \le a_3 \le b_3 \le a_4 \le b_4$.

III. MEDIATIVE FUZZY LOGIC

Fuzzy inference in intuitionistic case implies working with the membership function μ and the non-membership function ν. Hence, the output of an intuitionistic fuzzy system can be calculated as follows [18],

$$IFS = (1-\pi) * FS_\mu + \pi * FS_\nu$$

Where FS_μ is the traditional output of a fuzzy system using the membership function μ, and FS_ν is the output of the fuzzy system using the non-membership function ν. For π=0 in the last relation, the IFS is reduced to the output of a traditional fuzzy system.

A contradiction fuzzy set C in X is given by

$$\zeta_C(x) = \min(\mu_C(x), \nu_C(x)).$$

In this case, the functions μ_C and ν_C are named agreement membership function and agreement non-membership function, respectively. Using agreement and non-agreement instead of membership and non-membership as these names are more adequate for contradictory fuzzy sets. In order to compute the system's output, Montiel et al. [13] proposed the following expression:

$$MFS = \left(1-\pi-\frac{\zeta}{2}\right)*FS_{\mu} + \left(\pi+\frac{\zeta}{2}\right)*FS_{\nu}$$

In the case when the contradictory index ζ is equal to zero, the system's output is reduced to an intuitionistic fuzzy output.

IV. PROPOSED ALGORITHM

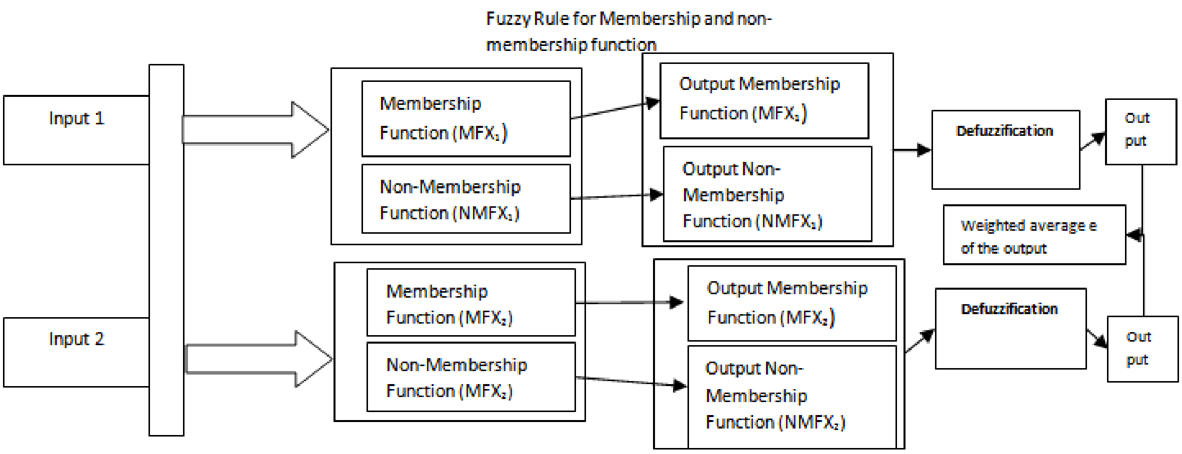
Step 1: Inference rules are developed taking one input and get single output as the consequence by constructing the membership and non-membership function for each input.
Step 2: Get the firing level for antecedent in the form of membership and non-membership and also the results in consequent for membership and non-membership.
Step 3: Compute the value of intuitionistic fuzzy index and contradiction function in the form of agreement and disagreement respectively by the following expressions

$$\pi = 1-(\mu_x+\nu_x) \text{ and } \zeta_c(x) = \min\{\mu_c(x), \nu_c(x)\}.$$

Step 4: From step 3 of the algorithm by using the membership, non-membership, intuitionstic fuzzy index and contradiction, we will construct the following functions

$$A = (1-\pi_x)\mu_x \quad B = \pi_x \nu_x \quad C = \left(1-\pi-\frac{\zeta}{2}\right)\mu_x, \quad D = \left(\pi+\frac{\zeta}{2}\right)\nu_x$$

Step 5: Values obtained in step 4 of the algorithm will be defuzzified by using Sugeno's defuzzification to get the output.
Step 6: Output obtained in step 5 will be aggregated and final output will be obtained.



V. FUZZY INFERENCE ENGINE & FUZZY RULE BASE SYSTEM

We have proposed Sugeno's fuzzy inference system and have made some fuzzy rules: using the data of [7], the fuzzy inference rules are as:
Rule 1: if temperature is cold then fan speed is high
Rule 2: if temperature is cool then fan speed is medium
Rule 3: if temperature is warm then fan speed is low
Rule 4: if temperature is hot then fan speed is zero
Taking the membership function of the input variable temperature, then
Rule 3 gives the fan speed low and degree of truth = 0.75, where

$$\mu_{low}(x) = \frac{x-0}{25}, \qquad \mu_{low}(x) = \frac{75-x}{50},$$

$$0.75 = \frac{x-0}{25}, \qquad 0.75 = \frac{75-x}{50},$$

$$x = 18.75 \qquad x = 37.5$$

Then

$$\mu_{low}(x)=\begin{cases}\frac{x-0}{25}, & if\ x\in[0,18.75],\\ 0.75, & if\ x\in[18.75,37.5]\\ \frac{75-x}{50}, & if\ x\in[37.5,75],\end{cases}$$

Rules 4 gives the fan speed zero and degree of truth=0.25, where

$$\mu_{zero}(x)=\frac{25-x}{25},$$
$$0.25=\frac{25-x}{25},$$
$$x=18.75,$$

Then

$$\mu_{zero}(x)=\begin{cases}0.25, & if\ x\in[0,18.75],\\ \frac{25-x}{25}, & if\ x\in[18.75,25],\end{cases}$$

Now taking the non-membership function of input variable temperature, then
Rule 2 gives the fan speed medium and degree of truth=0.88, where

$$v_{medium}(x)=\frac{75-x}{75-20}, \qquad v_{medium}(x)=\frac{x-75}{100-75},$$
$$0.88=\frac{75-x}{55}, \qquad 0.88=\frac{x-75}{25},$$
$$x=26.6, \qquad x=97,$$

$$v_{medium}(x)=\begin{cases}\frac{75-x}{55}, & if\ x\in[0,26.6],\\ 0.88, & if\ x\in[26.6,97]\\ \frac{x-75}{25}, & if\ x\in[97,100],\end{cases}$$

Rule 3 gives the fan speed low and degree of truth=0.25, where

$$v_{low}(x)=\frac{25-x}{25-0}, \qquad v_{low}(x)=\frac{x-25}{80-25},$$
$$0.25=\frac{25-x}{25}, \qquad 0.25=\frac{x-25}{55},$$
$$x=18.75, \qquad x=38.75,$$

$$v_{low}(x)=\begin{cases}\frac{25-x}{25}, & if\ x\in[0,18.75],\\ 0.25, & if\ x\in[18.75,38.75],\\ \frac{x-25}{55}, & if\ x\in[38.75,80],\end{cases}$$

Rule 4 gives the fan speed zero and degree of truth=0.53, where

$$v_{zero}(x)=\frac{x-0}{30-0},$$
$$0.53=\frac{x}{30}, \qquad v_{zero}(x)=\begin{cases}0.53, & if\ x\in[0,15.9],\\ \frac{x-0}{30-0}, & if\ x\in[15.9,30],\end{cases}$$
$$x=15.9,$$

VI. DEFUZZIFICATION

There are many methods to defuzzifying the fuzzy output into crisp output. One of the ordinary defuzzification method as follows:

$$x^*=\frac{\sum_{i=1}^{n}x\mu_x}{\sum_{i=1}^{n}\mu_x}$$

Here, we will use the weighted average method for defuzzification.

$$x^* = \frac{\sum_{i=1}^{n} x\left(\left(1-\pi_x\right)\mu_x + \nu_x \pi_x\right)}{\sum_{i=1}^{n}\left(\left(1-\pi_x\right)\mu_x + \nu_x \pi_x\right)}$$

VII. RESULTS AND NUMERICAL COMPUTATION

Table 1: Defuzzification for low fan speed

x	μ_x	ν_x	π_x	A	B	A+B	$x\times$ (A+B)	C	D	C+D	$x\times$ (C+D)
0	0.00	0.25	0.75	0.00	0.1875	0.1875	0.00	0.00	0.1875	0.1875	0.00
5	0.20	0.25	0.55	0.09	0.1375	0.2275	1.1375	0.07	0.1625	0.2325	1.1625
10	0.40	0.25	0.35	0.26	0.0875	0.3475	3.475	0.21	0.1187	0.3287	3.287
15	0.60	0.25	0.15	0.51	0.0375	0.5475	8.2125	0.435	0.0687	0.5037	7.5555
18.5	0.75	0.25	0.00	0.75	0.00	0.75	13.875	0.6562	0.0312	0.6874	12.7169
19	0.75	0.24	0.01	0.7425	0.0024	0.7429	14.1151	0.6525	0.0312	0.6837	12.9903
19.6	0.75	0.22	0.03	0.7275	0.0066	0.7341	14.388	0.645	0.0308	0.6758	13.24568
20	0.75	0.20	0.05	0.7125	0.01	0.7225	14.45	0.6375	0.03	0.6675	13.35
25	0.75	0.00	0.25	0.5625	0.00	0.5625	14.065	0.5625	0.00	0.5625	14.0625
30	0.75	0.09	0.16	0.63	0.0144	0.6444	19.33	0.5962	0.0184	0.6146	18.438
34.9	0.75	0.18	0.07	0.6975	0.0126	0.7101	24.782	0.63	0.0288	0.6588	22.9921
35	0.75	0.18	0.07	0.6975	0.0126	0.7101	24.853	0.63	0.0288	0.6588	23.058
38.75	0.75	0.25	0.00	0.75	0.00	0.75	29.062	0.6562	0.0312	0.6874	26.6367
40	0.70	0.25	0.05	0.665	0.125	0.6775	27.1	0.5775	0.0437	0.6212	24.848
45	0.60	0.25	0.15	0.51	0.0375	0.5475	24.6375	0.435	0.6875	0.5037	22.6665
50	0.50	0.25	0.25	0.375	0.0625	0.4375	21.875	0.3125	0.0937	0.4062	20.31
55	0.40	0.25	0.35	0.26	0.0875	0.3475	19.1125	0.21	0.1187	0.3287	18.0785
60	0.30	0.25	0.45	0.165	0.1125	0.2775	16.65	0.1275	0.1437	0.2712	16.272
65	0.20	0.25	0.55	0.09	0.1375	0.2275	14.7875	0.07	0.1625	0.2325	15.1125
70	0.10	0.25	0.65	0.035	0.1625	0.1975	13.825	0.03	0.175	0.205	14.35
75	0.00	0.25	0.75	0.00	0.1875	0.1875	14.0625	0.00	0.1875	0.1875	14.0625
80	0.00	0.25	0.75	0.00	0.1875	0.1875	15	0.00	0.1875	0.1875	15
						10.725	348.795			10.09	330.1951

Result for low speed (IFS) = 32.52
Result for low speed (MFS) = 32.72

Table 2: Defuzzification for zero fan speed

x	μ_x	ν_x	π_x	A	B	A+B	$x\times$ (A+B)	C	D	C+D	$x\times$ (C+D)
0	0.25	0.00	0.75	0.062	0.00	0.0625	0.00	0.0625	0.00	0.0625	0.00
5	0.25	0.16	0.583	0.1042	0.097	02014	1.007	0.0835	0.111	0.1945	0.9725
10	0.25	0.33	0.416	0.145	0.138	0.2846	2.846	0.1146	0.1805	0.2951	2.951
15	0.25	0.5	0.25	0.1875	0.125	0.3125	4.6875	0.1562	0.1875	0.3437	5.1555
15.9	0.25	0.53	0.22	0.195	0.1166	0.3116	4.9544	0.1637	0.1828	0.3465	5.5093
16	0.25	0.53	0.22	0.195	0.1166	0.3116	4.9856	0.1637	0.1828	0.3465	5.544
18	0.25	0.53	0.22	0.195	0.1166	0.3116	5.6088	0.1637	0.1828	0.3465	6.237
18.7	0.25	0.53	0.22	0.195	0.1166	0.3116	5.8425	0.1637	0.1828	0.3465	6.4968
20	0.20	0.53	0.22	0.146	0.1431	02891	5.782	0.126	0.1961	0.3221	6.442
25	0.00	0.53	0.47	0.00	0.2491	0.2491	6.2275	0.00	0.2491	0.2491	6.2275
						2.6456	41.913			2.85	45.5356

Result for zero speed (IFS) = 15.85
Result for zero speed (MFS) = 15.98

For (IFS), we got the result an average speed of heating fan is [24.18] rpm and for (MFS), we got the result an average speed of heating fan [24.35] rpm, which is better than of author [7].The author's results was the fuzzy solution only and the result provided by author was [22.08] rpm.

VIII. CONCLUSION

Fuzzy logic has proved that it logic gives better results than traditional logic. Fuzzy Logic (FL) is an effective tool for handling uncertainty in many situations and demonstrated its usefulness. But when we have situation where there exists an non-membership function then Intuitionistic Fuzzy Logic (IFL) an extension of FL plays an vital role. IFL is a logic that contains three functions membership function, non-membership function and hesitation margin. Which provides better results than FL. But FL and IFL are not effective when contradictory knowledge occurs. Generally experts decision cannot be one sided every time. To overcome this situation, Mediative Fuzzy Logic (MFL) is an approach which provides a common solution over the FL and IFL and MFL helps us to reduce the effect of contradictory knowledge by using the minimum of agreement and disagreement of contradictory function. MFS empowers us to handle imperfect knowledge more than FL and IFL. According to the membership functions, how they are defined, it reduces to IFL or FL. MFL is a good option for contradictory situation. Using this technique, we have improved "Intuitionistic fuzzy logic control for heater fans", (M. Akram 2013 Mathematics in Computer Science) and have shown that result obtained by our technique are better.

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