

Developing of Fuzzy Logic Controller for Air Condition System

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ABSTRACT

Fuzzy logic control was developed to control the compressor motor speed, fan speed, fan direction and operation mode to maintain the room temperature at or close to the set point temperature and save energy and keep devices from damage. This paper describes the development of Fuzzy logic algorithm for Air Condition control system. This system consists of four sensors for feedback control: first for input electric volt which used to save devices from damage due to alternated voltages, second for temperature and third for humidity and fourth for dew point. Simulation of the Fuzzy logic algorithm for Air Condition controlling system is carried out based on MATLAB.

Keywords

Fuzzy Logic Controller (FLC), Fuzzy Inference Systems(FIS), and Air Conditioning System.

1. INTRODUCTION

The human brain can reason with imprecise environments or decision based on uncertain or value judgment like the air is fine or the speed is fast or facts that are partially true. The fuzzy logic is a branch of machine intelligence that help computers to process and utilize vague data of humanistic systems [15]. Fuzzy inference systems (FIS) are information processing systems using fuzzy logic mechanism to represent the human reasoning process and to make decisions based on uncertain, imprecise environments. FIS consists of four parts: fuzzifier, rules, inference engine, and defuzzifier as shown in the following [9]. To design FIS, needed the personal experiences of human experts about field of research or knowledge base that observed and collected from operations of systems. Fuzzy logic manipulates such imprecise and vague data as fine or fast help engineering to controls and describes systems using commonsense rules that refer to indefinite quantities. So that it is possible to transition from one rule to another as the input is varied smoothly. These rules are linguistically natural representation of human's (or expert's) Knowledge base, that provides easy understanding knowledge representing scheme for explain information that has been learnt by a computer. For air condition system to manipulate temperature and the humidity close to an aimed value, and to save the electrical energy that taken by Air Condition compressor / Fan while utilizing all available resources in the most efficient manner [17]. Fuzzy logic system structure consists of database or prior knowledge that have to be crisp value to allow fuzzification using membership function, fuzzy control that manage fuzzification, rules evaluation, and defuzzification the output that also is crisp values as shown in figure (1).

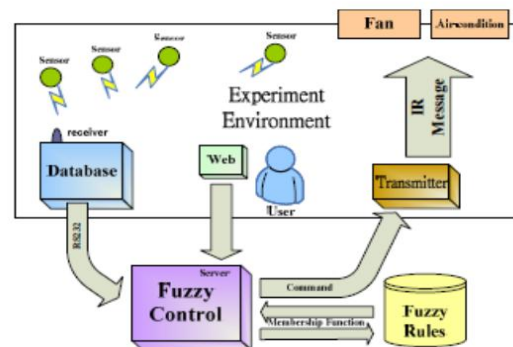


Figure 1. Fuzzy Logic system structure

To develop Air Condition system that control in humidity in own way without giving users any scope for changing the set point for the target humidity unlike the scope, it offer to change the set point for the target temperature through thermostat [24][25]. That's leads to huge reducing energy using and providing necessary conditions for comfort living inside building. This system consists of four Sensors that captures temperature, Electric Volt, user temperature and humidity these reading are fuzzified figure 1. These are used to decide the fuzzy qualifier, which is decoded into a crisp value that in turn controls different aspects of the Air Condition.

2. AIR SYSTEM ORGANIZATION

The dew point temperature determines what combinations of temperature and relative humidity (RH) will be possible in the storage environment. At a constant dew point, when the temperature goes up, the RH goes down and when the temperature goes down, the RH goes up. Controlling the dew point is key to managing the risk of material decay. Used Dew Point Calculator that designed to calculate and visually present the relationship between temperature, relative humidity and dew point. These evaluation are used to evaluate the preservation quality of the environment [33]. Dew point temperature is used to measure humidity instead of relative humidity (RH). A standard Dew Point Human Reaction table are evaluated as in table (1).

Dew Point	Reaction
Above 20°C (68F)	Oppressive
18°C (64F)	Sticky
16°C (61F)	Humid
13°C (55F)	Comfortable
10°C (50F)	Refreshing
Less than 10°C (50F)	Dry

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2. Majmaah Univ., Faculty of Science, CSI Dept.

Table (1) : Human reaction to different levels of dew point

Air Condition Fuzzy logic control System takes four variables into consideration showing in the following block:

- (1) User temperature (16°C→30°C continuous control).
- (2) Actual temperature.
- (3) dew point temperature.
- (4) Electricity Volt

User temperature subtracted from actual temperature before sending data for fuzzification step. Fuzzy arithmetic and criterion step is applied on these variables and final result is defuzzified step to get following crisp results as showing in the following figure (2):

- (1) Compressor Speed.
- (2) Fan Speed.
- (3) Mode of operation.
- (4) Fin Direction.

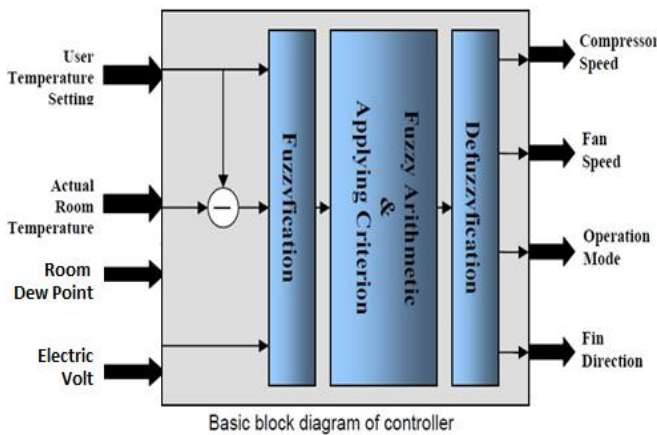


Figure (2)

3. FUZZY MEMBERSHIP FUNCTION

The membership function editor in Fuzzy tool box is used to define the shapes of all membership functions associated with each membership variable [9,10]. In that system for each of the input and output variables the membership function is defined as follows

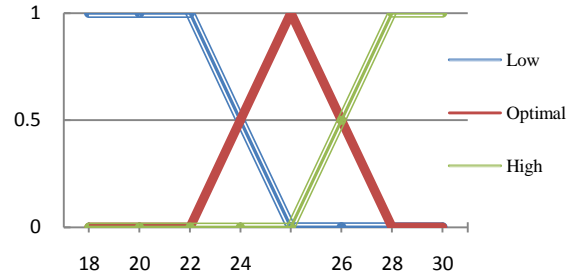
3.1 Input Variables

3.1.1 User temperature (UT)

users temperature that received by electronic, thermostat, are represented by three membership functions low, optimal, high as in table (2).

Table (2) : classification of user temperature (UT)

Input field	Range	Fuzzy set
User temperature (UT)	16 – 25	Low
	22 – 28	Optimal
	25 – 30	High



$$\mu_{low}(x) = \begin{cases} 1 & , x \leq 22 \\ \frac{25-x}{3} & , 22 \leq x \leq 25 \\ 0 & , other\ wise \end{cases}$$

$$\mu_{optimal}(x) = \begin{cases} \frac{x-22}{3} & , 22 \leq x \leq 25 \\ \frac{28-x}{3} & , 25 \leq x \leq 28 \\ 0 & , other\ wise \end{cases}$$

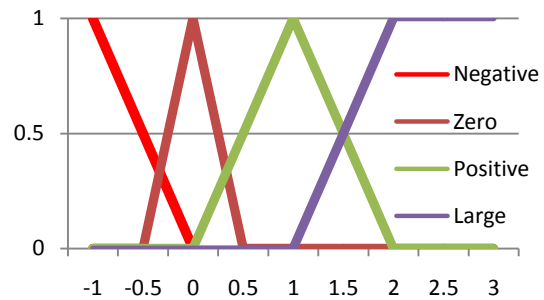
$$\mu_{high}(x) = \begin{cases} \frac{x-25}{3} & , 25 \leq x \leq 28 \\ 1 & , 28 \leq x \leq 30 \\ 0 & , other\ wise \end{cases}$$

3.1.2 Temperature difference (Tdif)

The different between room temperature actually and user temperature , are represented by four membership functions negative, zero, positive, large as in table (3).

Table (3) : Classification of Temperature Difference (Tdif)

Input field	Range	Fuzzy set
Temperature Difference (Tdif)	-1 – 0	Negative
	-0.5 – 0.5	Zero
	0 – 2	Positive
	1 – 3	Large



$$\mu_{negative}(x) = \begin{cases} 1 & , -1 \leq x \leq -0.9 \\ -0.9x & , -0.9 \leq x \leq 0 \\ 0 & , other\ wise \end{cases}$$

$$\mu_{zero}(x) = \begin{cases} 2(x+0.5) & , -0.5 \leq x \leq 0 \\ 2(0.5-x) & , 0 \leq x \leq 0.5 \\ 0 & , other\ wise \end{cases}$$

$$\mu_{positive}(x) = \begin{cases} x & , 0 \leq x \leq 1 \\ 2-x & , 1 \leq x \leq 2 \\ 0 & , other\ wise \end{cases}$$

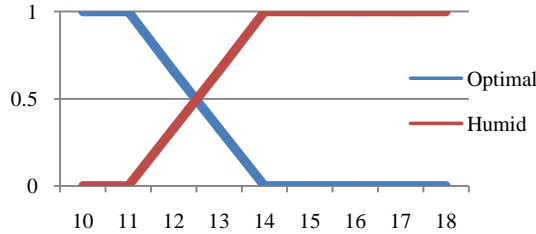
$$\mu_{large}(x) = \begin{cases} 1-x & , 1 \leq x \leq 2 \\ 1 & , 2 \leq x \leq 3 \\ 0 & , other\ wise \end{cases}$$

3.1.3 Dew Point (Td)

Dew point describes information about dew point temperature inside the room. Using two membership functions optimal, humid as in table (4) .

Table (4) : Classification of Dew Point (Td)

Input field	Range	Fuzzy set
Dew Point (Td)	10 – 14	Optimal
	12 – 18	Humid



$$\mu_{\text{optimal}}(x) = \begin{cases} 1 & , 10 \leq x \leq 11 \\ \frac{14-x}{3} & , 11 \leq x \leq 14 \\ 0 & , \text{other wise} \end{cases}$$

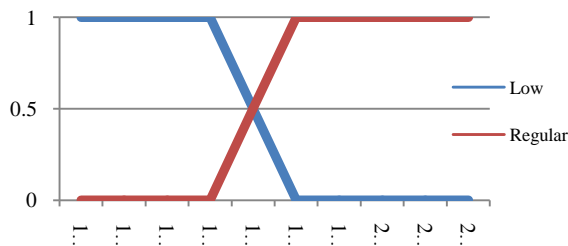
$$\mu_{\text{humid}}(x) = \begin{cases} \frac{x-12}{3} & , 12 \leq x \leq 15 \\ 1 & , 15 \leq x \leq 18 \\ 0 & , \text{other wise} \end{cases}$$

3.1.4 Electric Volt (EV)

Electric volt describes the information about alternating volt that difference and then according to that difference by controlling in compressor and fan to stand by or work as rule listed. Using two membership functions low, regular as in table (5).

Table (5) : Classification of Electric Volt (EV)

Input field	Range	Fuzzy set
Electric Volt (EV)	130 – 180	Low
	170 – 220	Regular



$$\mu_{\text{low}}(x) = \begin{cases} 1 & , 130 \leq x \leq 160 \\ \frac{180-x}{20} & , 160 \leq x \leq 180 \\ 0 & , \text{other wise} \end{cases}$$

$$\mu_{\text{regular}}(x) = \begin{cases} \frac{x-170}{20} & , 170 \leq x \leq 190 \\ 1 & , 190 \leq x \leq 220 \\ 0 & , \text{other wise} \end{cases}$$

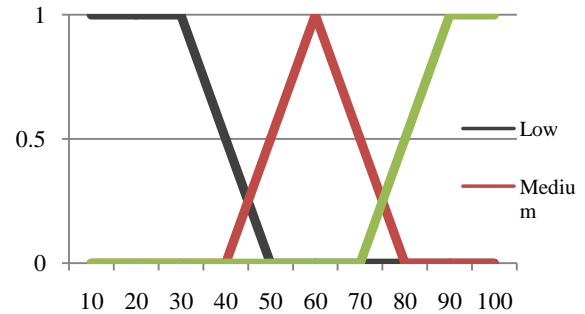
3.2 Output membership function

3.2.1 Compressor Speed (SC)

Compressor speed is characterized as low, medium and high different from 0 to 100%. To evaluate the membership function (MF) by scaling the ranges from 0 to 100 based on speed. Calculated MF and the range are given as in table (6).

Table (6) : Classification of Compressor Speed (SC)

Input field	Range	Fuzzy set
Compressor Speed (SC)	0 – 50	Low
	40 – 80	Medium
	70 – 100	Fast



$$\mu_{\text{low}}(x) = \begin{cases} 1 & , 0 \leq x \leq 30 \\ \frac{50-x}{20} & , 30 \leq x \leq 50 \\ 0 & , \text{other wise} \end{cases}$$

$$\mu_{\text{medium}}(x) = \begin{cases} \frac{x-40}{20} & , 40 \leq x \leq 60 \\ \frac{80-x}{20} & , 60 \leq x \leq 80 \\ 0 & , \text{other wise} \end{cases}$$

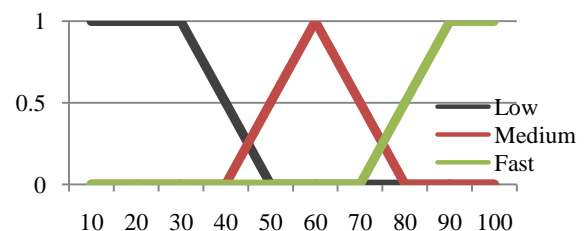
$$\mu_{\text{fast}}(x) = \begin{cases} \frac{x-70}{20} & , 70 \leq x \leq 90 \\ 1 & , 90 \leq x \leq 100 \\ 0 & , \text{other wise} \end{cases}$$

3.2.2 Fan Speed (Fc)

Fan speed is characterized as low, medium and high varied from 0 to 100%. To calculate membership function (MF) by scaling the ranges from 0 to 100 based on speed. Calculated MF and the ranges are given as in table (7).

Table (7) : Classification of Fan Speed (FC)

Input field	Range	Fuzzy set
Fan Speed (FC)	0 – 50	Low
	40 – 80	Medium
	70 – 100	Fast



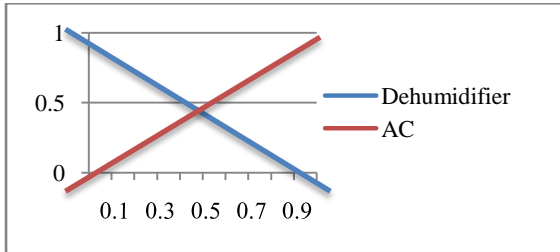
$$\mu_{\text{low}}(x) = \begin{cases} 1 & , 0 \leq x \leq 30 \\ \frac{50-x}{20} & , 30 \leq x \leq 50 \\ 0 & , \text{other wise} \end{cases}$$

$$\mu_{\text{medium}}(x) = \begin{cases} \frac{x-40}{20}, & 40 \leq x \leq 60 \\ \frac{80-x}{20}, & 60 \leq x \leq 80 \\ 0, & \text{otherwise} \end{cases}$$

$$\mu_{\text{fast}}(x) = \begin{cases} \frac{x-70}{20}, & 70 \leq x \leq 90 \\ 1, & 90 \leq x \leq 100 \\ 0, & \text{otherwise} \end{cases}$$

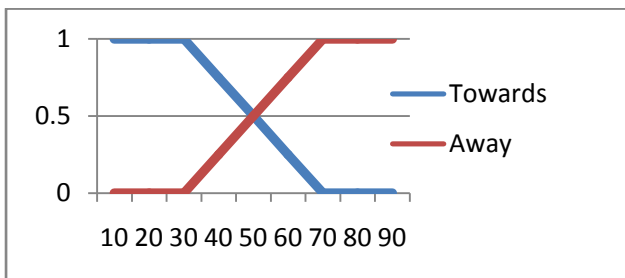
3.2.3 Mode of operation (Mo)

Mode of operation decides whether air condition work like a dehumidifier only or normal.



3.2.4 Fin direction (Fn)

Fin directions directs air from air condition towards or away from occupants. Assuming top mounted air condition, $\theta = 0^\circ$ can be considered as towards and $\theta = 90^\circ$ as away from occupant[28,29].



4. FUZZY RULE BASE

Fuzzy rules referred to as the IF-THEN rule base form and deductive form. And rules are based on natural language representation and models which are themselves based on fuzzy sets and fuzzy logic. It typically expressed inference like if the fact (premise, hypothesis, antecedent), then infer, or derive another fact called a conclusion. It design manual by a user, or automatic. The rules are defined by selecting the right sequence in the If-then sequence. It represent human empirical and heuristic knowledge in our language of communication that can be represented by fuzzy sets and logical connectivity of these sets. user temperature having three fuzzy ranges (low, optimal and high), temperature difference with four fuzzy ranges (negative, zero, positive and large), dew point with two fuzzy ranges (optimal and humid) and electric volt with two fuzzy ranges (low and regular) give a rule base matrix with size $3*4*2*2 = 48$ cells. Every cell has four outputs, each for compressor speed, fan speed, mode of operation and fin direction[11]. Fuzzy rules system are shown in table (8)

Table (8) : Fuzzy rules base

Rules	input variables				output variables			
	UT	Tdiff	Td	EV	CS	Fs	Mo	Fn
1	Low	Negativ	optim	low	Low	Low	ac	Away

2	Optim	Negativ	optim	low	Low	Low	ac	Away
3	High	Negativ	optim	low	Low	Low	ac	Away
4	Low	Zero	optim	low	Low	Low	ac	Away
5	Optim	Zero	optim	low	Low	Low	ac	Away
6	High	Zero	optim	low	Low	Low	ac	Away
7	Low	Positiv	optim	low	Low	Low	ac	Away
8	Optim	Positiv	optim	low	Low	low	ac	Away
9	High	Positiv	optim	low	Low	Low	ac	Away
10	Low	Large	optim	low	Low	Low	ac	Away
11	Optim	Large	optim	low	Low	Low	ac	Away
12	High	Large	optim	low	Low	Low	ac	Away
13	Low	Negativ	optim	hig	Low	Low	ac	Away
14	Optim	Negativ	optim	hig	Low	Low	ac	Away
15	High	Negativ	optim	hig	Low	Low	ac	Away
16	Low	Zero	optim	hig	Low	Fast	ac	Toward
17	Optim	Zero	optim	hig	Low	medium	ac	Toward
18	High	Zero	optim	hig	Low	Low	ac	Away
19	Low	Positiv	optim	hig	Fast	Fast	ac	Toward
20	Optim	Positiv	optim	hig	medium	medium	ac	Toward
21	High	Positiv	optim	hig	medium	medium	ac	Toward
22	Low	Large	optim	hig	Fast	Fast	ac	Toward
23	Optim	Large	optim	hig	Fast	Fast	ac	Toward
24	High	Large	optim	hig	Fast	Fast	ac	Toward
25	Low	Negativ	humid	low	Low	Low	ac	Away
26	Optim	Negativ	humid	low	Low	Low	ac	Away
27	High	Negativ	humid	low	Low	Low	ac	Away
28	Low	Zero	humid	low	Low	Low	ac	Away
29	Optim	Zero	humid	low	Low	Low	ac	Away
30	High	Zero	humid	low	Low	Low	ac	Away
31	Low	positive	humid	low	Low	Low	ac	Away
32	Optim	positive	humid	low	Low	Low	ac	Away
33	High	positive	humid	low	Low	Low	ac	Away
34	Low	Large	humid	low	Low	Low	ac	Away
35	Optim	Large	humid	low	Low	Low	ac	Away
36	High	large	humid	low	Low	Low	ac	Away
37	Low	negativ	humid	hig	Fast	Fast	de	Toward
38	Optim	negativ	humid	hig	Low	Low	de	Away
39	High	negativ	humid	hig	Low	Low	de	Away
40	Low	zero	humid	hig	Fast	Fast	de	Toward
41	Optim	zero	humid	hig	medium	Fast	de	Toward
42	High	zero	humid	hig	medium	medium	de	Toward
43	Low	positive	humid	hig	Fast	Fast	ac	Toward
44	Optim	positive	humid	hig	Fast	Fast	ac	Toward
45	High	positive	humid	hig	medium	Fast	ac	Toward
46	Low	large	humid	hig	Fast	Fast	ac	Toward
47	Optim	large	humid	hig	Fast	Fast	ac	Toward
48	High	large	humid	hig	Fast	Fast	ac	Toward

5. FUZZY LOGIC ALGORITHM

Fuzzy logic algorithm is an algorithm that solves the problems expressed in the basic IF-THEN rule format. It consists of four steps as following:

Step 1 : linguistic Variables are the input variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into a set of linguistic terms.

Membership Functions Membership functions are used in the fuzzification and defuzzification steps of a FLS, to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used to quantify a linguistic term.

Fuzzy Rules In a FLS, a rule base is constructed to control the output variable. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion.

Step 2 : Fuzzification means adding uncertainty by design to crisp sets or to sets that are already fuzzy and spreading the information provided by a crisp number or symbol to its vicinity so that the close neighborhood of the crisp number can be recognize by the computational tools.

Step 3: Inference For each rule which represented in fuzzy level as set of restriction on the output based on certain conditions of the input. That restriction modeled by fuzzy set and relations and connected by linguistic connections like and, or, not and else, Obtaining the output which is a new fuzzy set which is the conclusion of rule since an implication operator is applied to the value of the antecedent obtained.

Step 4: defuzzification is the process of converting the result in fuzzy set form to a crisp result. It is important process for hardware application which process based on crisp data exchange. There is not theory to justify behavior of exchange other than commonsense reasoning such that the defuzzified output must represent a weight, voted, or must suitable solution. There are two main mechanism centroid method which based on finding a balance point of a property and maxima method which based in search for the highest pack whereas

6. AIR CONDITION SYSTEM IMPLEMENTATION

6.1 Fuzzy Base Class

Using Mamdani fuzzy system for the illustration which uses max aggregation and centroid method for defuzzification. The FIS Editor defines the Fuzzy Base Class, the various inputs, i.e. User temperature (ut), Temperature Difference (Tdiff), Dew Point (Td), and Electric Volt (EV) and the various output variables like Compressor Speed (Sc), Fan Speed (Sf), Mode of Operation (Mo) and Fin Direction (Fn) [10] as shown in Fig3 .

6.2 Fuzzy Rule Base

Fuzzy rules can be designed manually by a user, or automatically, i.e. the Rule Editor generates rules for all combinations of selected input variable and a user fills consequent fuzzy terms. Inputs and sub-sequentially provide the fuzzy outputs [10] as shown in fig 4.

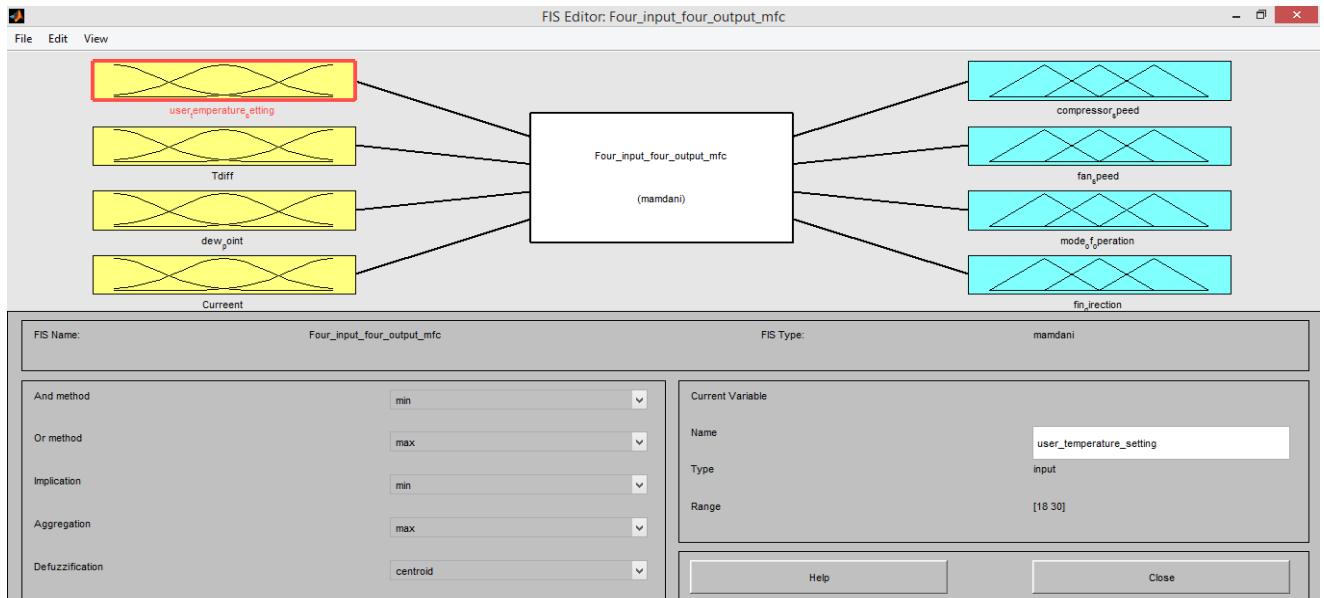


Figure (3) : Fuzzy base class

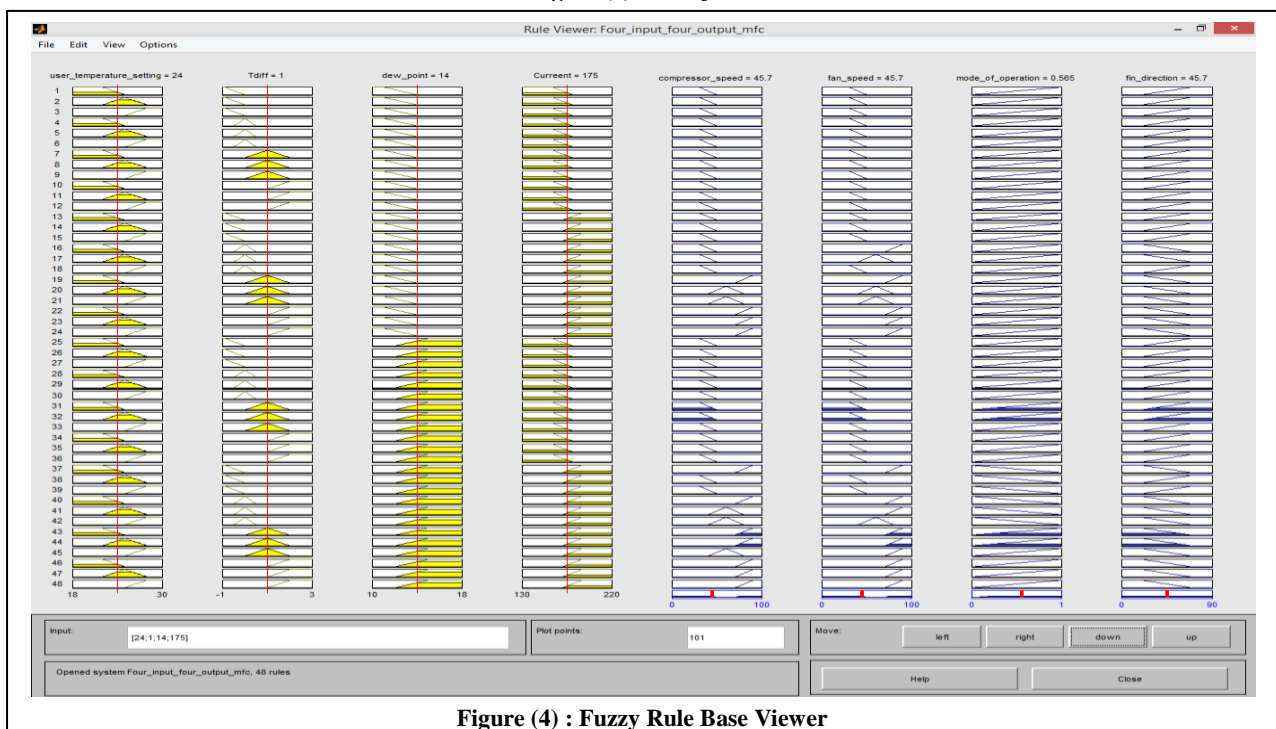


Figure (4) : Fuzzy Rule Base Viewer

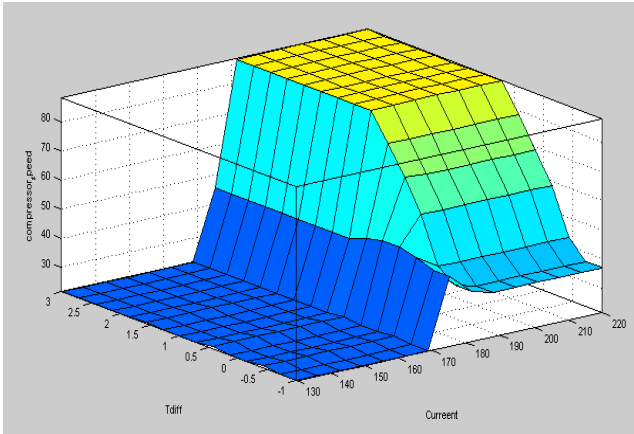


Figure (5) : Gradient Graph of Electric Volt vs. Temperature Difference vs compressor speed

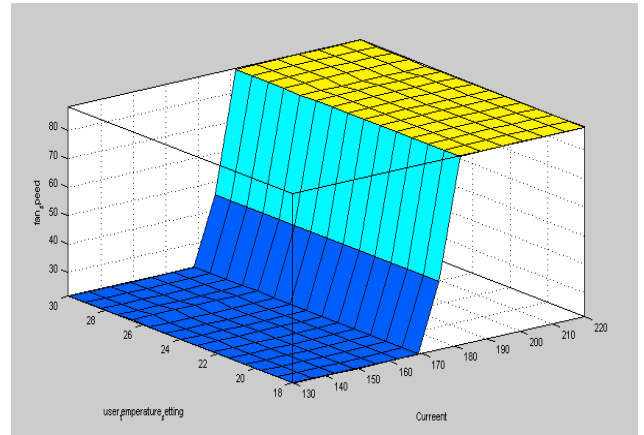


Figure (6) : Gradient Graph of Electric Volt vs. User Temperature vs. Fan speed

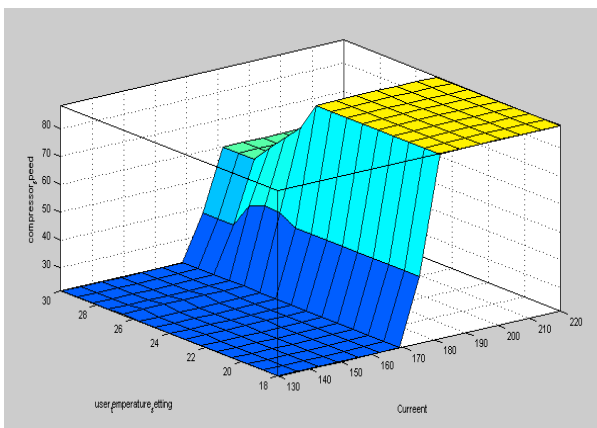


Figure (7) : Gradient Graph of Electric Volt vs. User Temperature vs. compressor speed.

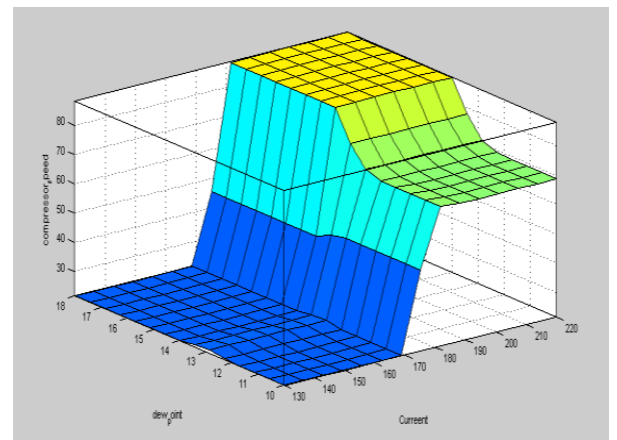


Figure (8) : Gradient Graph of Electric Volt vs. User Temperature vs. compressor speed.

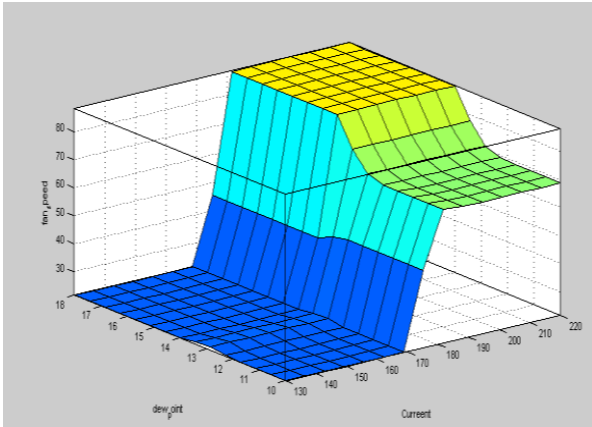


Figure (9): Gradient Graph of Electric Volt vs. Dew Point vs. Fan speed

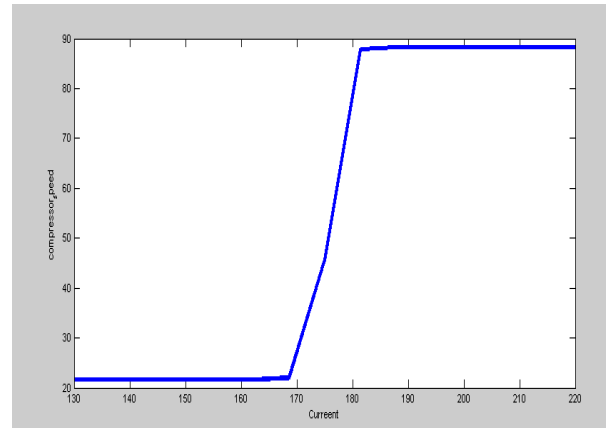


Figure (12) : Gradient Graph of Electric Volt vs. compressor speed

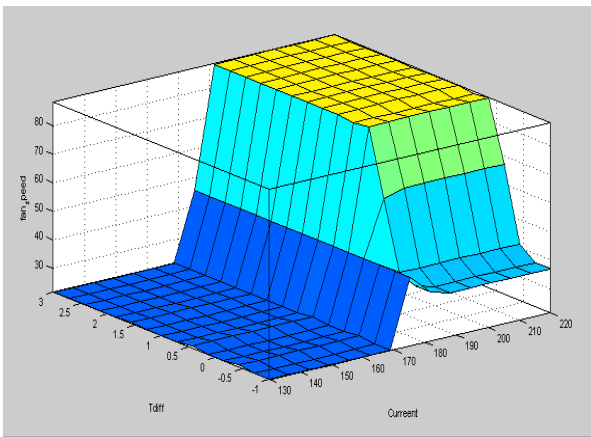


Figure (10) : Gradient Graph of Electric Volt vs. Temperature Difference vs. Fan

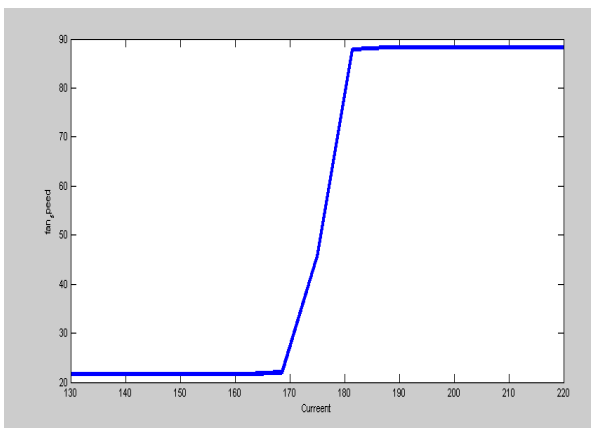


Figure (11) : Gradient Graph of Electric Volt vs. Fin speed

7. CONCLUSIONS AND FUTURE WORK

Previous Air Conditioning systems that are used to cool the rooms now can perform variety of functions. By adding intelligence to the system like fuzzy logic which is dealing with problems that are difficult and complex to study analytical that is now easy to solve in terms of linguistic variables. With most of the problems encountered in day to day life falling in this category, like washing machines, vacuum cleaners, etc., fuzzy logic is sure to make a great impact in human life. The neural net acts like computer because it maps input to output the neurons and synapses may be silicon component or equations in software that simulate their behavior. Supervised networks tune the rules of fuzzy system as if they were synapses. We will use neural network that can help fuzzy systems learn rules which can accepts pairs of input and output data and cluster them in a small number of classes.

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