Intelligent Air Conditioning System using Fuzzy Logic

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Abstract— With the exponential increase in the use of cooling device, the air conditioning systems are becoming an essential part of our day to day life. Data suggest an exponential rise in the use of air conditioners in urban as well as rural India. With the increase in the usage of air conditioners, there is a simultaneous increase in the electrical power consumption. In this paper a design has been proposed considering various input parameters and applying Fuzzy Logic System to the Air Conditioner. By considering the input parameters we can greatly modify the functioning of the AC and reduce the electrical energy intake of the AC compressor/Fan while utilizing all available resources in the efficient manner. For better implementation, we have considered the climatic condition of coastal region namely Bhubaneswar area in the state of Odisha, India. Bhubaneswar being in the coastal area, the values of temperature and humidity are higher in comparison to non-coastal areas of India.

Index Terms— Fuzzy, Air Conditioning System, Defuzzification, Dew Point, Fuzzy base class, Fuzzy rule base

1 INTRODUCTION

Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact [2]. Fuzzy logic was formulated by Lofti Zadeh of the University of California at Berkeley in the mid-1960s. Zadeh also formulated the notion of fuzzy control that allows a small set of 'intuitive rules' to be used in order to control the operation of electronic devices. Countries like Japan have home appliances those have integrated fuzzy logic such as vacuum cleaners, microwave ovens and video cameras. Such appliances can adapt automatically to different conditions; for instance, a vacuum cleaner would apply more suction to an especially dirty area. One of the benefits of fuzzy control is that it can be easily implemented on a standard computer. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Fuzzy logic imitates the logic of human thought, which is much less rigid than the calculations computer generally perform. Intelligent control strategies mostly involve a large number of inputs. The objective of using fuzzy logic has been to make the computer think like people. Fuzzy logic can deal with the vagueness intrinsic to human thinking and natural language and recognize its nature is different from randomness. Using fuzzy logic algorithm, we could enable machines to understand and respond to vague human concept such as hot, cold, large, small, etc

Air conditioners and air conditioning systems are integral part of almost every institution. They contribute significant part of total energy consumption. Studies suggest that in locations like auditoriums, indoor stadiums and conference halls, air conditioning can contribute as much as 75% of total energy intake. For example, a Survey in the Pantaloons mall, Bhubaneswar, Odisha in summer season shows a daily average consumption of 2300 units of electricity by their 320 ton central air conditioning system. Even in homes and offices, power consumed by air conditioners is significant.

With the present rate of electrification of urban and rural India, it is not long before we have to think of efficient ways to reduce electrical power consumption, especially in devices those are specifically designed for heating or cooling purposes as these are the devices those have the maximum power inake. There will be an exponential growth in the number of such devices both in urban and rural areas as per the data available in official portal of Ministry of Environment & Forestry, Govt. of India [1] given in Table 1.

TABLE1
POPULATION OF HEATING / COOLING APPLIANCES (MILLIONS)

Heating / Cooling		2006	2011	2016	2021	2026	2031
Electric Water Heater	Urban	27.0	38.9	55.7	78.1	103.9	132.4
	Rural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	27.0	38.9	55.7	78.1	103.9	132.4
Fans	Urban	123.1	179.7	254.7	344.7	435.5	527.3
	Rural	105.8	174.2	270.3	384.3	482.4	564.3
	Total	228.9	353.9	525.0	729.1	917.8	1,091.7
Air cooler	Urban	17.6	28.3	43.1	61.8	83.2	107.8
	Rural	4.9	10.1	19.5	33.5	48.2	61.1
	Total	22.5	38.5	62.6	95.3	131.4	168.9
Air-conditioning	Urban	1.7	4.0	8.9	17.5	28.5	40.0
	Rural	0.3	0.6	1.3	2.6	4.8	8.0
	Total	2.0	4.7	10.2	20.1	33.3	48.0

In this paper we have devised a scheme implementing Fuzzy Logic in the Air- Conditioning system. With the help of this logic the Air-Conditioner would assess the environmental factors like temperature, humidity, etc and thereby provides comfortable levels of cooling and optimized electricity consumption

2 Basic Design of an Air-conditioner

An air conditioner (often referred to as AC) is a home appliance, system, or mechanism designed to dehumidify and extract heat from an area [5]. The cooling is done using a simple refrigeration cycle which consists basically of the following steps [6]:

1. The compressor compresses cool Freon gas, causing it to become hot, high-pressure Freon gas.
2. This hot gas runs through a set of coils so it can dissipate its heat, and it condenses into a liquid.
3. The Freon liquid runs through an expansion valve, and in the process it evaporates to become cold, low-pressure Freon gas.
4. This cold gas runs through a set of coils that allow the gas to absorb heat and cool down the air inside the building.

3 Fuzzy Logic Controller

Fuzzy Logic controller forms the base of the Fuzzy Control System. It basically consists of the heuristics rules those define the parameters of the problem [4]. It consists of:

- *Data Base:* It normalizes the input crisp values and contains the fuzzy partitions of the input and output space.
- *Fuzzy Rule Base:* It contains the type of fuzzy rules and the source and derivation of the fuzzy control rules
- *Fuzzy Inference Machine:* The basic function is to compute the overall output of the control output variable based on the individual contribution of each rule in the Fuzzy Rule Base.
- *Defuzzification*: It converts the set of modified control output values into single point-wise (crisp) values and denormalizes the output onto its physical domain.

4 Fuzzy Variables

The various variables for the Fuzzy Controller are:

4.1 Fuzzy Input Variables

4.1.1 User Temperature (Ut)

User Temperature (Ut) is the temperature provided by the user through remote controller or thermostat. The range of this thermostat should vary between 18°C and 30°C. So the user set the temperature accordingly.

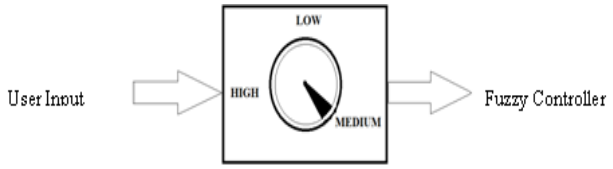

Fig 3: Arrangements to Accept User Temperature Preference (Ut)

Membership functions for Ut are shown in Fig. 4. The values taken into consideration during the membership Function are the values approximated from the data provided by IMD, Bhubaneswar [2].

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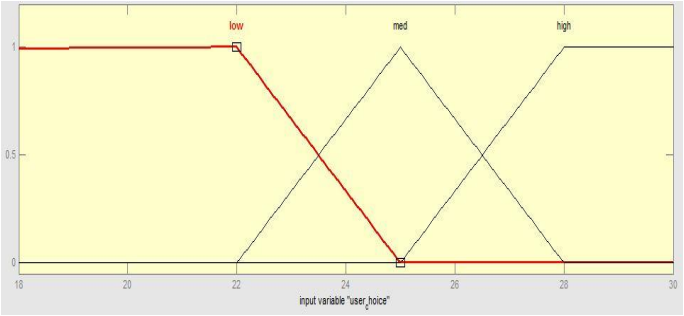

Fig 4: User Temperature Preference (Ut) Membership Functions

4.1.2 Temperature Difference (Td)

Temperature Difference (Td) is measure of the difference in the actual room temperature and the temperature which is provided by the user .The difference range is between -6C to +6C. Also AC cannot work as a heat pump and reverse its operation, so it is switched of once the difference go out of range.

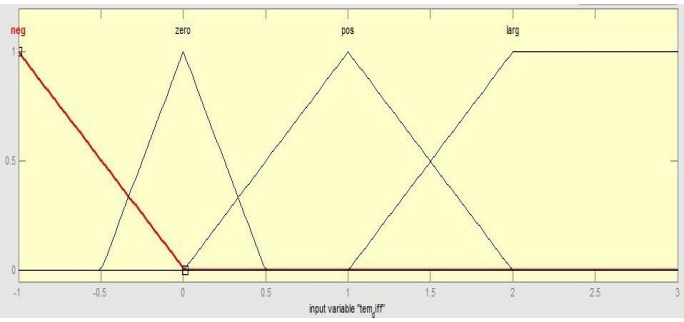

Fig 5: Temperature Difference (Td) Membership Functions

4.1.3 Dew Point (TDew)

Dew point temperature is the temperature at which water vapor in the air will condense into dew, frost, or water droplets given a constant air pressure. It can be defined alternately as the temperature at which the saturation vapor pressure and actual vapor pressure are equal [5]. Human reaction towards change in dew point temperature can be generally established. Based on the data provided by Indian Meteorological Department, stationed at Bhubaneswar, a standard Dew Point - Human Reaction table is generated. Based on this table, the membership function for Dew Point is determined and given in Fig 6.

TABLE 2
STANDARD DEW POINT TEMPERATURES

Dew Point	Human Reaction
28	Oppressive
26	Sticky
25	Humid
24	Comfortable
23	Refreshing

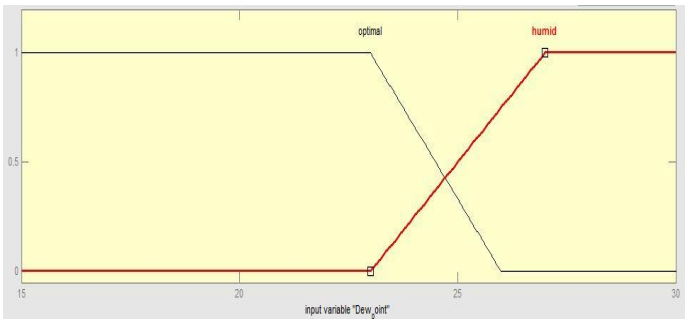

Fig 6: Dew Point Temperature (TDew) Membership Functions

4.1.4 Occupancy (Occ)

Occupancy is number of people exposed to air conditioner. The range of people will decide the level of occupancy as low, medium or high. In the absence of people the compressor as well as the fan remains off. We have taken into account the condition in a medium sized room. Level of Occupancy can also be applied to shopping malls where if it lies between 1-100 then it's considered as low else between 101-300 as medium or else above 300 as high. The ranges can be varied according to various scenarios like indoor stadiums, auditoriums, etc.

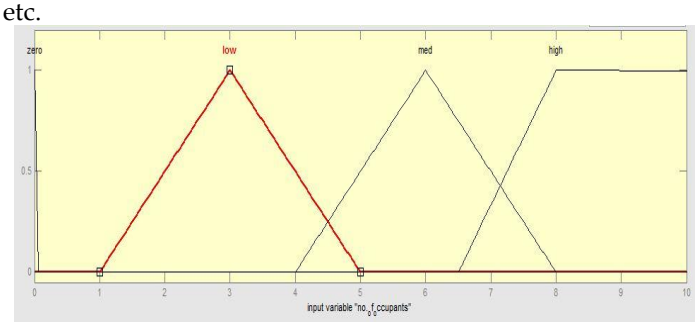

Fig 7: Occupancy (Occ) Membership Functions

4.1.5 Time of Day (TDay)

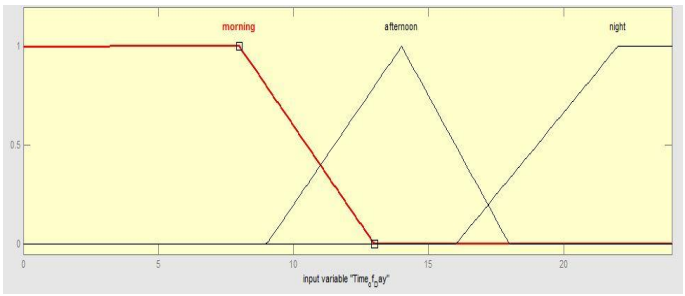

Fig 8: Time of Day (TDay) Membership Functions

Time of Day is the period during which the AC would be working. The temperature and dew point values vary significantly during morning/night time with that of afternoon time as per the data provided by IMD [2]. Also the value of Relative Humidity changes nearly between 15% to 20% at 0830hours and 1730 hours. Accordingly the range of requirement can be decided for an optimum cooling and power consumption. The range would be varied as 00:00 – 13:00 as morning, 09:00- 18:00 as afternoon, and 16:00-24:00 as night. Values of User Temperature and Dew Point Temperature are ranged keeping in mind the data provided by Indian Meteorological Department, Bhubaneswar [2]. The ranges of these values can be adjusted according to the specification of the area of operation of the AC.

4.2 Fuzzy Output Variables

The various outputs of the Fuzzy Controller are:

4.2.1 Compressor Speed (Sc)

The speed of compressor is varied between 30 to 100%. Accordingly it will affect the room temperature as per to the given input.

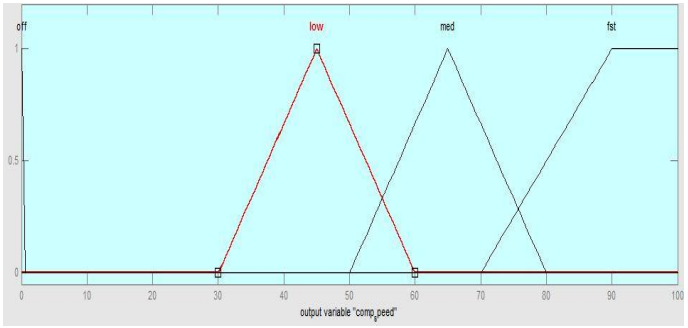

Fig 9: Compressor Speed (Sc) Member Function

4.2.2 Fan Speed (Sf)

The fan speed gives the information about the fan running inside the air conditioner .The speed of fan is accordingly varied between 30 to 100%.

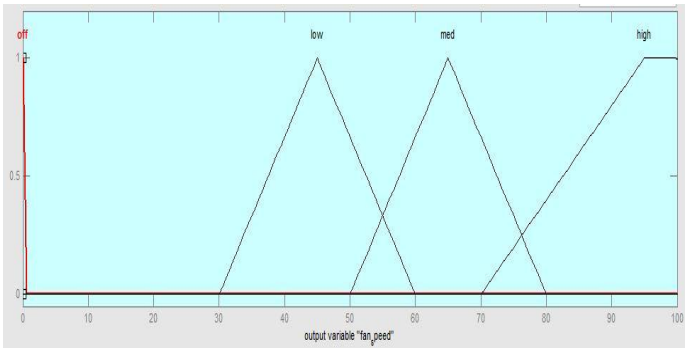

Fig 10: Fan Speed (Sf) Membership Functions

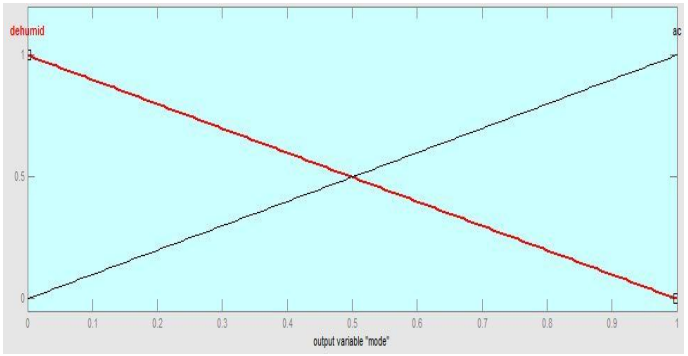

Fig 11: Operation mode (Mo) Membership Functions

4.2.3 Mode of Operation (Mo)

Air conditioning system can act as a cooler as well as dehumidifier. In the cooling state it will regulate the air to release cool air. But as dehumidifier it can absorb the humid content of the air by passing dry air into the room. This process does not increase the temperature of the room. This setting preference is usually not given to the user and is performed implicitly by the AC. Considering this parameter leads to greater efficiency and comfort levels.

4.2.4 Fin Direction (Fn)

The fins are the set of blades attached to the air conditioner to ensure a swift flow of air in a particular direction. The direction of these fins will define the flow of air either towards or away from the user. The angle of propagation of blades is set accordingly considering 0° as "towards" and 90° as "away".

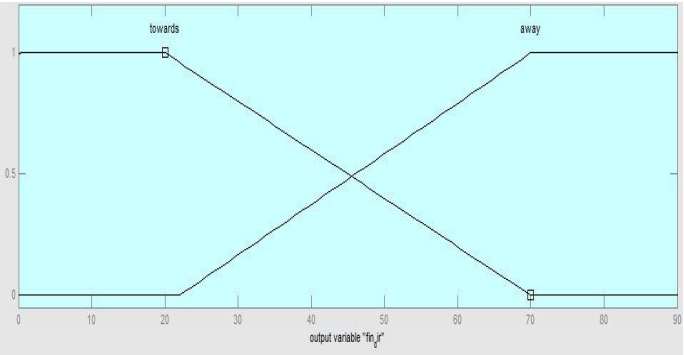

Fig 12: Fin direction (Fn) Membership Functions

5 FUZZY RULE BASE

Rules are formed keeping in mind heuristic relationship between input and output parameters. The inputs give rule base matrixes with size 2X3X3=18 matrices. Every cell has four outputs, each for compressor speed, fan speed, mode of operation and fin direction. This equates to total sets of 216 IF-THEN. For simplicity of understanding 4 of the 18 rule base output matrix is show below instead of the If-then statements.

TABLE 3
FUZZY BASE RULES FOR DEW POINT TEMPERATURE AT OPTIMAL VALUE AND OCCUPANCY AT LOW AND TIME OF DAY IS AFTERNOON

TDew-Optimal TDay-Afternoon Occ-Low

Td / ut	Negative		Zero		Positive		Large	
Low	O	A	O	A	L	T	L	T
	AC	M	AC	H	AC	M	AC	H
Medium	O	A	O	T	M	T	M	T
	AC	M	AC	M	AC	L	AC	M
High	O	A	L	T	M	T	M	T
	AC	H	AC	L	AC	M	AC	H

1	2
3	4

1.COMPRESSOR SPEED	O-off L-low M-medium F-fast
2.FIN ANGLE	A-away T-towards
3.MODE OF OPERATION	AC-airconditioner DH-dehumidifier
4.FAN SPEED	O-off L-low M-medium F-fast

TABLE 4
FUZZY BASE RULES FOR DEW POINT TEMPERATURE AT OPTIMAL POINT VALUE, OCCUPANCY AT HIGH AND TIME OF DAY IS NIGHT

TDew-Optimal TDay-Night Occ- High

Td / ut	Negative		Zero		Positive		Large	
Low	O	T	O	A	M	T	M	T
	AC	L	AC	M	AC	M	AC	H
Medium	O	T	O	A	M	T	H	T
	AC	M	AC	F	AC	H	AC	M
High	O	T	O	T	H	T	H	T
	AC	F	AC	F	AC	M	AC	H

TABLE 5
FUZZY BASE RULES FOR DEW POINT TEMPERATURE AT HUMID VALUE, OCCUPANCY AT HIGH AND TIME OF DAY AT AFTERNOON

TDew-Humid TDay-Afternoon Occ-High

Td / ut	Negative		Zero		Positive		Large	
Low	F	T	F	T	F	T	F	T
	DH	M	DH	F	AC	F	AC	F
Medium	M	T	M	T	F	T	F	T
	DH	F	DH	F	AC	F	AC	F
High	M	T	M	T	F	T	F	T
	DH	M	DH	M	AC	F	AC	F

TABLE 6
FUZZY BASE RULES FOR DEW POINT TEMPERATURE AT HUMID VALUE, OCCUPANCY AT MEDIUM AND TIME OF DAY AT MORNING

TDew-Humid TDay-Morning Occ-Medium

Td / ut	Negative		Zero		Positive		Large	
Low	M	T	F	T	M	T	F	T
	DH	F	DH	M	AC	F	AC	M
Medium	M	T	M	T	F	T	F	T
	DH	M	DH	M	AC	M	AC	F
High	L	T	M	T	F	T	F	T
	DH	F	DH	F	AC	F	AC	F

6 IMPLEMENTATION IN MATLAB

6.1 Fuzzy Base Class

We have used 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 Choice (ut), Temperature Difference (Td), and Occupancy (Occ), Time of Day (TDay) and the various output variables like Compressor Speed (Sc), Fan Speed (Sf), Mode of Operation (Mo) and Fin Direction (Fn) as shown in Fig. 13.

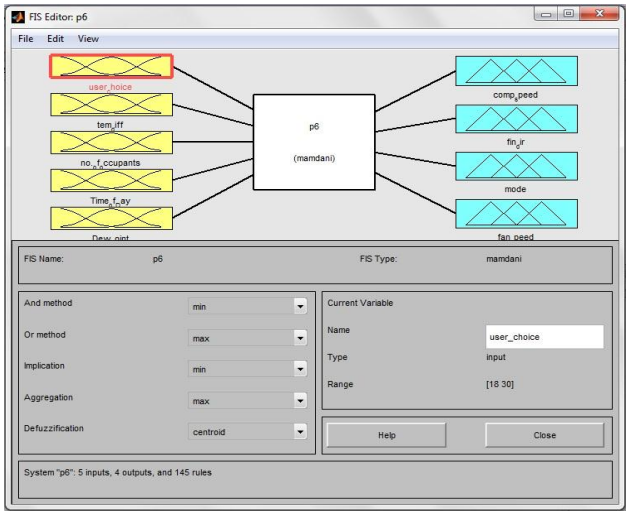

Fig 13: Fuzzy Base Class

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. Every rule can be deactivated and independent rule weight can be defined for each consequent variable. The rules are defined by selecting the right sequence in the If-then sequence. These rule sets form the basis upon which the fuzzy rules are implemented upon the provided inputs and subsequentially provide the fuzzy outputs.

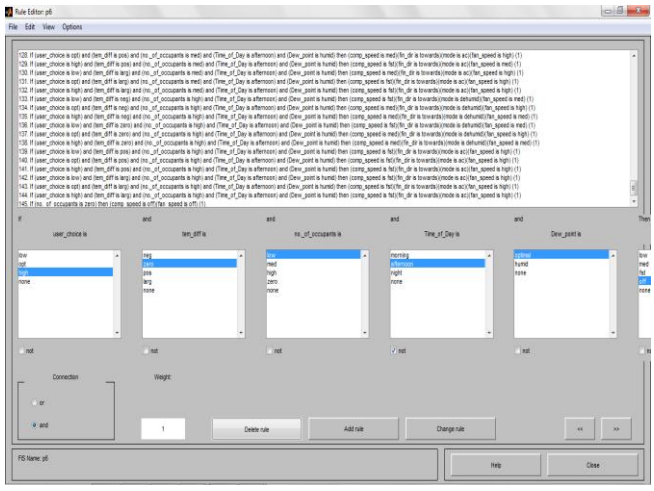

Fig 14: Fuzzy Base Rules

6.3 Simulated Graphs

With the help of the Surface Viewer of the Fuzzy Logic Toolbox, the following Graphs are generated:

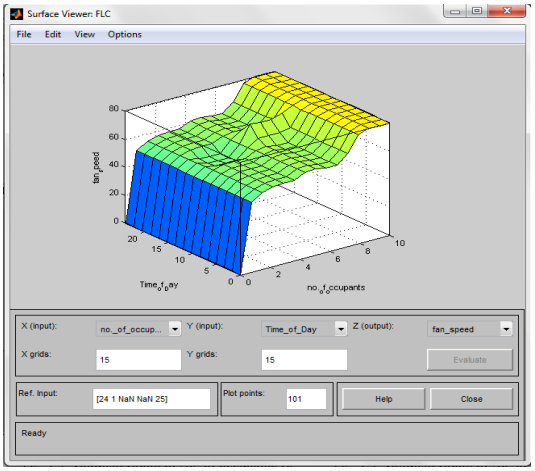

Fig 15: Gradient Graph of No. of Occupant vs Time of Day vs. Fan Speed

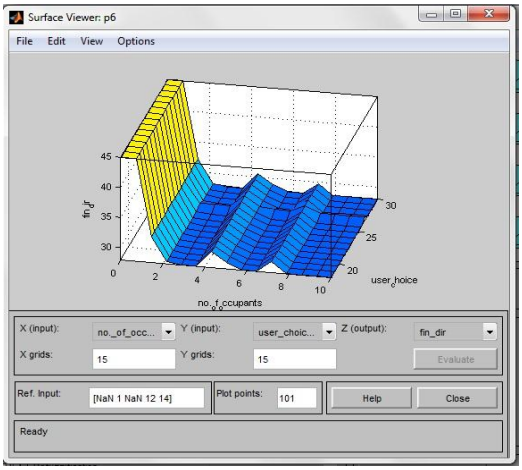

Fig 16: Gradient Graph of No. of Occupant vs. User Choice vs. Fin Direction

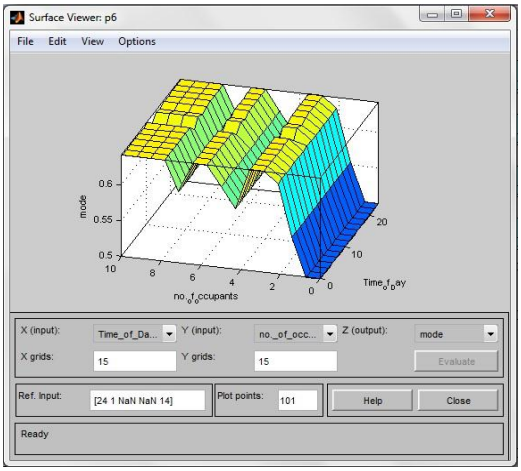

Fig 17: Gradient Graph of Temp Diff vs No. of Occupants vs. Compressor Speed

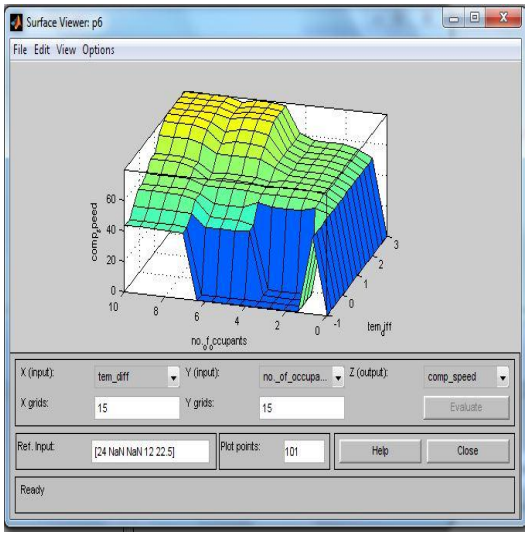

Fig 18: Gradient Graph of Time of Day vs. Number of Occupants vs. Mode of Operation

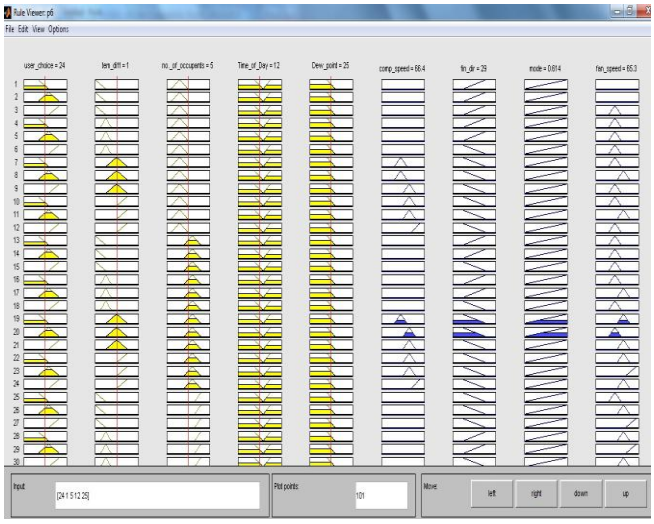

Fig 19: Fuzzy Rule Viewer

The Rule Viewer shown in Fig 19 gives us the insight about the application of the fuzzy member function to input values of the simulation. A set of inputs are taken, i.e. Ut=24, Td=1, Occ=5, TDay= 1200 hours, TDew=25 and the outputs are Sc=66.4, Fn=29, Mo=0.614, Sf=65.3.

7 Conclusions and Future Work

Previously the Air-Conditioning systems which were used to simply cool the rooms now can perform a variety of functions. By adding intelligence to the Air-Conditioning system we do not have to worry about the cooling process. The analysis clearly maps out advantage of fuzzy logic in dealing with problems that are difficult to study analytically yet are easy to solve intuitively in terms of linguistic variables. In case of the Air-Conditioning system, fuzzy logic helped solve a complex problem without getting involved in intricate relationships between physical variables. Intuitive knowledge about input and output parameters was enough to design an optimally performing system. 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. In future we will come up with a device that implements the Fuzzy Logic controller in an embedded system which can be used for increasing the efficiency of Air Conditioners.

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