Fuzzy Logic in HVAC for Human Comfort

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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.

Key words : Fuzzy, Air Conditioning System, Defuzzification, Dew Point, Fuzzy base class, Fuzzy rule base

1 INRTODUCTION

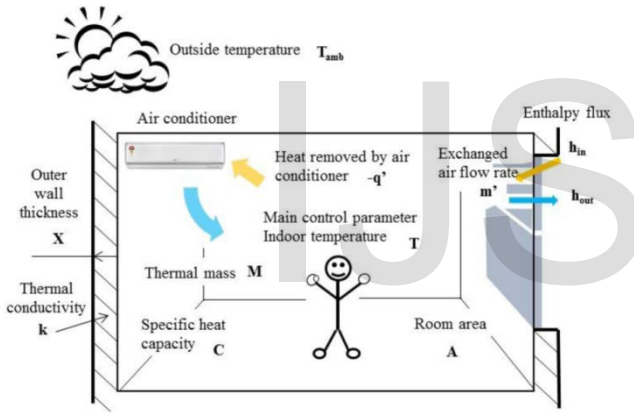


Figure 3. Mathematical modeling of temperature control in the air conditioning space.

$$-q' + kA(T_{amb}-T)/_X = \frac{d}{dt}\iiint_{CV} \rho u d\forall - m'C_p(T_{amb}-T)$$

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean **logic** on which the modern computer is based. The idea of **fuzzy logic** was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s.

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1, considered to be "fuzzy". By contrast, in Boolean logic, the truth values of variables may only be 0 or 1, often called "crisp" values. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false.[1] Furthermore, when linguistic variables are used, these degrees may be managed by specific (membership) functions.[2]

Classical logic only permits conclusions which are either true or false. For example, the notion that 1+1=2 is a fundamental mathematical truth.

Humans often operate using fuzzy evaluations in many everyday situations. In the case where someone is tossing an object into a container from a distance, the person does not compute exact values for the object weight, density, distance, container height and width and air resistance to determine the force and angle to toss the object. Instead the person uses quick "fuzzy" estimates, based upon previous experience, to determine what output values to use to make the toss. [3]

2 DESIGN OF HVAC

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 simplerefrigeration 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.

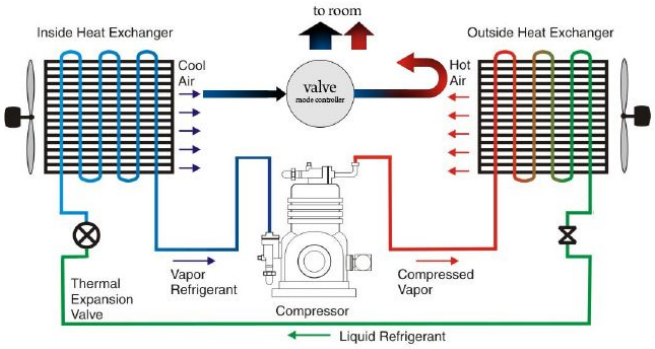


Figure 1 Simplified working diagram of AC

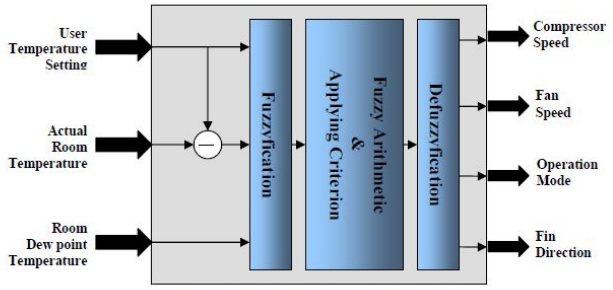


Figure 2: Basic block diagram of controller

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 con-tains 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 out-put 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.

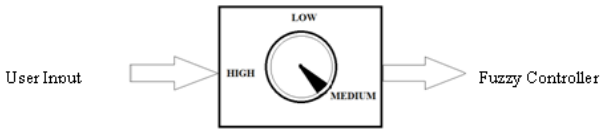
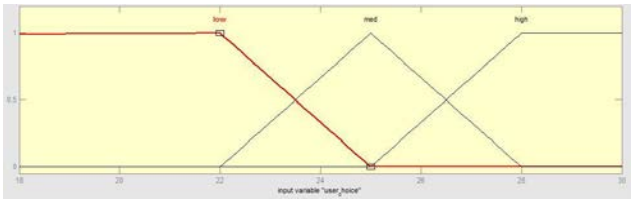


Fig 3: Arrangements to Accept User Temperature Preference (Ut)

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].



4.1.2 Temperature Difference (Td)

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

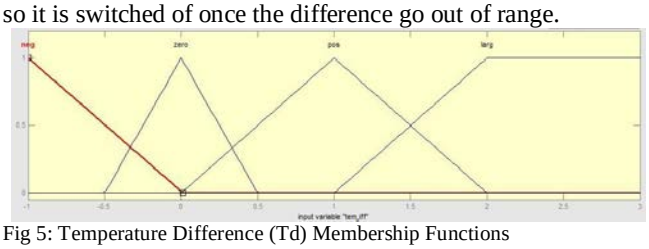


Fig 5: Temperature Difference (Td) Membership Functions

4.1.3 Dew Point (TDew)

Dew point temperature is the temperature at which water va-por 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 pressureare equal [5]. Human reaction towards change in dew point temperature can be generally established. Based on the data provided by Indian Meteorological Depart-ment, stationed at Bhubaneswar, a standard Dew Point -Hu-man Reaction table is generated. Based on this table, the mem-bership 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

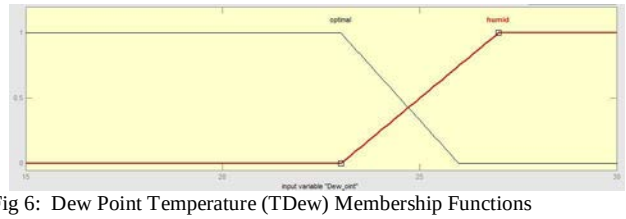


Fig 6: Dew Point Temperature (TDew) Membership Functions

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 medi-

um or else above 300 as high. The ranges can be varied according to various scenarios like indoor stadiums, auditoriums, etc.

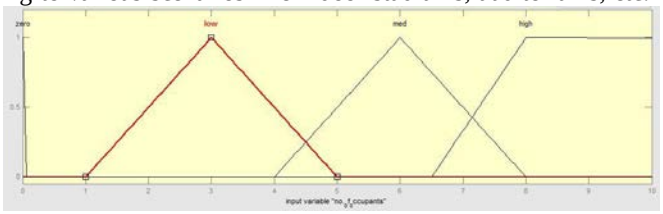


Fig 7: Occupancy (Occ) Membership Functions

4.1.5 Time of Day (T Day)

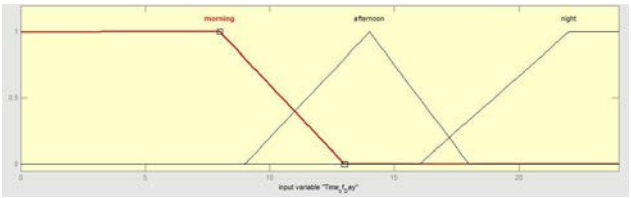


Fig 8:Time of Day (TDay) Membership Functions

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 Rela-tive Humidity changes nearly between 15% to 20% at 0830hours and 1730hours. Accordingly the range of require-ment can be decided for an optimum cooling and power con-sumption. The range would be varied as 00:00 –13:00 as morn-ing, 09:00-18:00 as afternoon, and 16:00-24:00as 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 opera-tion 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.

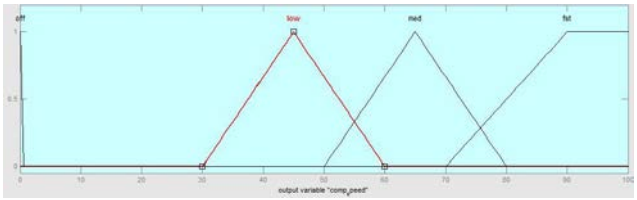


Fig 9: Compressor Speed (Sc) Member Function

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%.

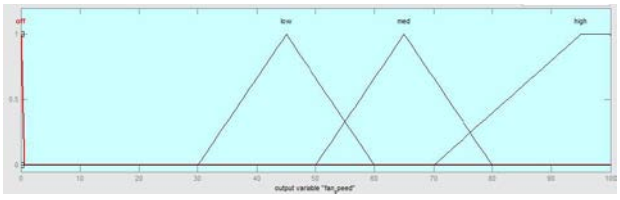


Fig 10: Fan Speed (Sf) Membership Functions

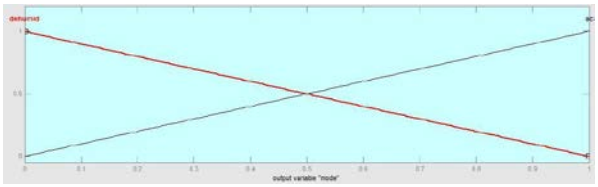


Fig 11: Operation mode (Mo) Membership Functions

4.2.3Mode 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 prefer-ence is usually not given to the user and is performed implicit-ly by the AC. Considering this parameter leads to greater effi-ciency 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”.

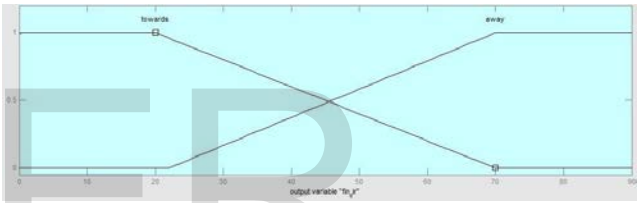


Fig 12:Fin direction (Fn) Membership Functions

5 FUZZY RULE BASE

Rules are formed keeping in mind heuristic relationship between input and output parameters. The inputs give rule base matrixeswith 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

Sf / 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. CONCLUSION 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 Cond

7. REFERENCES

1. Novák, V., Perfilieva, I. and Močkoř, J. (1999) *Mathematical principles of fuzzy logic* Dodrecht: Kluwer Academic. ISBN 0-7923-8595-0
2. **Jump up**^ Ahlawat, Nishant, Ashu Gautam, and Nidhi Sharma (International Research Publications House 2014) "Use of Logic Gates to Make Edge Avoider Robot." *International Journal of Information & Computation Technology* (Volume 4, Issue 6; page 630) ISSN 0974-2239 (Retrieved 27 April 2014)
3. Fuzzy Logic Control of Air Conditioners On September 1, 2007, in Energy, Research, Soft Computing, by Amiya - See more at: http://aptnk.in/2007/09/fuzzy-logic-control-of-air-conditioners/#sthash.ExnzyxX2.dpuf
4. Chin-Chi Cheng and Dasheng Lee, Sensors 2014, 14, 11179-11203; doi:10.3390/s140611179 sensors ISSN 1424-8220 www.mdpi.com/journal/sensors
5. Sanjit Kumar Dash, Gouravmoy Mohanty, Abhishek Mohanty, International Journal of Scientific & Engineering Research Volume 3, Issue 12, December-2012 1 ISSN 2229-5518
6. http://moef.nic.in/downloads/public-information/ Residen-tialpowerconsumption.pdf
7. Indian Meterological Department, Bhubhaneswar, Odisha, Govern-ment of India.
8. http://en.wikipedia.org/wiki/Fuzzy_logic US Patent – 5,921,099; Air conditioner temperature control apparatus; Inventor: Seon Woo Lee; Assignee: Samsung Electronics Co., Ltd. Issue date: Jul 13, 1999
9. I J Nagrath and M Gopal, Control system engineering; New Age In-ternational Publisher 2010.
10. http://en.wikipedia.org/wiki/Air_conditioner.
11. http://www.alcornaire.com/howdo.shtml
12. Mohanad Alata , Moh'd Al-Nimr, and Rami Al-Jarrah, World Academy of Science, Engineering and Technology International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:6, No:11, 2012