FUZZY LOGIC SIMULATIONS FOR A SMART AIR CONDITIONING SYSTEM

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ABSTRACT

The temperature control, fan speed, and other features of the air conditioning system we use every day are all manually automated. Recent air conditioners offer automatic temperature control, variable fan speed, variable compressor speed, and more. However, using a Fully Logic Control System, we have refined it in this study to move automation one step further ahead. We count the number of people in the room using an IR sensor, and the temperature and fan speed are then adjusted accordingly. We estimate the room's size using sonar, and based on this data, we determine the fin's tilt position and maintain fan speed. We determine the inside temperature using an external temperature and humidity sensor. These are the three variables or ways by which we calculate the temperature, fan speed, and fin direction necessary to maintain the desired temperature.

Keywords: Fuzzy Logic Control, MATLAB, Air conditioner, Sensor, FLC System.

1. INTRODUCTION

In our daily lives, the air conditioning system has grown in importance. It has evolved into the most prevalent and fundamental need for people everywhere in the planet. Reeds were hung fastened to the window side and trickling water was used to wet the air in the ancient Egyptian air conditioning system. The seed's evaporation caused the air blowing from the window to become cold.

The modern air conditioners use the fuzzy logic controller system to provide instructions to the conditioners when and what to do. There is a small electronic box holding all electronic components in which fuzzy logic has been coded into it **[1].**

In paper **[6]** it has been reviewed that the use of smart machines like air conditioner and washing machines makes use of fuzzy logic controller. It has been stated that, "Researchers are converting crisp phenomena to fuzzy"

Fuzzy logic was first introduced in the year 1965 by Professor Lotfi A.Zadeh, University of California **[7].** It is used to develop control system using powerful design technology. It is used by engineers to implement complex systems by simple methods **[8]**.

It accepts various degree inputs in a particular amount of time and can develop a system in more natural ways **[9].** Fuzzy logic controllers are similar to the classical controllers which uses knowledge gained from human thoughts and operators**.** Using fuzzy logic behavioral model, gas heaters were also designed **[2].**

The performances of these fuzzy logic are controlled by the embedded automatic controller **[3]**. The fuzzy logic is a logic where when an input is given, it produces the output which already coded for the particular input.

The simulation of the fuzzy logic controller system is done using the software called MATLAB. It is a toolbox which can be used to design fuzzy logic controller **[4].** It is the most used simulation software for simulation of any kind of input and to read the output and we can compare it with our expected result. It is being used by many engineers and scientists across the world.

Fuzzy Logic is a mathematical system which is used to analyze the analog input in terms of fuzzy logic values **[5].** According to the present-day technology, Fuzzy Logic has become a focused interest for both the industrial usage and fundamental perspectives**.** Using this technique [19], basic necessities of an agricultural land can be satisfied and is also useful for productive farming technique. The main concentration of this idea will be based on the cultivation of three different varieties of the Paddy.

The input given for the process is type of clothes, degree of dirt and mass of the cloth load and the output received is wash time, RPM, dry time, temperature. The simulation results show that the system provides a good wash quality [16]. The principle [18] of this process is to subject input to Fuzzy arithmetic which in turn returns the value of the temperature of water and washing time.

2. PROPOSED DESIGN

The fuzzy logic system can be determined by using inputs and outputs given. The main task of this air conditioner is to provide a cool temperature to the room with best possible current consumption with respect to room size, number of persons, atmospheric temperature and ton capacity of the air conditioner. There are 27 rules for input and output for smart air conditioning system which is produced to provide the proposed fuzzy logic. To achieve the best economical usage of air conditioner, the input parameters for the fuzzy logic are:

1. Number of Persons
2. Room size
3. Atmospheric temperature

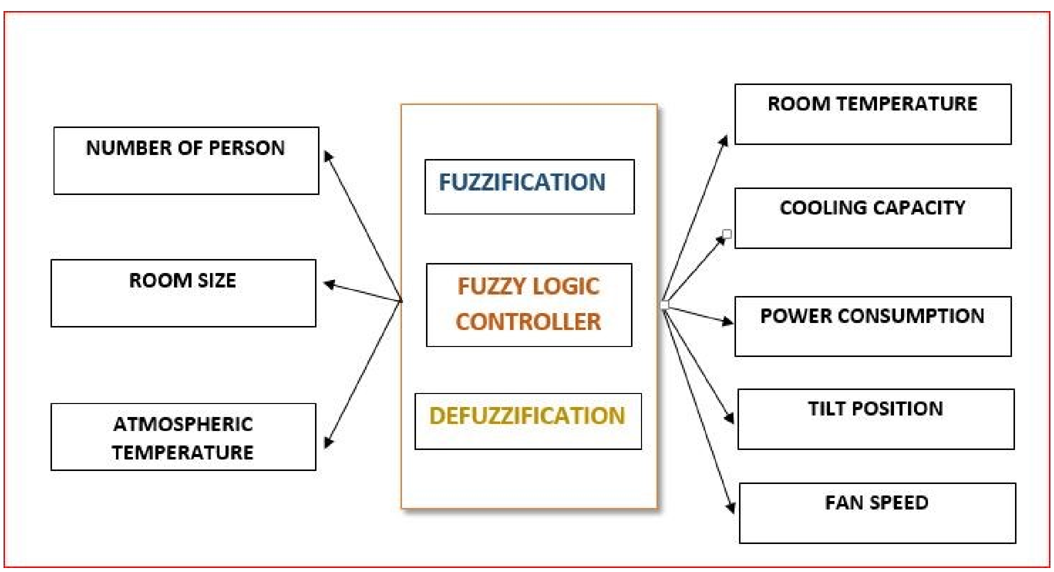

Figure 1: Fuzzy logic system of air conditioner

The fuzzy logic system processes the input and provides the outputs such as:

1. Room temperature
2. Cooling capacity
3. Power consumption
4. Tilt position
5. Fan speed

The input values are converted into corresponding fuzzy-set values by the process of fuzzification. The desired input derives the output for the rules applied to the machine by inference engine to obtain a crisp output. Defuzzification is carried out by the center of gravity method.

The input and output values are decided in advance to deal with the details of fuzzy logic controller. The crisp input values are mapped to the fuzzy values by the Membership function and after the suitable operation on them. The process which converts crisp value into Fuzzy value is known as Fuzzification.

2.1 Automation using IR sensor

We have the IR sensor placed inside the logic board. The IR sensor detects the number of persons present in the room. The fuzzy logic system takes the number of persons as the input and determines the temperature needed for the room.

For example: If the input is 2, (i.e.,) two persons, the room temperature is 24°C

If the input is 4, then the temperature reduces to 20°C,

Thus, maintaining the room temperature to be sufficient enough for the human body.

2.2 Automation using SONAR

Sonar is a device which detects the distance of any object from the source. It uses the ultrasonic waves to detect it. We use this in our system placed in the logic board which detects the size of the room and gives the input to the fuzzy logic as large, medium or small and produces the output of the tilt direction of the fin and fan speed.

For e.g. If the input is large, i.e., size of a room, then the tilt position and fan speed is high

If the input is small, then the output, i.e., the tilt position is low and the fan speed is dependent of the number of persons.

2.3 Automation using the atmospheric condition

We use the temperature and humidity sensor which is placed in the outdoor unit. These sensors detect the temperature and humidity of the atmosphere. This sensor output is given as an input to the fuzzy logic system in the logic board. This determines the temperature to be maintained in the room as low or high.

For e.g. If the input is low, i.e. the atmospheric temperature, then the temperature inside the room is slightly high. Consider the atmospheric temp to be 30°C, then the room temperature to be maintained is 24°C.

2.4 Rule base for Fuzzy Logic System

Rule 1: If (Number of persons is Less) and (Room Size is Small) and (Atmospheric Temperature is Cold) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 2: If (Number of persons is Less) and (Room Size is Medium) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 3: If (Number of persons is Less) and (Room Size is Large) and (Atmospheric Temperature is Hot) then (Room Temperature is High) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Rule 4: If (Number of persons is Normal) and (Room Size is Small) and (Atmospheric Temperature is Cold) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 5: If (Number of persons is Normal) and (Room Size is Medium) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 6: If (Number of persons is Normal) and (Room Size is Large) and (Atmospheric Temperature is Hot) then (Room Temperature is High) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Rule 7: If (Number of persons is More) and (Room Size is Small) and (Atmospheric Temperature is Cold) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 8: If (Number of persons is More) and (Room Size is Medium) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 9: If (Number of persons is More) and (Room Size is Large) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Fast)

Rule 10: If (Number of persons is Less) and (Room Size is Small) and (Atmospheric Temperature is Cold) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 11: If (Number of persons is Normal) and (Room Size is Small) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 12: If (Number of persons is More) and (Room Size is Small) and (Atmospheric Temperature is Hot) then (Room Temperature is High) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Rule 13: If (Number of persons is Less) and (Room Size is Medium) and (Atmospheric Temperature is Cold) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 14: If (Number of persons is Normal) and (Room Size is Medium) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate).

Rule 15: If (Number of persons is More) and (Room Size is Medium) and (Atmospheric Temperature is Hot) then (Room Temperature is High) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Rule 16: If (Number of persons is Less) and (Room Size is Large) and (Atmospheric Temperature is Cold) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 17: If (Number of persons is Normal) and (Room Size is Large) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 18: If (Number of persons is More) and (Room Size is Large) and (Atmospheric Temperature is Hot) then (Room Temperature is High) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Rule 19: If (Number of persons is Less) and (Room Size is Small) and (Atmospheric Temperature is Cold) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 20: If (Number of persons is Normal) and (Room Size is Medium) and (Atmospheric Temperature is Cold) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 21: If (Number of persons is More) and (Room Size is Large) and (Atmospheric Temperature is Cold) then (Room Temperature is Medium) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Rule 22: If (Number of persons is Less) and (Room Size is Small) and (Atmospheric Temperature is Warm) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 23: If (Number of persons is Normal) and (Room Size is Medium) and (Atmospheric Temperature is Warm) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 24: If (Number of persons is More) and (Room Size is Large) and (Atmospheric Temperature is Warm) then (Room Temperature is High) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Rule 25: If (Number of persons is Less) and (Room Size is Small) and (Atmospheric Temperature is Hot) then (Room Temperature is Low) (Cooling Capacity is Warm) (Power Consumption is Low) (Tilts Position is Low) (Fan Speed is Low)

Rule 26: If (Number of persons is Normal) and (Room Size is Medium) and (Atmospheric Temperature is Hot) then (Room Temperature is Medium) (Cooling Capacity is cold) (Power Consumption is Medium) (Tilts Position is Centre) (Fan Speed is Moderate)

Rule 27: If (Number of persons is More) and (Room Size is Large) and (Atmospheric Temperature is Hot) then (Room Temperature is High) (Cooling Capacity is Very Cold) (Power Consumption is High) (Tilts Position is High) (Fan Speed is Fast)

Table 1: The rules for set of inputs and outputs are derived using MATLAB

S. NO	LINGUISTIC INPUTS			LINGUISTIC OUTPUTS				
	NUMBER OF PERSON	ROOM SIZE	ATMOSSPHERIC TEMPERATURE	ROOM TEMPERAT URE	COOLING CAPACITY	POWER CONSUM PTION	TILTS POSITION	FAN SPEED
1	Less	Small	Cold	Low	Very cold	Low	Low	Low
2	Less	Medium	Warm	Medium	Cold	Medium	Centre	Mediu m
3	Less	Large	Hot	High	warm	High	High	Fast
4	Normal	Small	Cold	Low	Very cold	Low	Low	Low
5	Normal	Medium	Warm	Medium	Cold	Medium	Centre	Mediu m
6	Normal	Large	Hot	High	warm	High	High	Fast
7	More	Small	Cold	Low	Very cold	Low	Low	Low
8	More	Medium	Warm	Medium	Cold	Medium	Centre	Mediu m
9	More	Large	Hot	High	warm	High	High	Fast
10	Less	Small	Cold	Low	Very cold	Low	Low	Low
11	Normal	Small	Warm	Medium	Cold	Medium	Centre	Mediu m
12	More	Small	Hot	High	warm	High	High	Fast
13	Less	Medium	Cold	Low	Very cold	Low	Low	Low
14	Normal	Medium	Warm	Medium	Cold	Medium	Centre	Mediu m
15	More	Medium	Hot	High	warm	High	High	Fast
16	Less	Large	Cold	Low	Very cold	Low	Low	Low
17	Normal	Large	Warm	Medium	Cold	Medium	Centre	Mediu m
18	More	Large	Hot	High	warm	High	High	Fast
19	Less	Less	Cold	Low	Very cold	Low	Low	Low
20	Normal	Normal	Cold	Medium	Cold	Medium	Centre	Mediu m
21	More	More	Cold	High	warm	High	High	Fast
22	Less	Less	Warm	Low	Very cold	Low	Low	Low
23	Normal	Normal	Warm	Medium	Cold	Medium	Centre	Mediu m
24	More	More	Warm	High	warm	High	High	Fast
25	Less	Less	Hot	Low	Very cold	Low	Low	Low
26	Normal	Normal	Hot	Medium	Cold	Medium	Centre	Mediu m
27	More	More	Hot	High	warm	High	High	Fast

3. SIMULATION AND RESULTS

There are four inputs and five outputs of fuzzy logic are provided and produced respectively in terms of membership functions which are mentioned in the table 1. In this part, we find membership functions for each and every corresponding input and output. The fuzzy logic of the air conditioner is shown in figure 2.

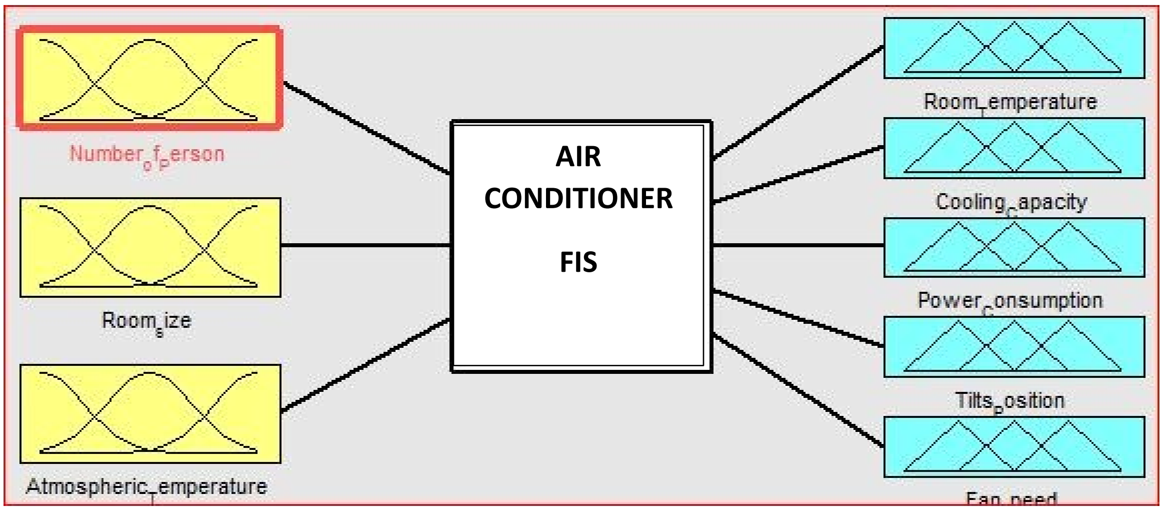

Figure 2: Fuzzy Inference System for smart air conditioner

4. MEMBERSHIP FUNCTIONS FOR FUZZY LOGIC

4.1 Membership functions for inputs

In FLC system, the crisp input values are converted into fuzzy values. The fuzzy logic controller system inputs can be represented by using membership functions in terms of linguistic inputs. The membership functions can be defined with parameters which are used. For number of persons such as less, normal and more, the membership functions are [-5 0 5], [2 5 8] and [5 10 15] respectively. For room size such as small, medium and large, the membership functions are [-5 0 5], [2 5 8] and [5 10 15] respectively. For capacity tons such as cold, warm and very cold, the membership functions are [-5 0 15], [2 5 8] and [5 10 15] respectively. Similarly, for atmospheric temperature such as cold, warm and hot, the membership functions are [-5 0 15], [2 5 8] and [5 10 15] respectively.

4.1.1 Number of persons

Number of persons can be calculated using thermal sensor fitted into the air conditioning system. Number of persons is represented by three membership functions such as less, normal and more as in table 2.

Table 2: Range of number of persons for a fuzzy set

INPUT	FUZZY SET	RANGE
Number of persons	Less	1-3
	Normal	4-6
	More	7-9

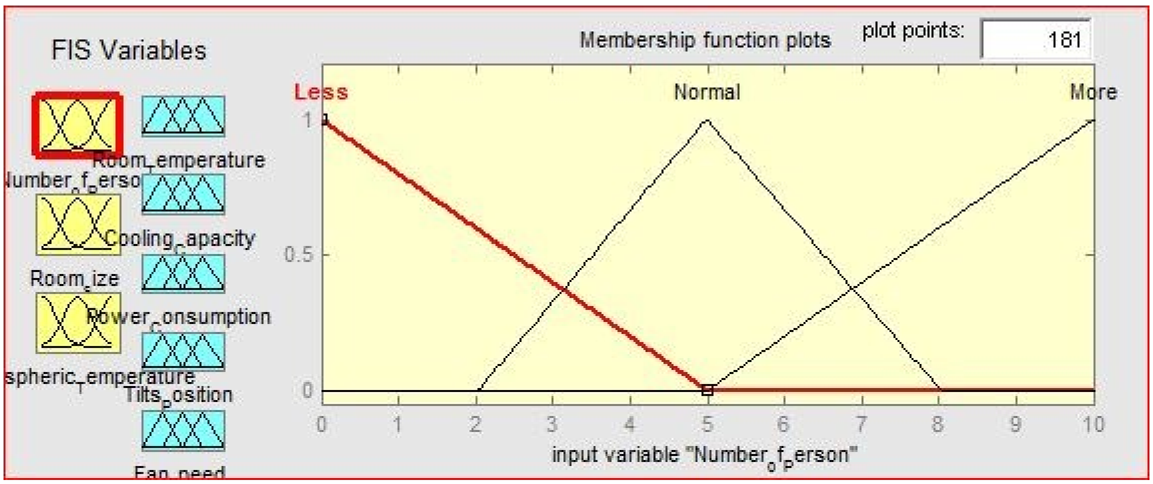

Figure 3: Fuzzy membership function for No. of persons

4.1.2 Room size

It is calculated with the use of sonar attached in the air conditioner. The size of the room is represented by three membership functions such as small, medium and large as given in the table 3.

Table 3: Range of room size for a fuzzy set

INPUT	FUZZY SET	RANGE
Room size	Small	1-100 sq. ft.
	Medium	101-150 sq. ft.
	Large	151-200 sq. ft.

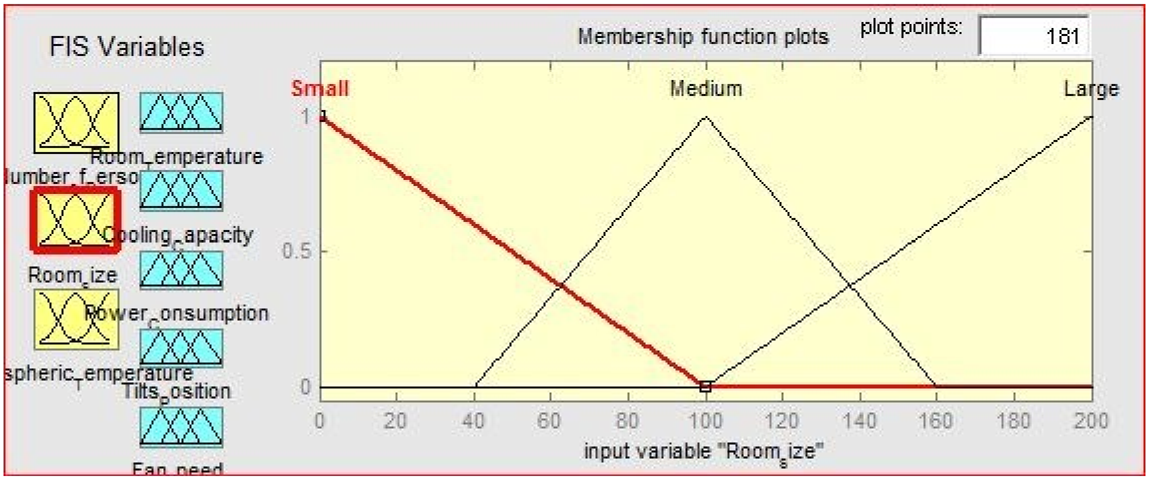

Figure 4: Fuzzy membership function for Room size

4.1.3 Atmospheric Temperature

Atmospheric temperature is represented by three membership functions such as cold, warm and hot as in table 4.

Table 4: Range of atmospheric temperature for a fuzzy set

INPUT	FUZZY SET	RANGE
Atmospheric Temperature	Cold	<25^{0}C
	Warm	26^{0}C-30^{0}C
	Hot	31^{0}C-45^{0}C

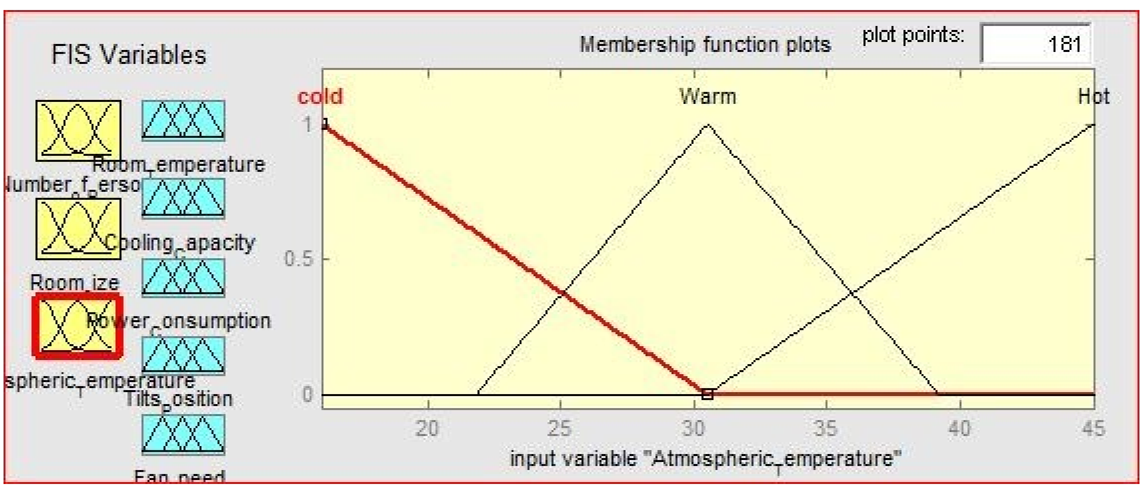

Figure 5: Fuzzy membership function for Atmospheric Temperature

4.2 Membership functions for outputs

The membership functions for room temperature are low [-20 0 20], medium [10 25 40] and high [35 30 50]. Membership functions for cooling capacity are very cold [-40 0 40], cold [10 50 30] and warm [60 100 140]. The membership functions for power consumption are low [-40 0 40], medium [10 50 30] and high [60 100 140]. The membership functions for tilt position are low [-4 0 4], center [1 5 9] and high [6 10 14]. The membership functions for fan speed are low [-450 0 450], medium [120 600 1080] and high [720 1200 1200].

4.2.1 Room Temperature

Room temperature can be calculated with the use of atmospheric temperature and number of persons. Room temperature is represented by three membership functions such as low, medium and high as in table 5.

Table 5: Range of room temperature for a fuzzy set

INPUT	FUZZY SET	RANGE
Room Temperature	Low	<16^{0}C
	Medium	17^{0}C-25^{0}C
	High	26^{0}C-30^{0}C

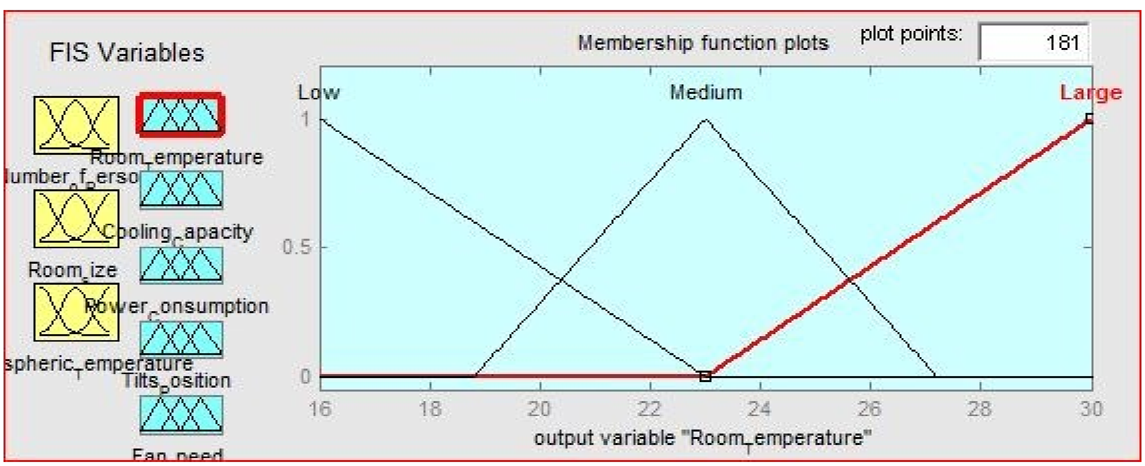

Figure 6: Fuzzy membership function for Room temperature

4.2.2 Cooling capacity

Cooling capacity can be calculated using the number of persons present and room temperature. Cooling capacity is represented by three membership functions such as very cold, cold and warm as in table 6.

INPUT	FUZZY SET	RANGE
Cooling Capacity	Very cold	<3500W
	Cold	3600W-5100W
	warm	5200W-6200W

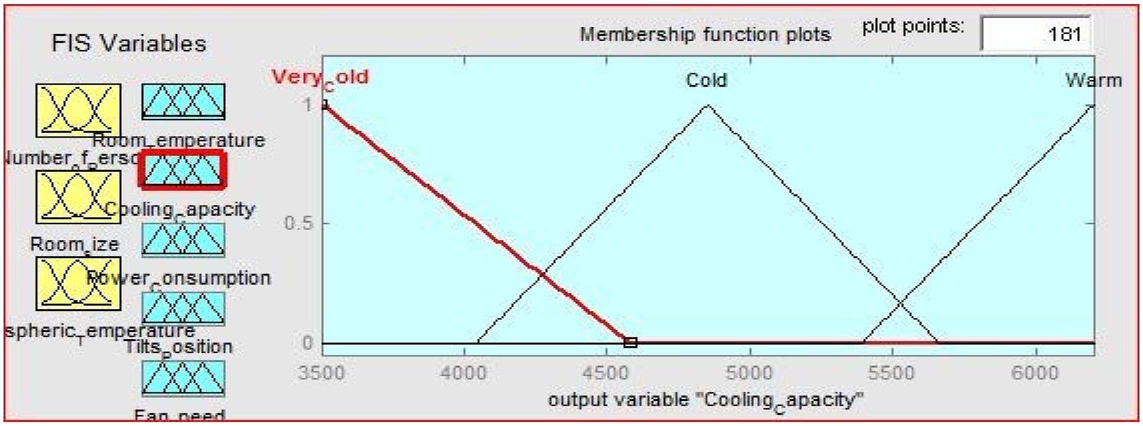

Figure 7: Fuzzy membership function for Cooling capacity

4.2.3 Power consumption

Power consumption is represented by three membership functions such as low, medium and high as in table 7.

Table 7: Range of power consumption for a fuzzy set

INPUT	FUZZY SET	RANGE
Power consumption	Low	<1080W
	Medium	1100W-1500W
	High	1600W-2000W

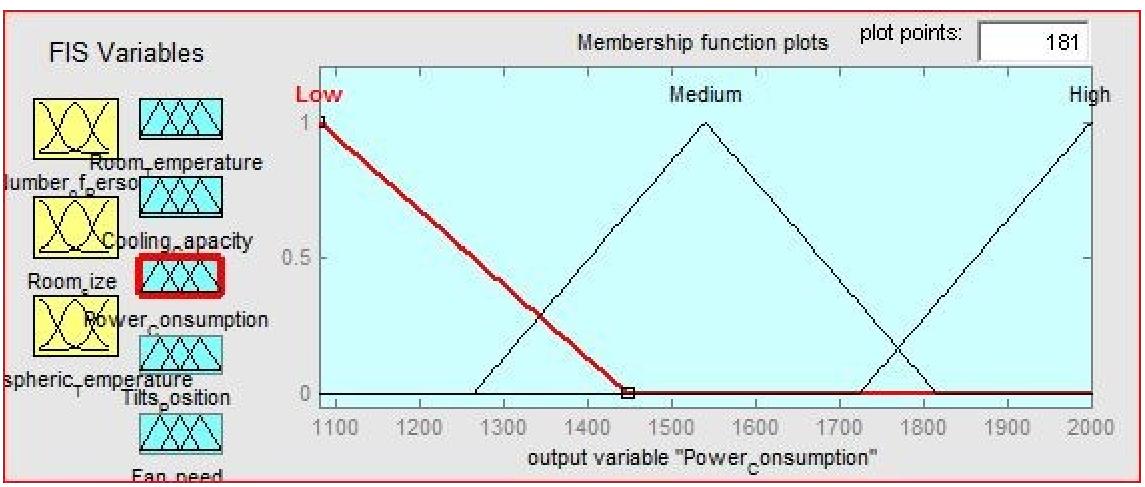

Figure 8: Fuzzy membership function for Power consumption

4.2.4 Tilts Position

Tilt position can be identified by using the size of the room which uses sonar to find the room size. Tilt position is also known as fin direction, which is a group of blades attached to the air conditioner which defines the direction and pitch of flow of air like low or away from the AC. Tilts position are represented by three membership functions such as low, centre and high as in table 8.

Table 8: Range of tilts position for a fuzzy set

INPUT	FUZZY SET	RANGE
Tilts position	Low	1-10 ft
	Centre	11-20 ft
	High	21- 30 ft

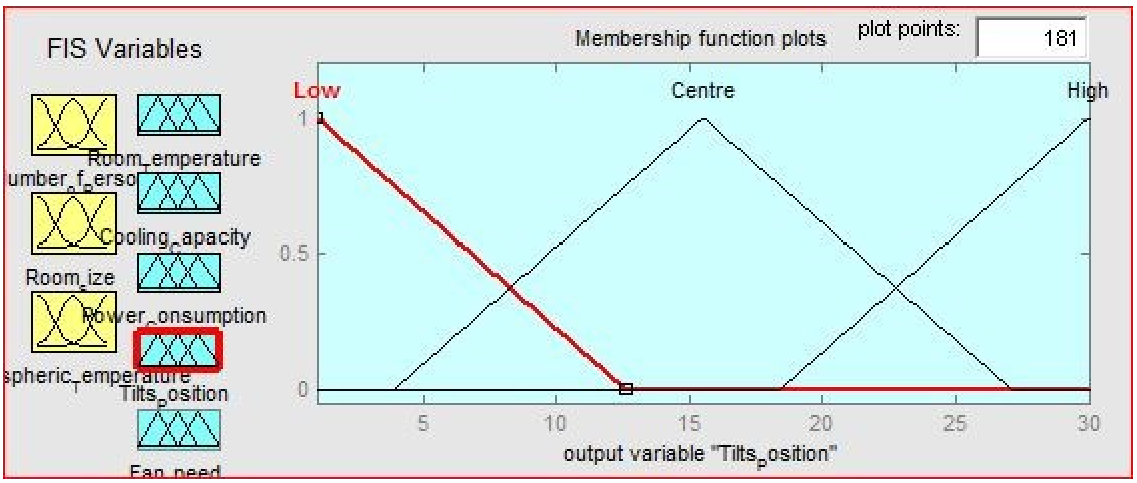

Figure 9: Fuzzy membership function for Tilt position

4.2.5 Fan speed

Fan speed can be calculated by using the size of the room and number of persons present in the room. The fan speed is calculated with three characters such as low, medium and high or fast with scales ranging from 0 – 1200 rpm. Fan speed is represented by three membership functions such as low, medium and fast as in table 9.

Table 9: Range of fan speed for a fuzzy set

INPUT	FUZZY SET	RANGE
Fan speed	Low	0 - 850 rpm
	Medium	650-1150 rpm

	Fast	950-1200 rpm

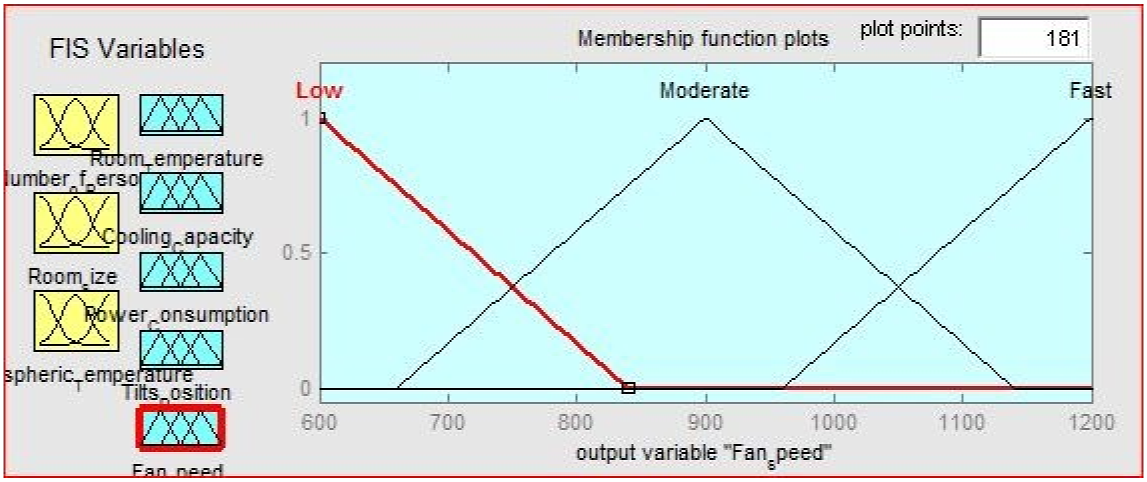

Figure 10: Fuzzy membership function for Fan speed

6. RULE VIEWER FOR SMART AIR CONDITIONER USING FUZZY LOGIC SYSTEM

The rule viewer graph represented here represent how the five outputs such as room temperature, cooling capacity, power consumptions, tilt positions and fan speed are obtained based on the inputs such as number of persons, room size and atmospheric temperature. For example, when we consider less, normal and more, the value generated for the number of persons are five. For small, medium and large, the value generated for room size is 100 sq. ft. For cold, warm and hot, the value generated for the atmospheric temperature is 30.5^{0}C. When we consider the outputs, for low, medium and high the value generated for room temperature is 23^{0}C. For very cold, hot and warm, the value generated for cooling capacity is 4,850 W**.** For low, medium and high, the power consumption value generated is 1,540 W. For low, center and high, the value generated for the tilt position is 15.5 ft.. For low, medium and fast, the value generated for the fan speed is 678 rpm. Hence these results for the if-then rules by the MATLAB are obtained using the rule viewer.

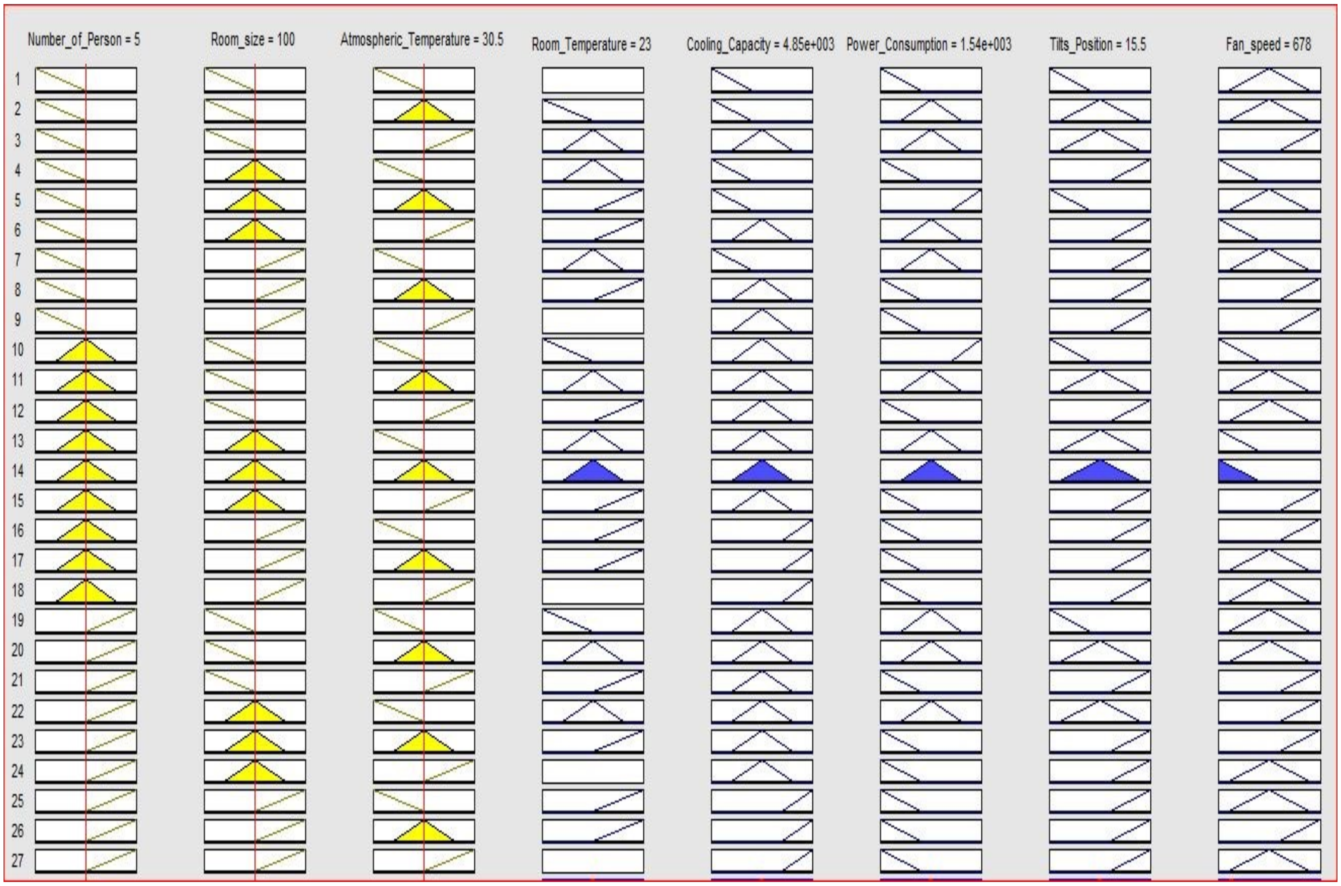

Figure 11: Rule viewer for Fuzzy logic system of air conditioner

6. SURFACE VIEWER FOR FUZZY LOGIC SYSTEM OF AIR CONDITIONER

The fuzzy logic system has been implemented to provide output for the given input of the air conditioner. Fuzzy logic toolbox in MATLAB is used to develop the fuzzy logic system of the air conditioner. The surface viewer helps us to represent the relation between the input and the output parameter of the membership function. The 3D surface viewer for the input and output are graphed in the figure 12.

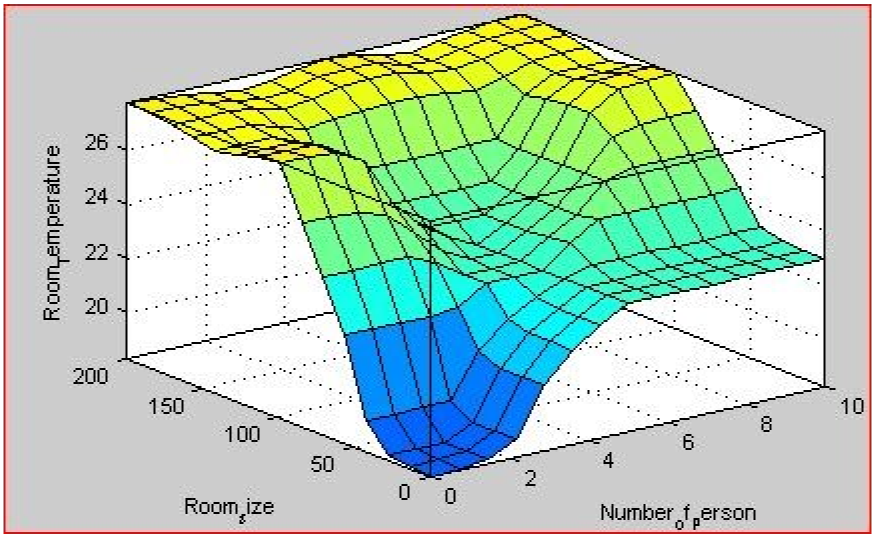

Figure 12: Surface viewer for Number of person vs Room size for Room temperature

According to the surface viewer shown in the figures from 13 to 15, as the number of persons increase, the room temperature also increases. Simultaneously, as the room size increases, room temperature decreases. Eventually, when both increase, the temperature is at the peak. So to maintain the room temperature cool, fuzzy logic used in the air conditioner, senses the temperature using sensor and to maintain it.

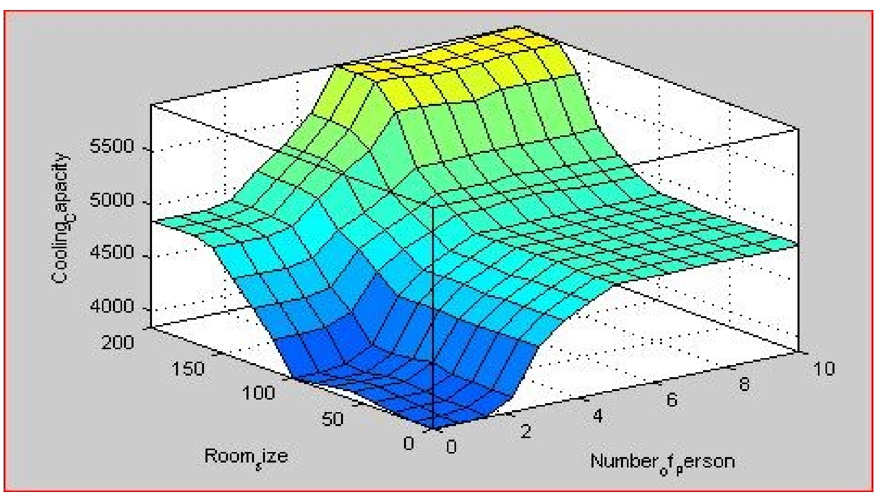

Figure 13: Surface viewer for Number of person vs Room size for the Cooling capacity

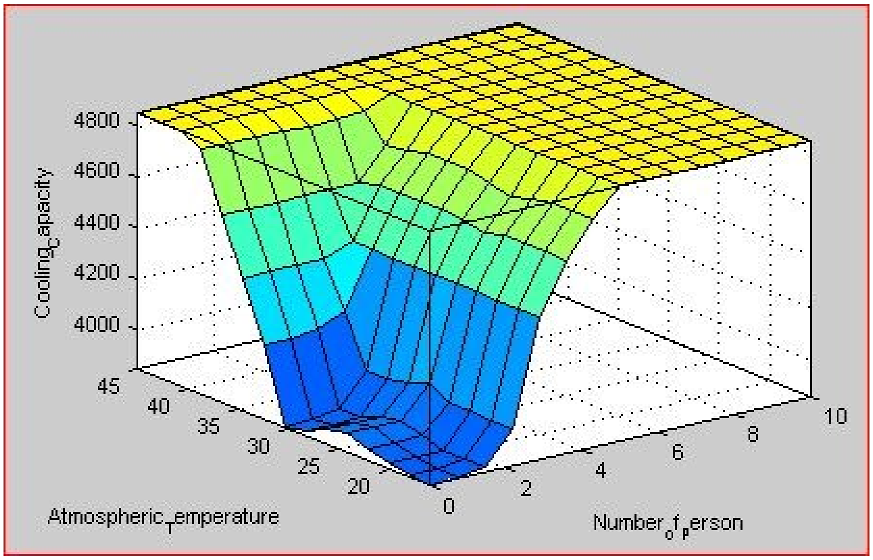

Figure 14: Surface viewer for number of person vs atmospheric temperature for cooling capacity

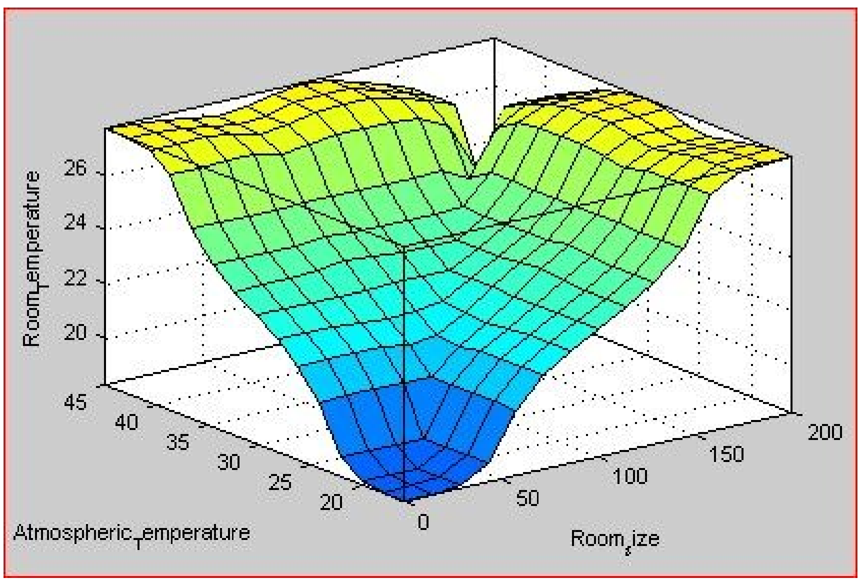

Figure 15: Surface viewer for room size vs atmospheric temperature for room temperature

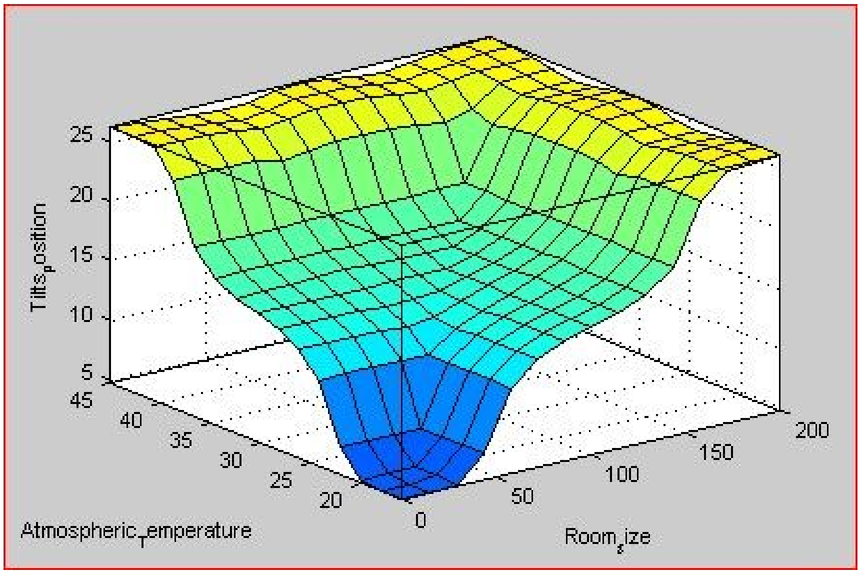

Figure 16: Surface viewer for room size vs atmospheric temperature for tilt position

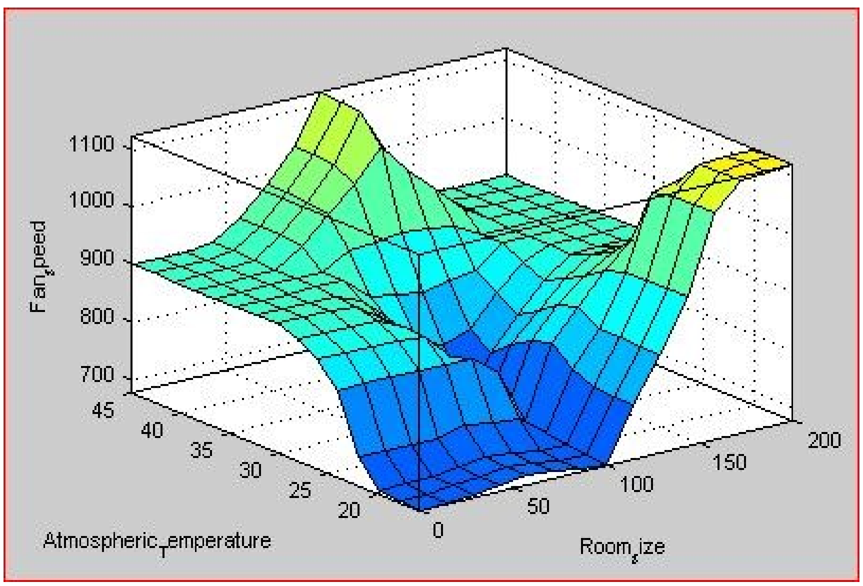

Figure 17: Surface viewer for room size vs atmospheric temperature for fan speed

According to the surface viewer shown in the figures 16 and 17, as the atmospheric temperature increases, the fan speed also increases. Simultaneously, as the room size increases, fan speed also increases. Eventually, when both increase, the temperature is at the moderate. So to maintain the room temperature cool, fuzzy logic used in the air conditioner senses the temperature using sensor and maintains it.

CONCLUSION

From the above work, we conclude the following results:

i.) Using these smart systems like prediction of number of persons to maintain room temperature, tilt position to find the best distance coverage, fan speed for appropriate temperature, number of persons to maintain room temperature, room size for maintaining tilt position and fan speed etc.

ii.) These smart prediction techniques may reduce the usage of current and may increase the efficiency of the air conditioner.

iii.) The usage of fuzzy logic to assign actions to the various operations of the air conditioner has made easy to calculate the need of temperature maintenance and fan speed with tilt position and prediction of best temperature to maintain using the atmospheric temperature.

iv.) All these advantages and uses of the smart air conditioning system is a great economical and advanced technological system for daily usage in all areas.

Ethical Approval

Any of the authors' investigations with human participants or animals are not included in this article.

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Conflict of Interest

The authors have no applicable financial or non-financial interests to expose this article.

Informed Consent

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