Fuzzy Logic Simulations for a Smart Air Conditioning System

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Research Article

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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.

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.

2. Proposed Design

The outputs and inputs provided can be used to determine the fuzzy logic system. The primary function of this air conditioner is to chill the room while using the least amount of current possible given the room's size, the number of people in it, the temperature outside, and its tonnage. For the smart air conditioning system that is built to supply the proposed fuzzy logic, there are 27 rules for input and output. The input parameters for the fuzzy logic are as follows in order to get the most economical air conditioner usage:

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

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

2.1 Automation using IR sensor

The IR sensor is housed within the logic board. The presence of people in the room is determined by the IR sensor. The number of people is inputted into the fuzzy logic system, which then calculates the ideal room temperature.

For e.g. The room temperature is 24°C if there are two people entering, or the input.

If the input is 4, the temperature drops to 20°C,

maintaining the room temperature at a level that is comfortable for human physiology.

2.2 Automation using SONAR

Sonar is a tool that measures how far away an object is from its source. It uses the ultrasonic waves to detect it. This is used in our system, which is integrated into the logic board, to determine the size of the room and provide inputs of large, medium, or small to the fuzzy logic, which then outputs the tilt direction of the fin and the fan speed.

For e.g. When the input is huge, such as a room, the tilt position and fan speed are both high.

The tilt position is low and the fan speed is dependent on the number of people if the input is small.i.e. from theory 1.

2.3 Automation using the atmospheric condition

We make advantage of the external unit's temperature and humidity sensor. These sensors measure the atmosphere's temperature and humidity. The fuzzy logic system on the logic board receives this sensor output as its input. This controls whether the room should be kept at a low or high temperature.

For e.g. The temperature inside the room is slightly higher if the input, or the temperature of the atmosphere, is low. If the ambient temperature is 30°C, the required room temperature is 24°C.

2.4 Rule base for Fuzzy Logic System:

1. If (Number_of_person 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)
2. If (Number_of_person 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)
3. If (Number_of_person 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)
4. If (Number_of_person 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)
5. If (Number_of_person 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)
6. If (Number_of_person 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)
7. If (Number_of_person 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 TEMPERATURE	COOLING CAPACITY	POWER CONSUMPTION	TILTS POSITION	FAN SPEED
1	Less	Small	Cold	Low	Very cold	Low	Low	Low
2	Less	Medium	Warm	Medium	Cold	Medium	Centre	Medium
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	Medium
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	Medium
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	Medium
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	Medium
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	Medium
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	Medium
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	Medium
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	Medium
27	More	More	Hot	High	warm	High	High	Fast

3. Simulation And Result

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

4. Membership Functions For Fuzzy Logic

4.1 Membership functions for inputs

The FLC system transforms the crisp input values into fuzzy values. By applying membership functions in terms of linguistic inputs, this FLC system inputs can be expressed. Through the use of parameters, the membership functions can be defined. The membership functions are [-5 0 5], [2 5 8], and [5 10 15] for various numbers of individuals, such as less, normal, and more. The membership functions are [-5 0 5], [2 5 8], and [5 10 15] in that order for different room sizes, such as small, medium, and big. The membership functions are, [-5 0 15], [2 5 8], and [5 10 15] for capacity tons such as chilly, warm, and very cold 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. The membership functions are plotted as given below

4.1.1 Number of persons

No. of persons can be calculated using thermal sensor fitted into the air conditioning system. Number of Persons are represented by three membership functions less, normal, more as in table.

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

4.1.2 Room size

It is calculated with the use of sonar attached in the air conditioner. Room size are represented by three membership functions Small, Medium, Large as given in the table.

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

4.1.3 Atmospheric Temperature

Atmospheric Temperature are represented by three membership functions Cold, Warm, Hot as in table.

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

4.2 Membership functions for outputs:

The membership functions for room temperature are low [-20 0 20], medium [10 25 40], high [35 30 50]. Membership functions for cooling capacity are very cold [-40 0 40], cold [10 50 30], warm [60 100 140]. The membership functions for power consumption are low [-40 0 40], medium [10 50 30], 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 no. of persons. Room Temperature are represented by three membership functions Low, Medium, High as in table.

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

4.2.2 Cooling capacity

Cooling capacity can be calculated using the no. of persons present and room temperature. Cooling Capacity are represented by three membership functions Very cold, cold, Warm as in table.

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

4.2.3 Power consumption

Power consumption are represented by three membership functions Low, Medium, High as in table.

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

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 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**[A3]**. Tilts position are represented by three membership functions Low, Centre, High as in table.

INPUT	FUZZY SET	RANGE
Tilts position	Low	1–10 F
	Centre	11–20 F
	High	21–30 F

4.2.5 Fan speed

Fan speed can be calculated by using the size of the room and no. 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 0–100 with respect to the speed percentage from 0–100%**[A1]**. Fan speed are represented by three membership functions Low, Medium, Fast as in table (9).

INPUT	FUZZY SET	RANGE
Fan speed	Low	0–40
	Medium	50–70
	Fast	80–100

5. Rule Viewer For Smart Air Conditioner Using Fuzzy Logic System

The rule viewer graph represented here shows 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, more, the value generated for the number of persons are 5. For small, medium, large, the value generated for room size is 100. For cold, warm, hot, the value generated for the atmospheric temperature is 30.5. When we consider the outputs, for low, medium, high the value generated for room temperature is 23. For very cold, cold and warm, the value generated for cooling capacity is 4.85e + 003. For low, medium and high, the power consumption value generated is 1.54e + 003. For low, center, high, the value generated for the tilt position is 15.5. For low, medium and fast, the value generated for the fan speed is 678. Hence these results for the if-then rules by the MATLAB are obtained using the rule viewer.

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 ac. 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 as follows:

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

According to the surface viewer shown here, as the number of persons increases, the cooling capacity also increases. Simultaneously, as the room size increases, cooling capacity increases. Eventually, when both increases, the temperature is at the peak. So as to maintain the cooling capacity correctly, fuzzy logic used in the air conditioner senses the temperature using sensor to maintain it.

According to the surface viewer shown here, 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 as to maintain the room temperature cool, fuzzy logic used in the air conditioner senses the temperature using sensor and maintains it.

Conclusion

Utilizing these sophisticated systems, such as prediction of the number of people needed to maintain the desired temperature, tilt position to determine the best distance coverage, fan speed for the desired temperature, number of people needed to maintain the desired temperature, room size needed to maintain tilt position and fan speed, etc. These clever prediction methods might lower the amount of electricity used and might boost the air conditioner's effectiveness. It is now simple to calculate the demand for temperature maintenance, fan speed with tilt position, and prediction of the optimal temperature to maintain using the

atmospheric temperature thanks to the use of fuzzy logic to assign actions to the various air conditioner activities. With all these benefits and applications, the smart air conditioning system is a fantastic, high-tech, and cost-effective system for daily use in all locations.

Declarations

Ethical approval:

This article does not contain any studies with human participants or animals performed by any one of the authors.

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Figures

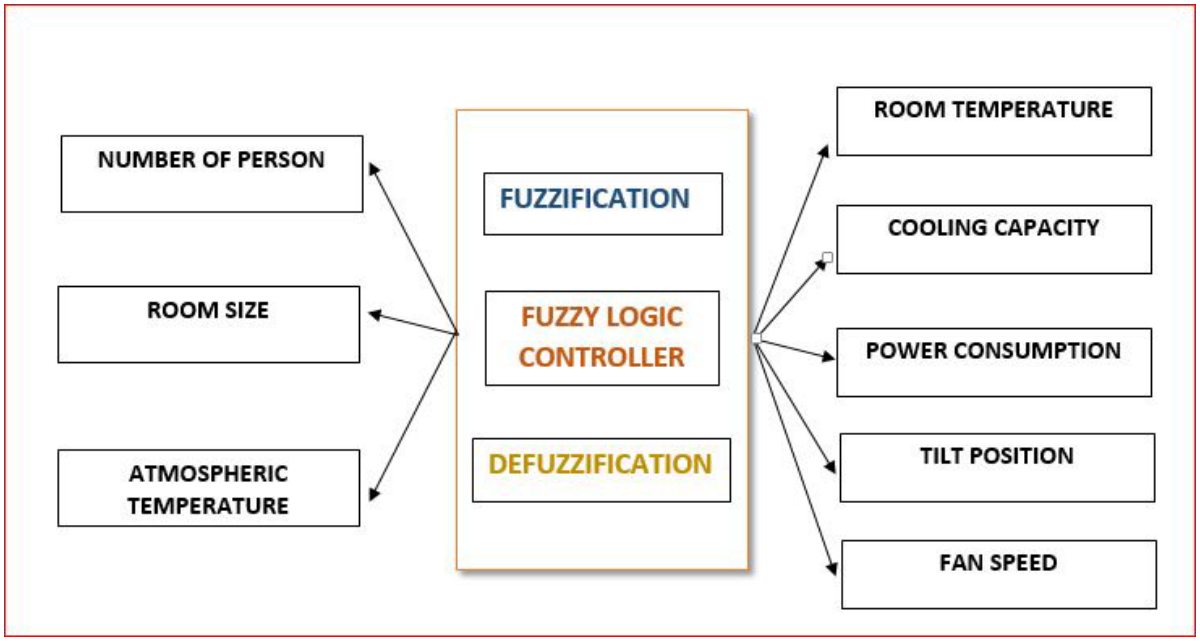

Figure 1

Fuzzy logic system of air conditioner

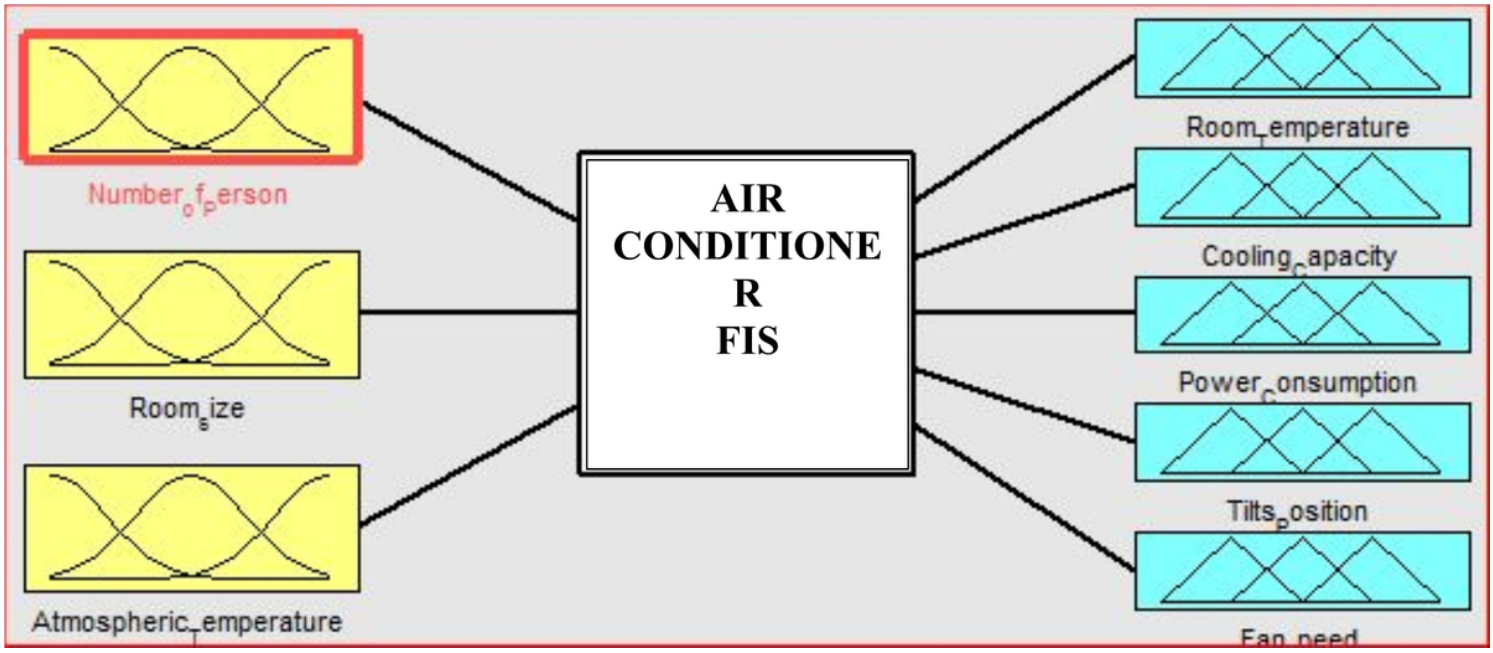

Figure 2

Fuzzy Inference System for smart air conditioner

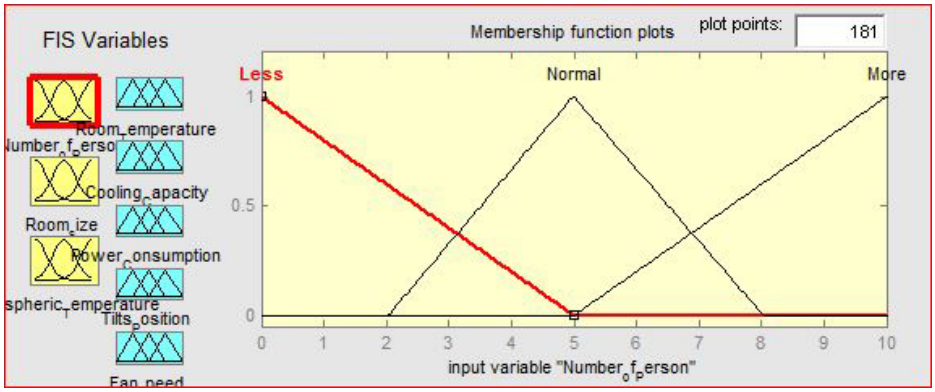

Figure 3

Fuzzy membership function for No. of persons

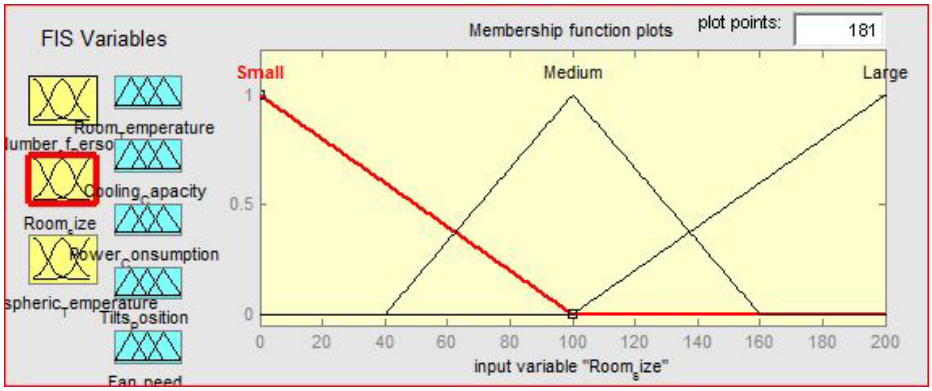

Figure 4

Fuzzy membership function for Room size

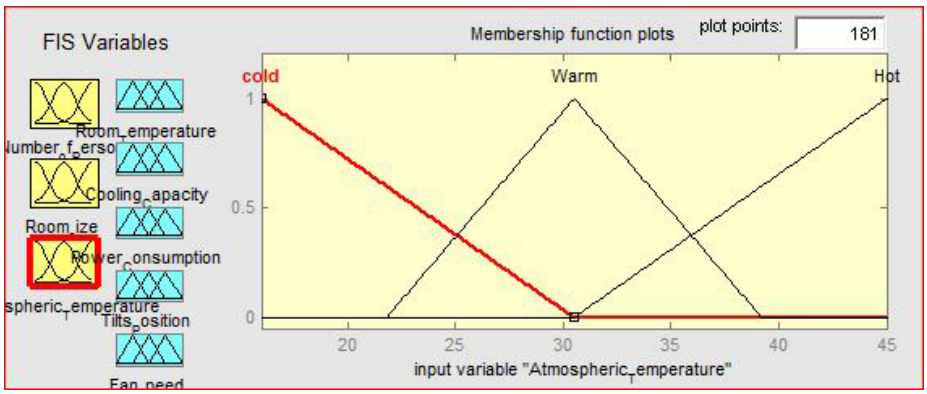

Figure 5

Fuzzy membership function for Atmospheric Temperature

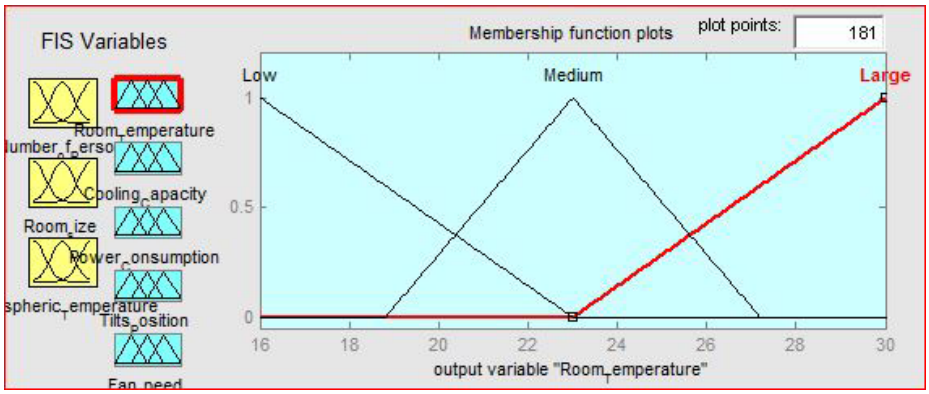

Figure 6

Fuzzy membership function for Room temperature

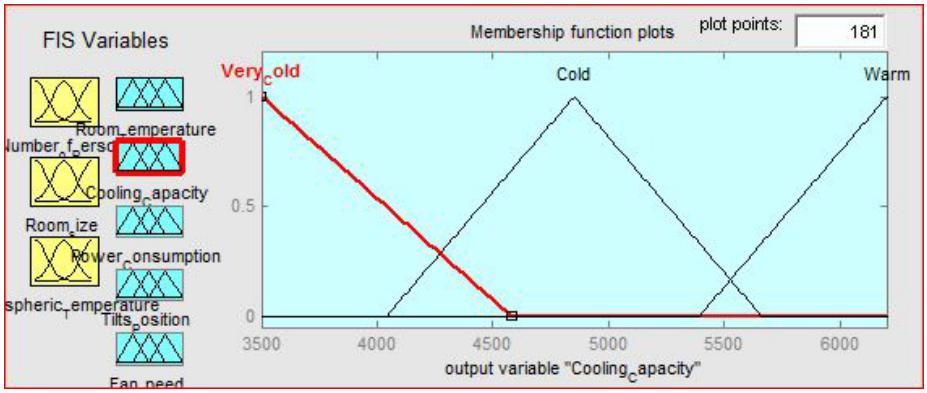

Figure 7

Fuzzy membership function for Cooling capacity

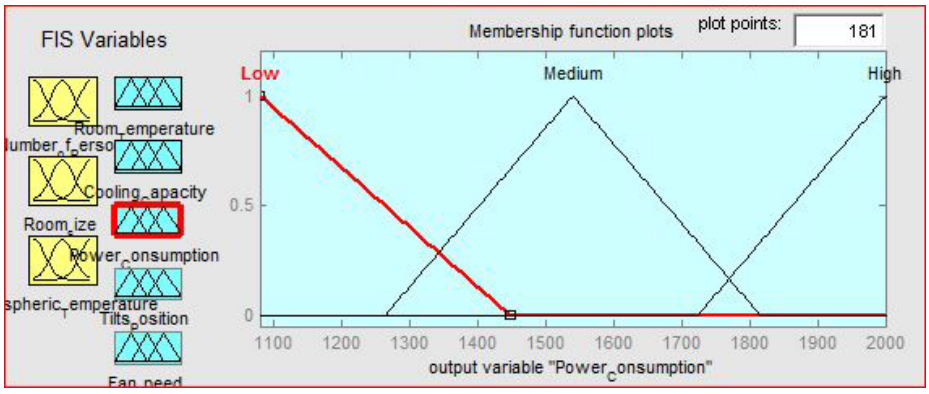

Figure 8

Fuzzy membership function for Power consumption

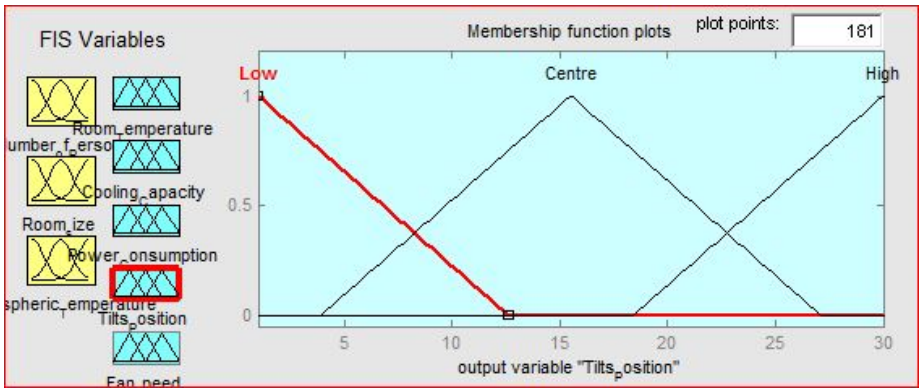

Figure 9

Fuzzy membership function for Tilt position

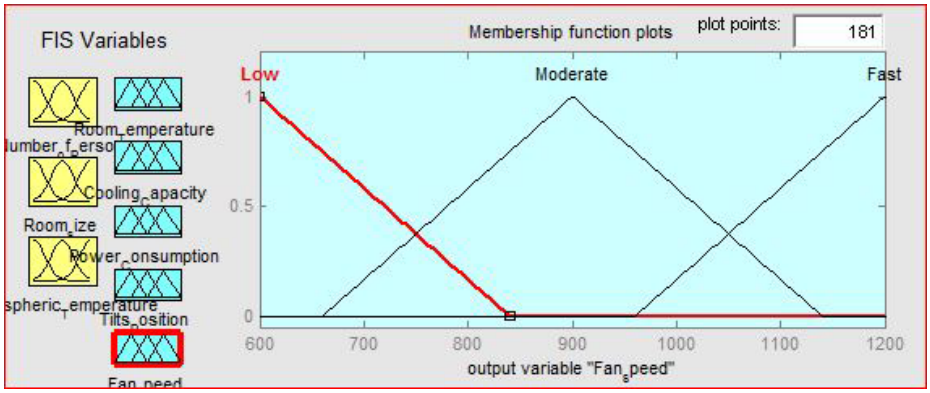

Figure 10

Fuzzy membership function for Fan speed

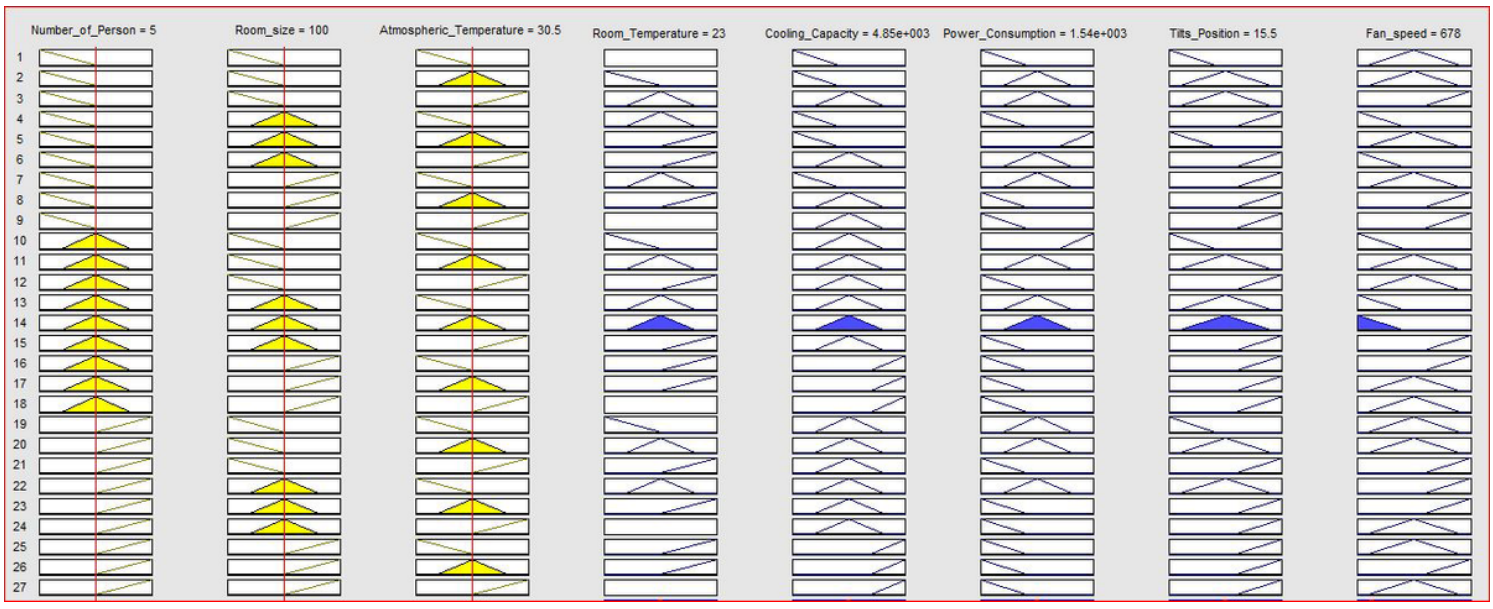

Figure 11

Rule viewer for Fuzzy logic system of air conditioner

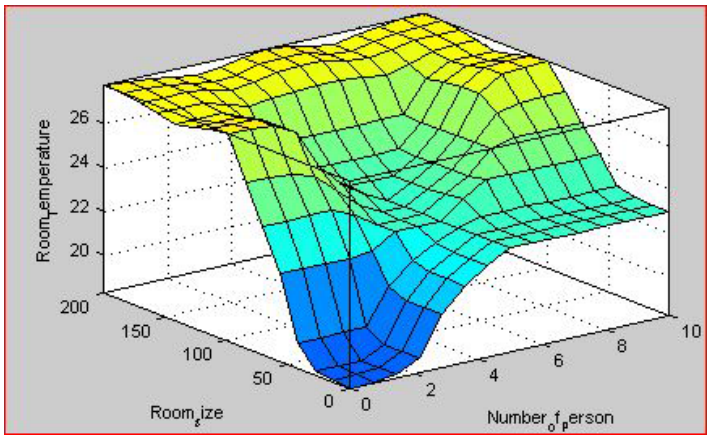

Figure 12

Surface viewer for Number of person vs Room size for Room temperature

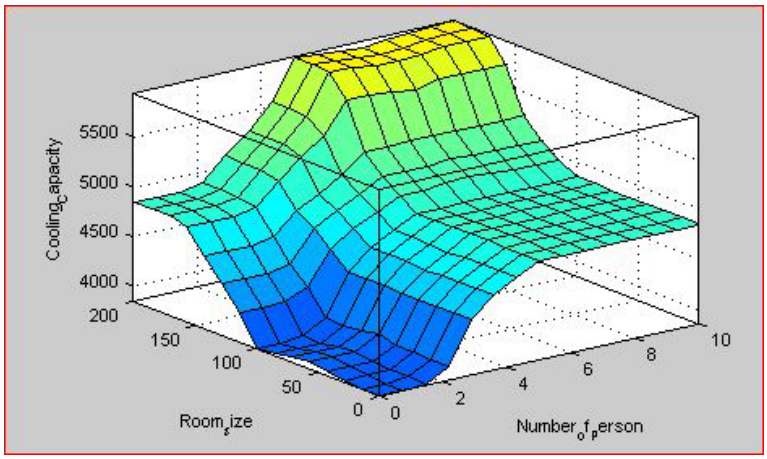

Figure 13

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

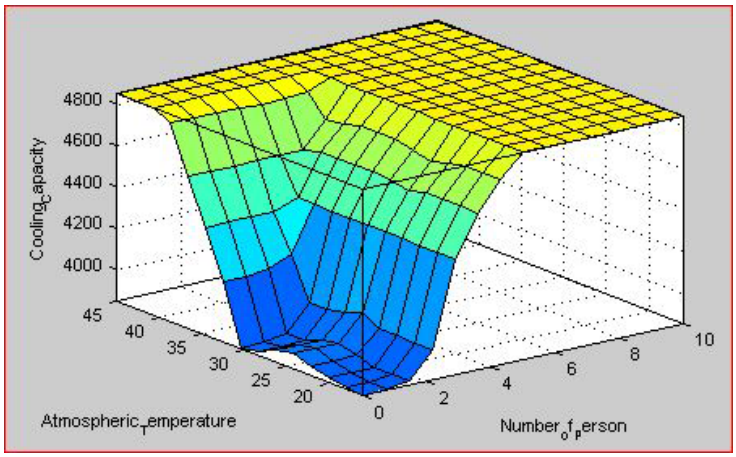

Figure 14

Surface viewer for number of person vs atmospheric temperature for cooling capacity

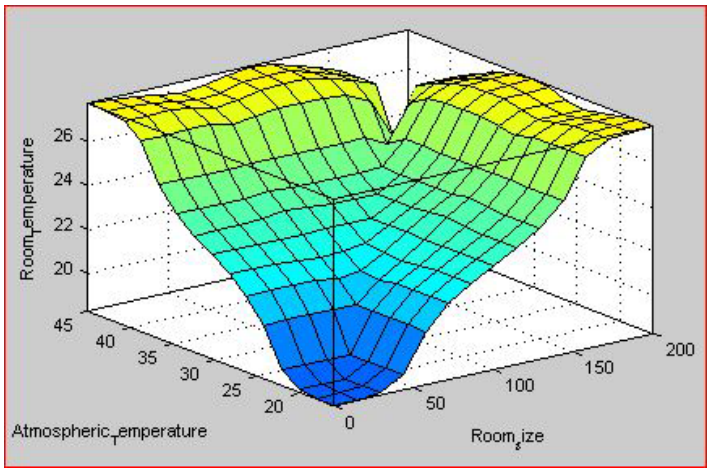

Figure 15

Surface viewer for room size vs atmospheric temperature for room temperature

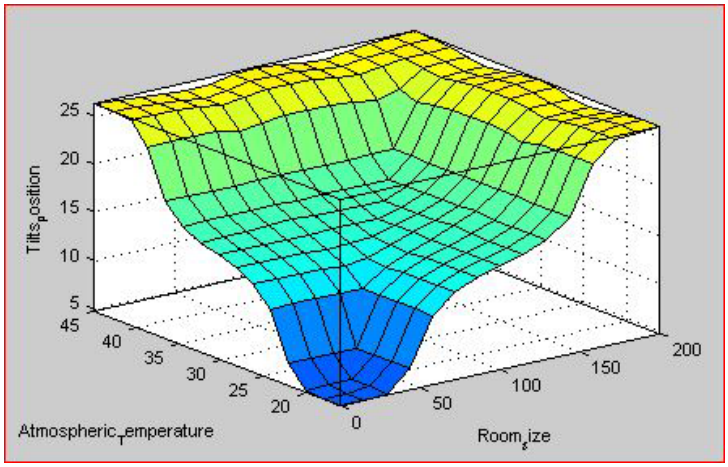

Figure 16

Surface viewer for room size vs atmospheric temperature for tilt position

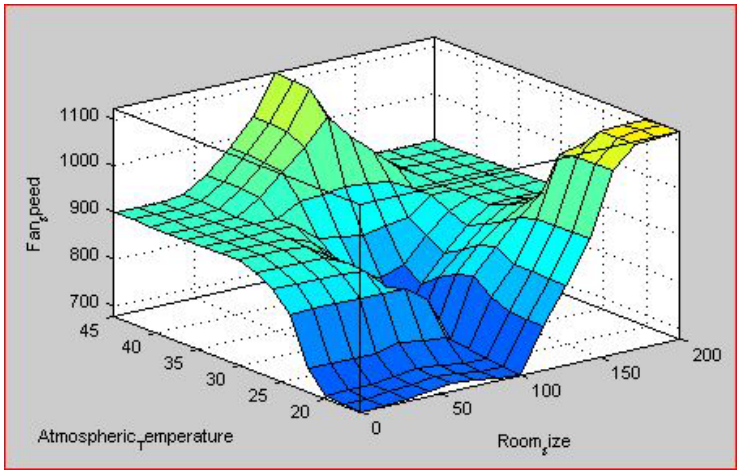

Figure 17

Surface viewer for room size vs atmospheric temperature for fan speed