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Intelligent Room Temperature Controller System Using MATLAB Fuzzy Logic Toolbox

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Abstract: ***In this paper, an intelligent system of room temperature controller that based on fuzzy logic controller has been presented. The system is an intelligent autonomous control of the two control parameter that is room temperature and the humidity of a room. MATLAB fuzzy toolbox is used where a fuzzy logic controller is designed to improve the system efficiency based on control input such as user temperature, dew point, temperature difference, feeling mode and mode selection. The output control will be the compressor speed, fan speed and operation mode (humidified or air conditioner).The result will be described in terms of the speed of compressor and fan changing with the difference in input temperature***

Keywords: temperature; speed; fuzzy logic control; MATLAB fuzzy toolbox.

1. Introduction

An intelligent room temperature controller system and sometimes known as air conditioner is basically same as a refrigerator without the insulated box. It uses the evaporation of a refrigerant, like Freon to provide cooling. The mechanics of the Freon evaporation cycle are the same in a refrigerator. The compressor compresses cool Freon gas, causing it to become hot, high-pressure Freon gas [1-4]. This hot gas runs through a set of coils so it can dissipate its heat, and it condenses into a liquid. The Freon liquid runs through an expansion valve, and in the process it evaporates to become cold a low-pressure Freon gas. This cold gas runs through a set of coils that allow the gas to absorb heat and cool down the air inside the building. The cooling level of the air conditioner system is base on the compressor speed and the fan speed [5]. But it is waste of energy if the compressor and fan is always run in a certain speed to provide the cooling lever. With add in controller system, the speed of compressor and fan can be autonomous according to the room temperature setting [6]. Figure 1 shows the air conditioner mechanical system.

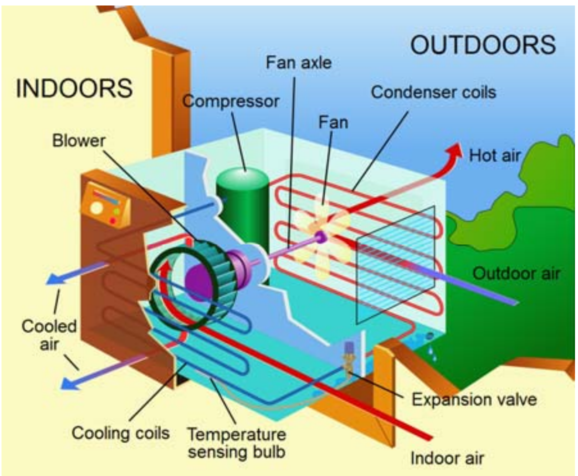


Figure 1: The air conditioner mechanical system [1]

The objective of this system is to design an intelligent controller that used the fuzzy logic controller technique to control room temperature based on outputs control. This system will control the speed of compressor and fan to save the energy.

MATLAB Fuzzy logic Toolbox is use to design fuzzy logic controller. Basically, the Fuzzy Logic controller consists of four basic components: fuzzification, a knowledge base, inference engine, and a defuzzification interface as shown in Figure 2. Each component affects the effectiveness of the fuzzy controller and the behavior of the controlled system [7-9]. In the fuzzification interface, a measurement of inputs and a transformation, which converts input data into suitable linguistic variables, are performed which mimic human decision making [10-15]. The results obtained by fuzzy logic depend on fuzzy inference rules and fuzzy implication operators. The knowledge base provides necessary information for linguistic control rules and the information for fuzzification and defuzzification. In the defuzzification interface, an actual control action is obtained from the results of fuzzy inference engine [16].

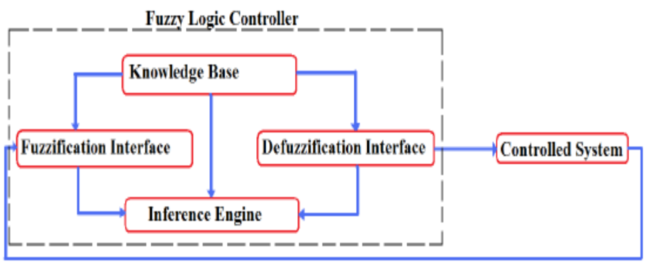


Figure 2: Basic Configuration of Fuzzy Logic Controller

2. System Design Concept

2.1 System Design Methodology

Figure 3 shows the flow chart of the over system to give an overview of methodology of design of this system. The Mamdani techniques will be used in this system consists of four control inputs and four control outputs as shown in Figure 4. To simplify this system, only two outputs will be considered in terms of the speed of compressor and fan changing with the difference input temperature.

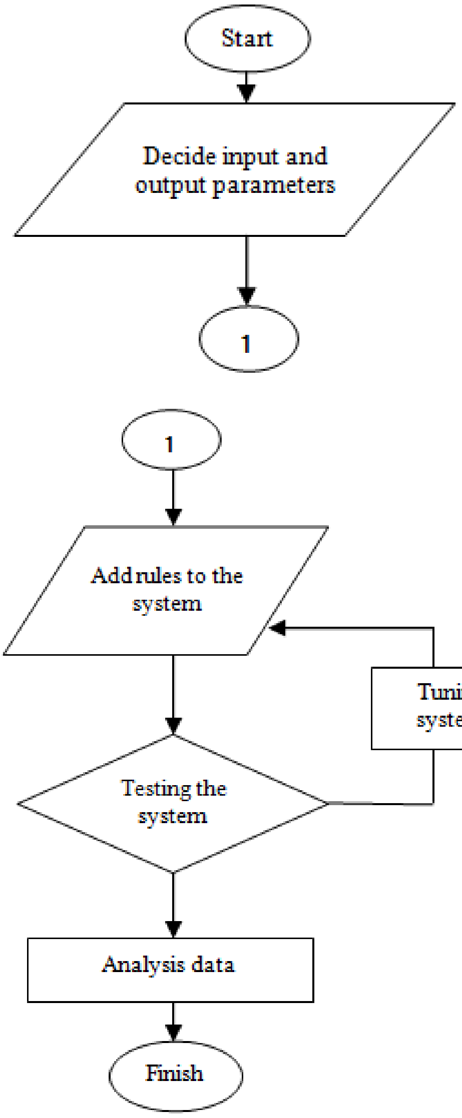


Figure 3: Flowchart of overall system

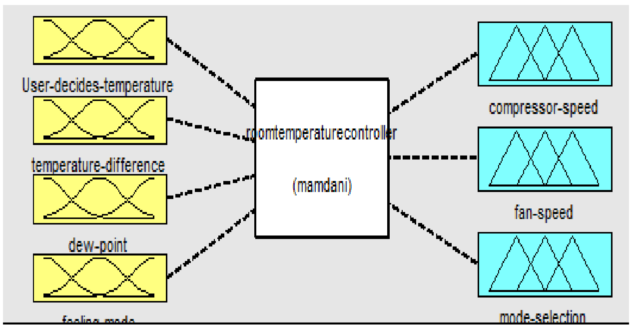


Figure 4: Room temperature controller

2.2 Input of the system

Input 1 is set as the user decides temperature, it is divided into 5 membership functions, where three types of membership function are used such as z, s and trigonometri membership function as shown in Figure 5. User decides temperature holds user's preferred temperature received by remote/front control unit. The control unit allows user to set temperature on a continuous dial over full range of 16 ^{o}C to 30 ^{o}C.

MF1='Very Cool':'zmf', [16 18]
MF2='Cool':'trimf', [17 20 23]
MF3='Medium':'trimf', [20 23 26]
MF4='hot':'trimf', [24 26 28]
MF5='very hot':'smf', [27 28]

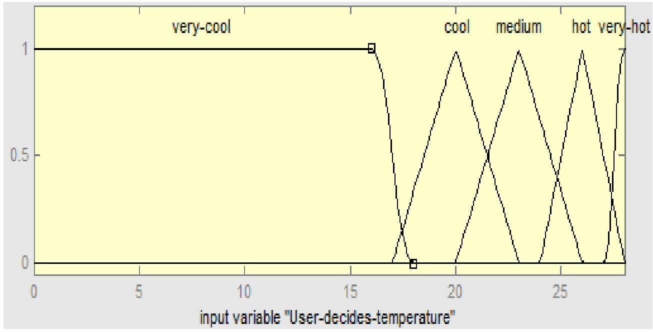


Figure 5: Membership function of user decides temperature

Input 2 is the temperature difference which is divided into 5 membership functions as same with input 1 as shown in Figure 6. Temperature difference gives information on difference between actual room temperature as received by electronic thermostat and user decides temperature. The thermostat range should be wide enough to take care of climatic and regional fluctuation. In this case the range is between 5 ^{o}C to 45 ^{o}C, which constraints temperature difference between -10 ^{o}C to 10 ^{o}C.

MF1='High negative':'zmf', [-5 -3]
MF2='negative':'trimf', [-5 -2.5 0]
MF3='Zero':'trimf', [-0.75 0 0.75]
MF4='positive':'trimf', [0 2.5 5]
MF5='high positive':'smf', [3 5]

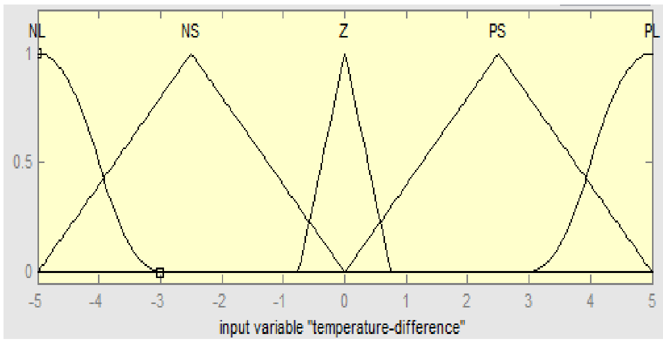


Figure 6: Membership function of temperature difference

Input 3 is the dew point detection which is divided into 3 membership functions, the outlook for the system is shown in Figure 7. Dew point detection gives information about dew point temperature inside the room as received by electronic dew point sensor. Dew point is a direct measure of moisture content of air and is independent of temperature.

F1='Dry:'zmf', [10 11]
MF2=' Comfortable':'trimf', [10 12 14]
MF3=' Humid:'smf', [13 14]

Table 1: Human perception versus dew point [17]

Dew Point °C	Dew Point °F	Human Perception[1]	Rel. Humidity at 90°F (32°C)
>Higher than 26°C	>Higher than 80°F	Severely high. Even deadly for asthma related illnesses	65% and higher
24 - 26°C	75 - 80°F	Extremely uncomfortable, fairly oppressive	62%
21 - 24°C	70 - 74°F	Very humid, quite uncomfortable	52% - 60%
18 - 21°C	65 - 69°F	Somewhat uncomfortable for most people at upper edge	44% - 52%
16 - 18°C	60 - 64°F	OK for most, but all perceive the humidity at upper edge	37% - 46%
13 - 16°C	55 - 59°F	Comfortable	31% - 41%
10 - 12°C	50 - 54°F	Very comfortable	31% - 37%
<10°C	<49°F	A bit dry for some	30%

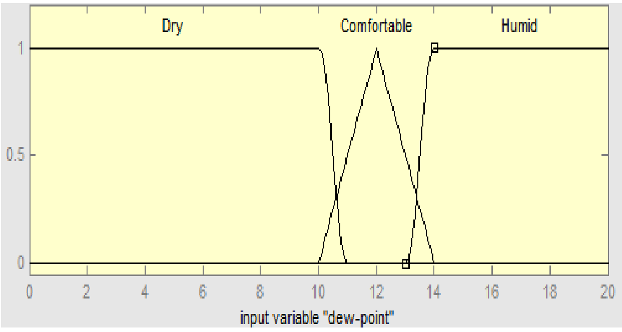


Figure 7: Membership function of dew point

Input 4 (feeling mode) and input 5 (mode selection) will not be discuss in this paper because it is about the commercial function of the product. This system contain of 3 output design, and the membership function of the system will be discussed in next section.

2.3 Output of the system

Output 1 is the compressor speed which is divided into 6 membership function, the outlook for the system is shown in Figure 8. The range of this output is 0 to 100 which means the percentage speed of the compressor.

MF1=stop':'zmf', [5 8]
MF2='Very Slow':'trimf', [6 13 20]
MF3=' Slow ':'trimf', [10 30 50]
MF4=' Medium ':'trimf', [40 55 70]
MF5='Fast':'trimf', [60 75 90]
MF6= 'very fast': 'smf', [85 86]

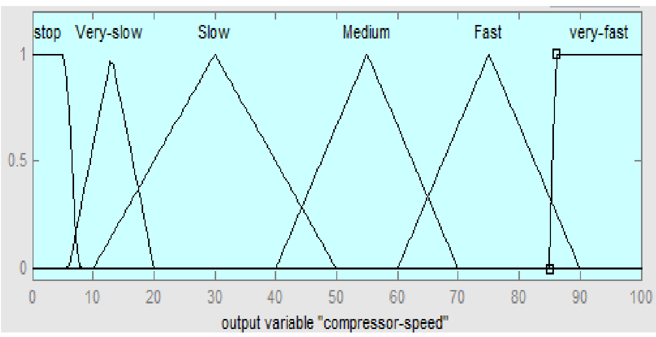


Figure 8: membership function of compressor speed

Output 2 is the fan speed which is divided into 5 membership function the outlook for the system is shown in Figure 9. The range of this output is 0 to 100 which means the speed percentage of the fan.

MF1='Very Slow':'zmf', [9 15]
MF2=' Slow ':'trimf', [10 30 55]
MF3=' Medium ':'trimf', [30 55 75]
MF4='Fast':'trimf', [55 75 90]
MF5= 'very fast': 'smf', [85 86]

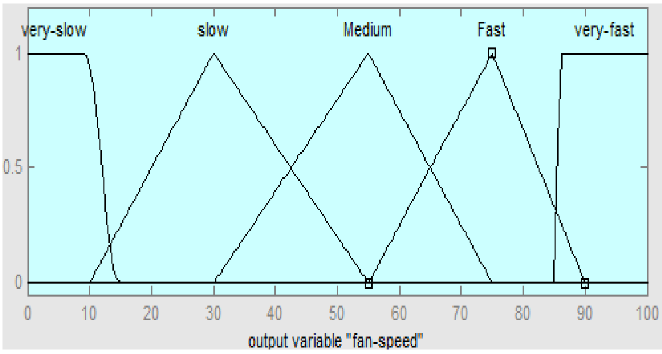


Figure 9: membership function of fan speed

Output 3 is the operation mode which is divided into 2 membership function, the outlook for the system is shown in Figure 10

MF1=' dehumidifier':'trimf', [-1 0 1]
MF2='Airconditioner':'trimf', [0 1 1.77]

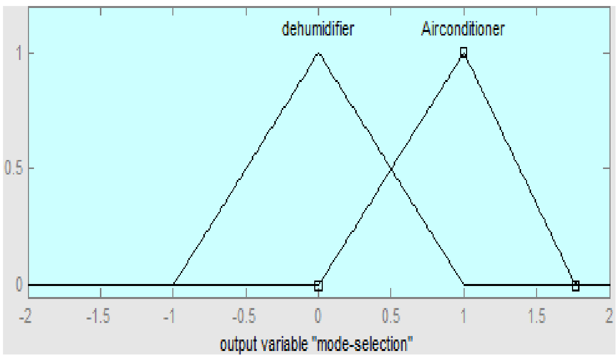


Figure 10: membership function of mode selection

2.4 Rules for the system

This system contains 29 rules that cover for the 5 inputs and 3 outputs membership functions as shown in Figure 11.

There is a combination of compressor speed and fan speed in order to control the room temperature according to the designed room temperature. The examples of the rules are shown as below:

1) If (USERTemperature is VeryCool) and (dewpoint is Dry) and (TemperatureDIFF is highnegative) and (Modeselection is MANUAL) then (Compressorspeed is stop)(fanspeed is Veryslow)(Operationmode is Airconditioner)
2) If (USERTemperature is cool) and (dewpoint is Dry) and (TemperatureDIFF is highnegative) and (Modeselection is MANUAL) then (Compressorspeed is stop)(fanspeed is Veryslow)(Operationmode is Airconditioner)
3) If (USERTemperature is veryhot) and (dewpoint is Dry) and (TemperatureDIFF is highnegative) and (Modeselection is MANUAL) then (Compressorspeed is stop)(fanspeed is Veryslow)(Operationmode is Airconditioner)
4) If (dewpoint is Dry) and (I_FEEL is hot) and (Modeselection is AUTO) then (Compressorspeed is veryfast)(fanspeed is Veryfast)(Operationmode is dehumidifier)
5) If (dewpoint is Dry) and (I_FEEL is Comfortable) and (Modeselection is AUTO) then (Compressorspeed is Medium)(fanspeed is Medium)(Operationmode is dehumidifier)

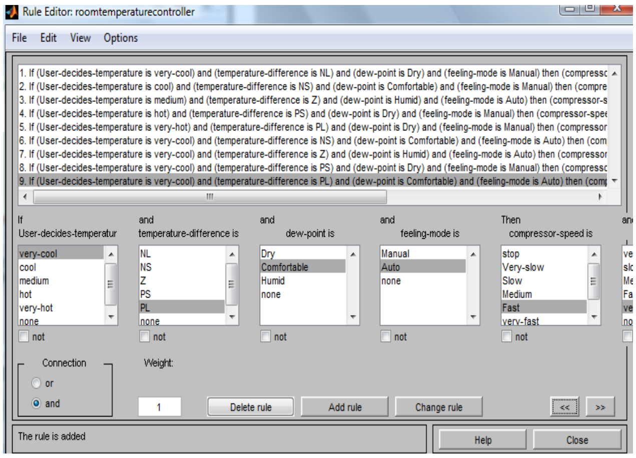


Figure 11: Rule editor in MATLAB

3. Result

After adding rules to the system, the result can be obtained from 'Rule Viewer' in MATLAB FIS tools as shown in Figure 12.

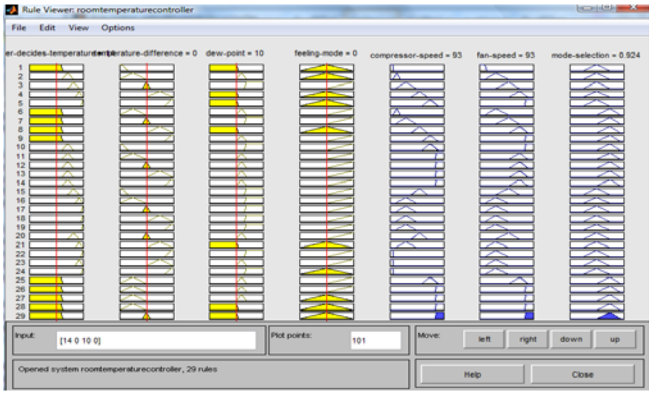


Figure 12: Rule viewer in MATLAB

From the rule viewer the result can be summarized as in Table 2 (a) – (e). Based on the results, the speed of compressor and fan is slow when the user temperature is low and temperature difference is high negative, this is because the room temperature is lower than the user setting temperature. The speed of compressor and fan is increase when the user temperature is low and temperature difference is high. These results show that the air conditioner is function to achieve room temperature that set by user.

Table 2: The results of compressor speed and fan speed with different User temperature and Temperature difference

(a) User temperature =17

Temperature difference, C	Compressor speed, %	Fan speed, %
-5	3.24	6.3
-2.5	13	31.9
0	93	31.9
2.5	93	33.1
5	93	93

(b) User temperature =20

Temperature difference, C	Compressor speed, %	Fan speed, %
-5	3.03	5.81
-2.5	13	31.7
0	75	31.7
2.5	75	53.3
5	75	93

(c) User temperature =23

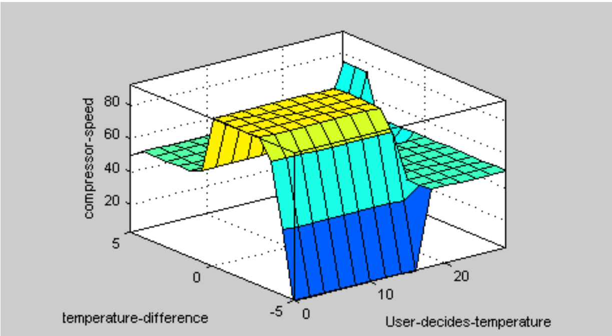
Temperature difference, C	Compressor speed, %	Fan speed, %
-5	3.03	5.81
-2.5	13	31.7
0	55	31.9
2.5	58	33.1
5	59	93

(d) User temperature =26

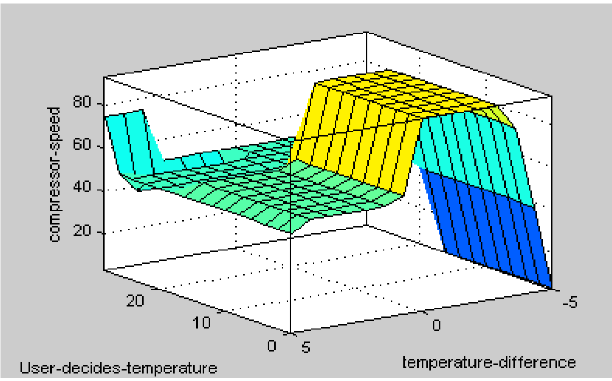
Temperature difference, C	Compressor speed, %	Fan speed, %
-5	3.03	5.81
-2.5	13	31.7
0	30	31.9
2.5	32	33.1
5	40	93

(e) User temperature =28

Temperature difference, C	Compressor speed, %	Fan speed, %
-5	3.03	5.81
-2.5	13	31.7
0	13	31.7
2.5	13	53.3
5	13	93



(a)



(b)

Figure 13: Surface viewer of the system.

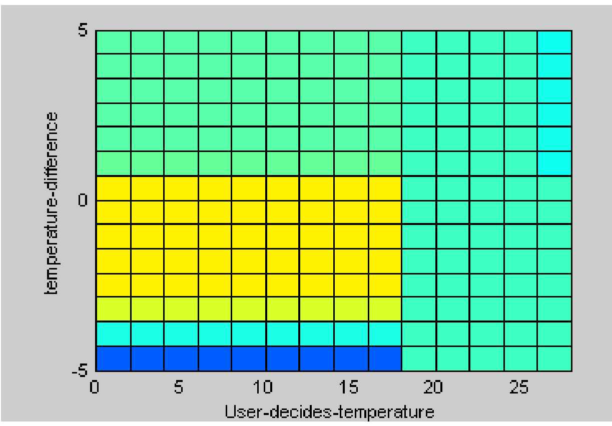


Figure 14: Pseudo Color for surface viewer

Figure 13 (a) and (b) shows the surface viewer of the system while Figure 14 shows the pseudo color for surface viewer.

4. Conclusion

The fuzzy room temperature controller had been design to control the temperature according to the room environment. Every input (user temperature and temperature difference) and output (compressor speed, fan speed and mode selection) consists of several membership functions to increase the performance of the system. In this project, visual Basic.net had been tried in crating the Fuzzy logic based temperature controller, but seems that it involves a lot of calculation and independent algorithm, so MATLAB Fuzzy Logic Toolbox is used for system design. This system design is useful for designer to room temperature control using intelligence controller. This techniques can be used as references to implement in real time system. For future planning to implement this system into real time and can be commercialize to market if the performances is same with simulation.

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