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Performance Evaluation of Membership Functions on the Air-Conditioner Based on Fuzzy Logic Controllers

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FISs are developed for air-conditioning system exploitation Mamdani-type and Sugeno-type fuzzy models. Sugeno type FC is chosen for analysis, because it is simple to implement in simulation. The membership functions elect for analysis square measure triangular, trapezoidal, Gaussian and bell shaped functions. The various membership perform analysis is completed considering four linguistic sets for temperature and humidness. The simulation model of various membership functions within the fuzzy control (FC) of air-conditioning system is enforced in Matlab/simulink. The results of the simulated performances are collated. The quality of triangular membership perform shows higher performance compared to various membership functions.

Keywords: Air Conditioning, Temperature, Fuzzy Inference System (FIS), Fuzzy Logic, Mamdani and Sugeno.

1. INTRODUCTION

Fuzzy logic idea is similar to the human being's feeling and inference process. Unlike classical control strategy, which is a point-to-point control, fuzzy logic control is a range-to-point or range-to-range control. The output of a fuzzy controller is derived from fuzzifications of both inputs and outputs using the associated membership functions. A crisp or fuzzy input will be converted to the different members of the associated membership functions based on its value. From this point of view, the output of a fuzzy logic controller is based on its different membership functions, which can be considered as a range of inputs.[1]

Fuzzy logic plan is comparable to the human being's feeling and reasoning method. Notlike classical control strategy, that may point control, symbolic logic control may be a range-to-point or range-to-range control. The output of a fuzzy controller comes from fuzzifications of each inputs and outputs victimization the associated membership functions. A crisp or fuzzy input are going to be regenerate to the totally different members of the associated membership functions supported its worth. From now of read, the output of a symbolic logic controller is predicated on its totally different membership functions, which may be thought-about as a variety of inputs. The results of the simulated performances are compared. The triangular membership shows higher performance compared to different membership functions.

Fuzzyrule-based systems, fuzzy models and fuzzy skilled systems area unit usually referred to as fuzzy inference systems. The most role of this method is higher cognitive process FIS employs "IF…THEN" rules beside connectors "OR" or "AND" for making necessary decision rules. Reference [2] usually, there are two types of FIS are Mamdani FIS and Sugeno FIS respectively.

Ebsahim Mamdani proposed mamdani in the year 1975 to control a steam engine and boiler combination by synthesizing a set of fuzzy rules obtained from folks functioning on the system. In this case, the output membership functions are expected to be fuzzy sets. Sugeno fuzzy method was proposed by Takagi, Sugeno and Kang in the year 1985. The main difference between Mamdani and Sugeno methods lies in the output membership functions. The Sugeno output membership functions are either liner or constant.

The Fuzzy Logic Controller (FLC) is easy to perform in industry due to its simple control structure, ease of design and Inexpensive cost. In this study we have tried necessary condition and suitable for air balance and temperature in the operating room, using a fuzzy logic controller. The main reason for using fuzzy logic in this type of air conditioning is for energy conservation and human comfort. Fuzzy control systems are specifically used in controlling operating rooms in which complex and uncertain parameters play a difficult role hence, require careful control and vital importance.

The Fuzzy Logic Controller (FLC) is simple to perform in business owing to its simple control structure,

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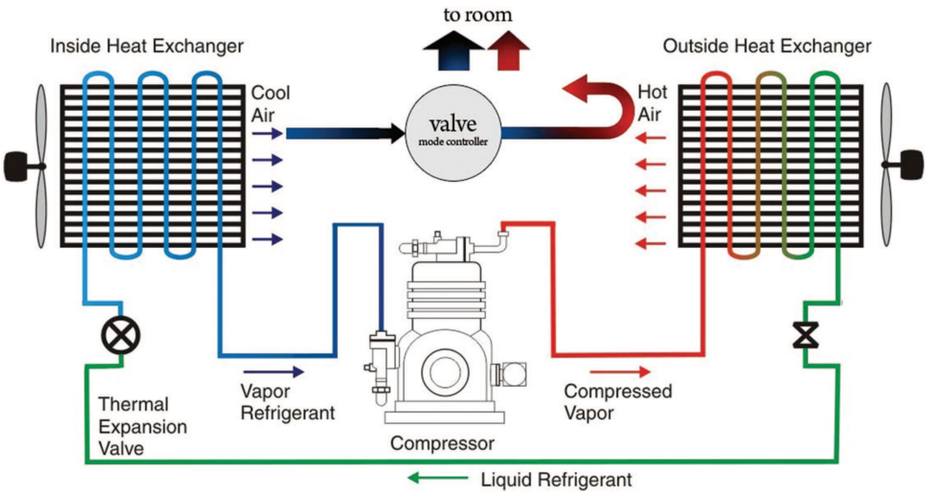


Fig. 1. Simplified working diagram of AC.

easy style and Inexpensive value. During this study we've tried necessary condition and appropriate for air balance and temperature within the OR, employing a mathematical logic controller. The most reason for exploitation mathematical logic during this sort of air conditioning is for energy conservation and human comfort. Fuzzy control systems square measure specifically employed in dominant operative rooms within which advanced and unsure parameters play a troublesome role thus, need careful management and very important importance.

The rest of the paper is structured as follows: Section 2, offers the distinction between Mamdani-type

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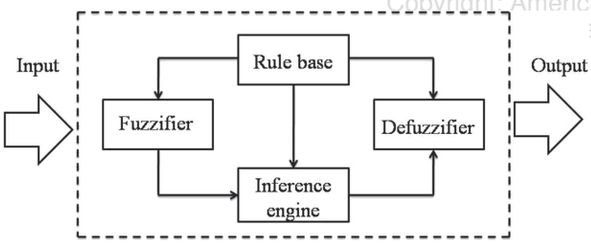


Fig. 2. The basic elements of a FLC.

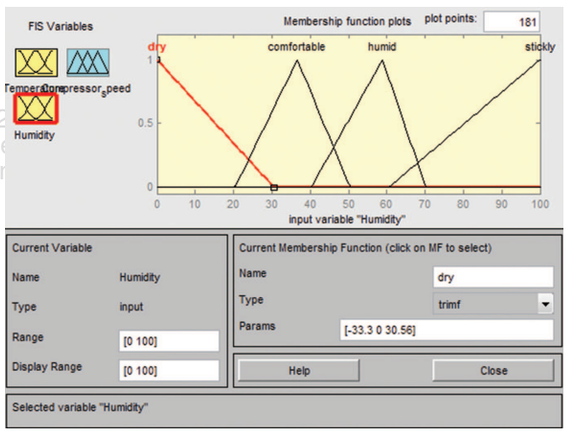


Fig. 4. Humidity membership functions.

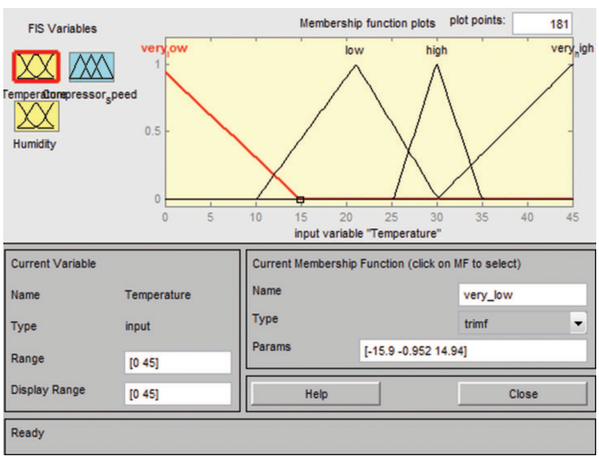


Fig. 3. Temperature membership functions.

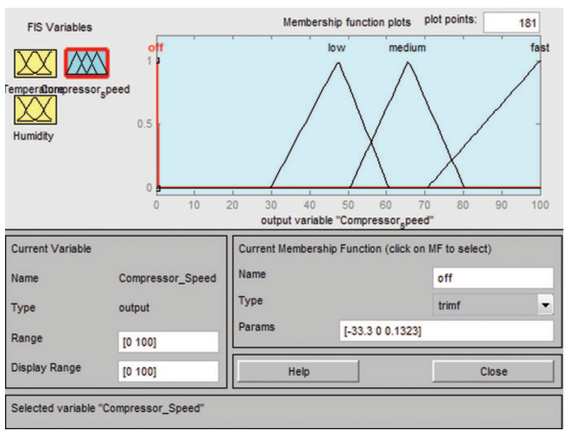


Fig. 5. Mechanical device speed membership functions.

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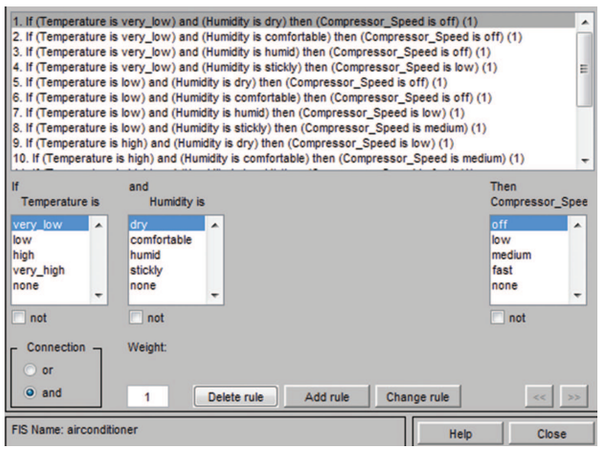


Fig. 6. Rules for Mamdani-type model.

and Sugeno-type FIS. Section 3, shows the improvement of Mamdani-type FIS. Section 4, shows the improvement of Sugeno-type FIS. Section 5, offers results and discussion and Section 6 conclusions.

Table I. Rule base of Mamdani-type FIS.

Rules	Temperature	Humidity	Compressed speed
1	Very low	Dry	Off
2	Very low	Comfortable	Off
3	Very low	Humid	Off
4	Very low	Sticky	Low
5	Low	Dry	Off
6	Low	Comfortable	Off
7	Low	Humid	Low
8	Low	Sticky	Medium
9	High	Dry	Low
10	High	Comfortable	Medium
11	High	Humid	Fast
12	High	Sticky	Fast
13	Very high	Dry	Medium
14	Very high	Comfortable	Fast
15	Very high	Humid	Fast
16	Very high	Sticky	Fast

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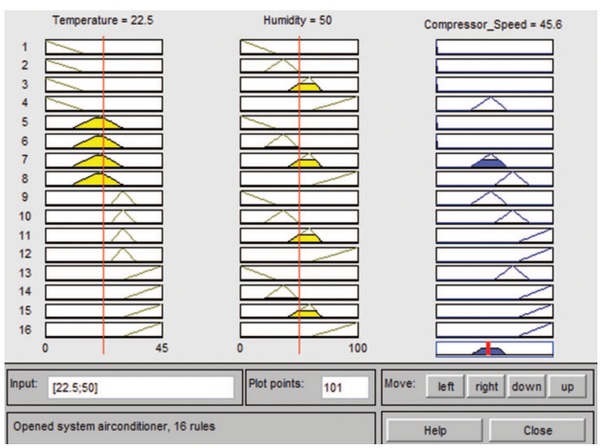


Fig. 7. Rule viewer of Mamdani type model.

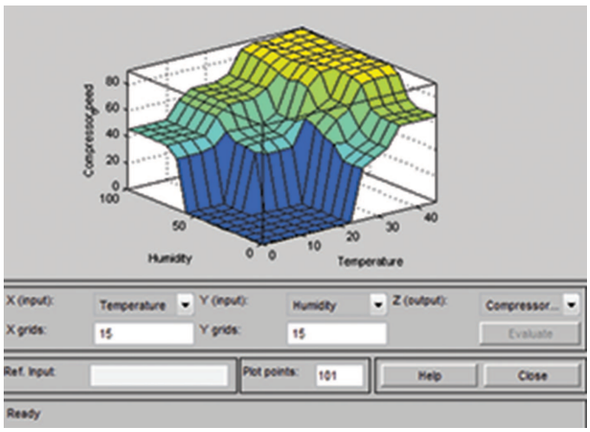


Fig. 8. Surface view of Mamdani-type FIS.

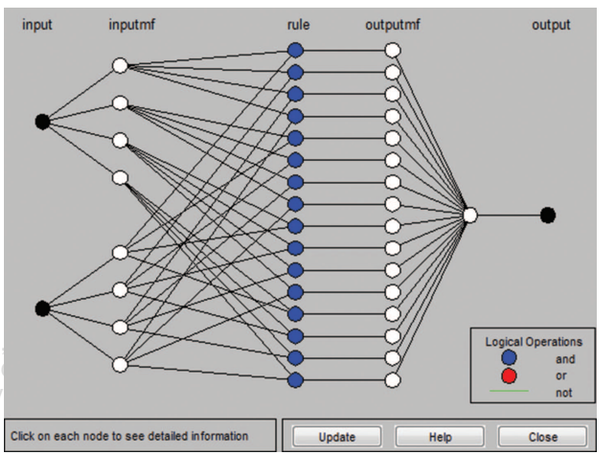


Fig. 9. ANFIS model structure.

2. DETAILS ABOUT THE PROBLEM

Slight modifications (Fig. 1) in air circulation method around heat exchangers allow a conventional AC to function anywhere between only normal AC mode and

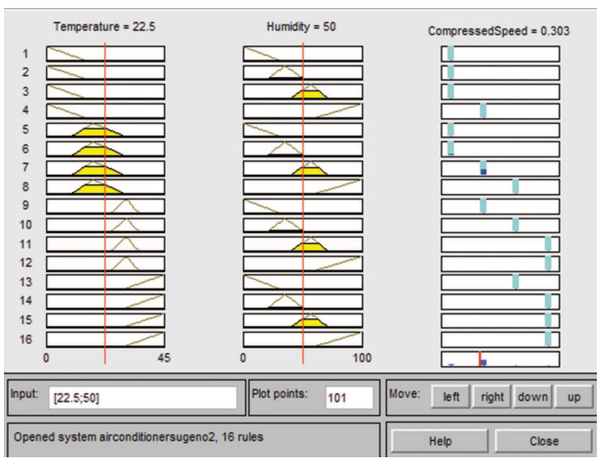


Fig. 10. Rule viewer of Sugeno type model.

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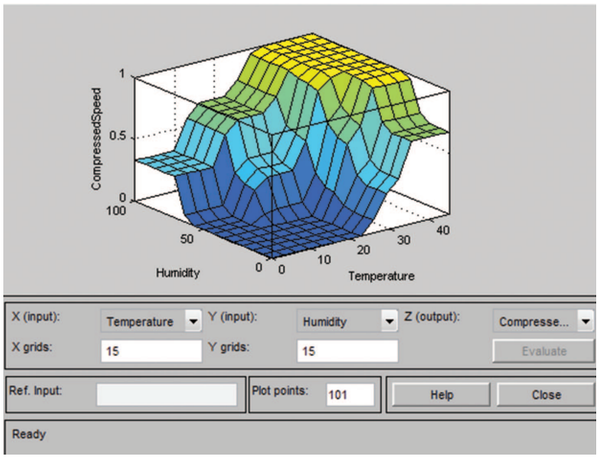


Fig. 11. Surface view of Sugeno-type FIS.

Dehumidifier mode. In dehumidifier only mode chilled air is completely passed via hot aspect of heat exchanger. So the AC dehumidifies with none change in output temperature.

Table II. Mechanical device speed membership functions Sugeno-type FIS.

Mechanical device speed	Constant value
Off	0
Low	0.3333
Medium	0.6667
Fast	1

The problem takes 3 variables into consideration…

- User temperature preference (18 °C∼30 °C continuous control).
- Actual room temperature variable.
- Room dew point temperature variable.

3. MAMDANI-TYPE FIS VERSUS SUGENO-TYPE FIS

Mamdani method is widely preferred for capturing expert knowledge. It permits us to explain the experience in additional intuitive, a lot of human-like manner. But Mamdani-type FIS entails a considerable process burden. On the other hand, sugeno method is computationally effiecient and works well with optimisation and adaptive

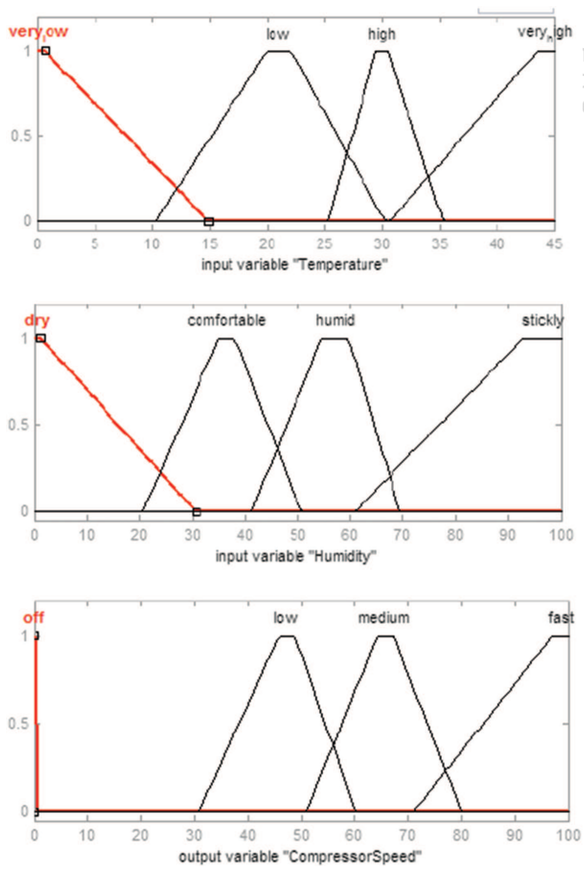


Fig. 12. Spread of fuzzy membership for trapezoidal functions.

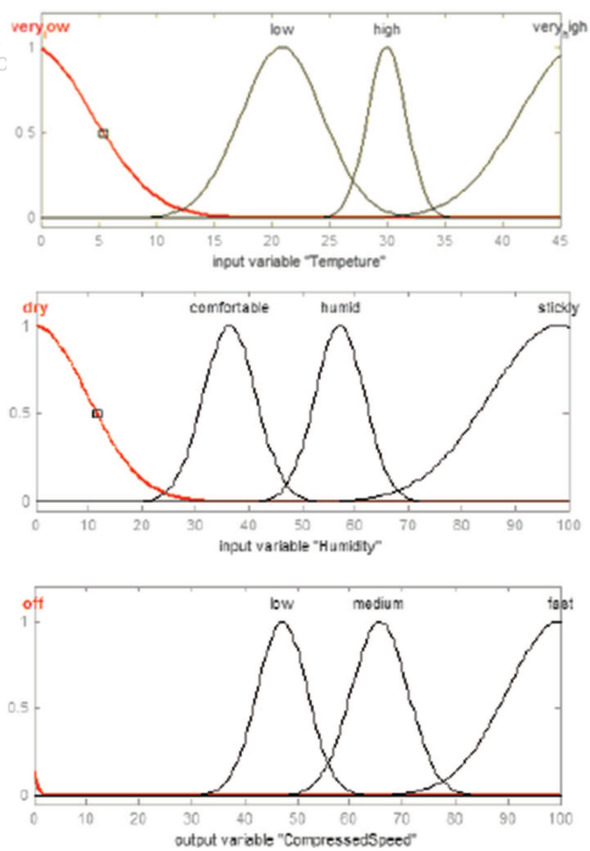


Fig. 13. Spread of fuzzy membership for Gaussian functions.

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techniques, that makes it terribly desirable in control issues. These adaptive techniques may be used to customise the membership functions in order that fuzzy system best models the data. The most basic discrimination between mamdani type FIS and Sugeno type FIS is that the method the crisp output is generated from the fuzzy inputs whereas mamdani type FIS uses the technique of defuzzification of a fuzzy output, sugeno type FIS uses weighted average to compute the crisp output. In the sugeno, the expressive power and interpretability is lost. Since the results of the protocols aren't fuzzy.[4] But sugeno has higher time interval since the weighted average replaces the time consuming defuzzification method. Due to the interpretable and intuitive nature of the protocol base, mamdani type FIS is widely used in particular for decision support application, other discrimination between the mamdani FIS has output membership functions whereas sugeno FIS has no output membership functions.[5] Mamdani is less flexible in system design in comparison to sugeno FIS as latter can be integrated with ANFIS tool to optimize the output.

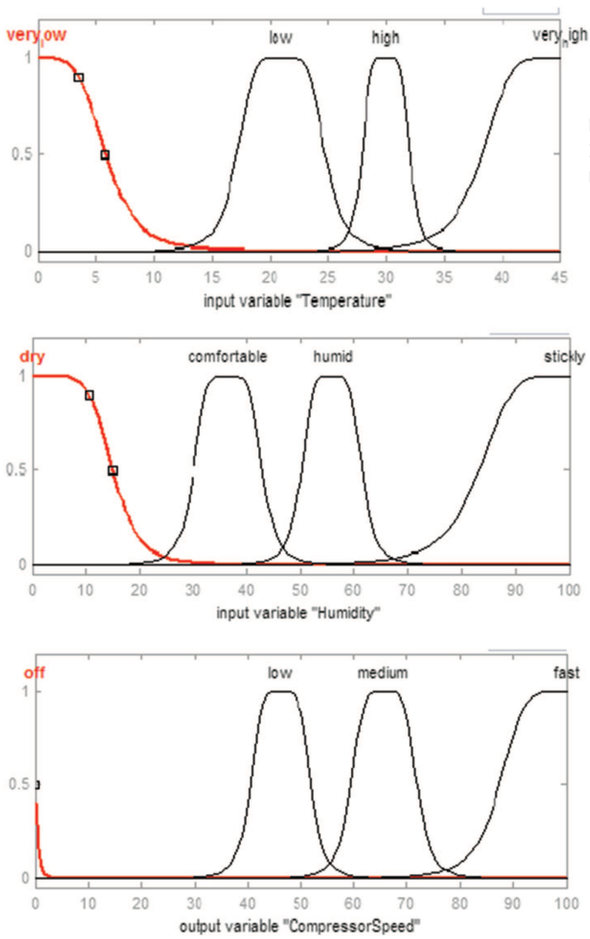


Fig. 14. Spread of fuzzy membership for bell shaped functions.

4. DEVELOPMENT OF MAMDANI-TYPE FIS

The Mamdani fuzzy model was first utilized to develop air conditioning system. The temperature and humidity are the source as the input from temperature and humidity sensors and it is sensed from the room.[6] The speed of the compressor is controlled by the output of the system. The ranges of the temperature and humidity is 0 °C to 45 °C and 0% to 100% respectively. Each of the inputs consists of four triangular membership functions as shown in Figures 4 and 5. The mechanical device speed is taken as output and in range from 0% to 100% and have four triangular membership functions as shown in Figure 6. The protocols included for the air conditioning system are described in Table I. The performance of fuzzy logic controller is well equipped for improvements of voltage sag. Since the appropriate mathematical model of fuzzy logic controller is not required, it is very useful. The fuzzy logic system will be classified into four main useful blocks specifically knowledge base, fuzzification, inference mechanism and defuzzification role base.

The Basic parts of a FLC.

The main plan underlying the fuzzy logic control is, to focus on the problems concerned, Figure 3 shows the

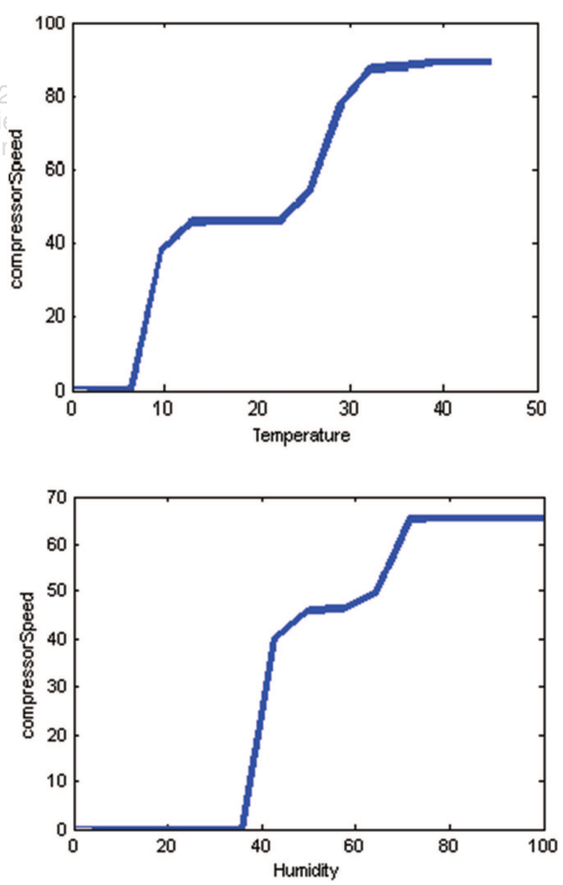


Fig. 15. Fuzzy controller response with triangular membership functions for Mamdani-type FIS.

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essential component of FLC, that includes four principal components: a fuzzification, a Rule base, Inference engine, and defuzzification.

1. The fuzzification interface involves the following functions.
   a. Measure the values of input variables,
   b. Performs a scale mapping that transfers the range of values of input variables, into corresponding universes of discourse,
   c. Performs the perform of fuzzification that converts input file into appropriate linguistic values.
2. The knowledge based mostly includes a information the applying domain and attendant control goal. It consists of a "data base" and a "linguistic (fuzzy) management rule base."
   a. The data base provides necessary definitions, that area unit accustomed outlined linguistic control rules and fuzzy information manipulations in fuzzy logic control.
   b. The Rule base characterizes the control goals and control policy of the domain specialists by suggests that of set linguistic control rules.
3. The decision-making logic is that the kernel of fuzzy logic control. It's the aptitude of simulating human decision-making supported fuzzy ideas and inferring fuzzy control action using fuzzy implication and therefore the rule inference fuzzy logic.
4. The defuzzification interface performs the subsequent functions:
   a. A scale mapping, that converts the range of values output variables into corresponding universe of discourse.
   b. Defizzification, that yields a non-fuzzy control action from associate inferred fuzzy control action.[7]

The design of FCSs with Mamdani FC is sometimes performed by heuristic means that incorporating human skills and knowledge, and it's usually administered by a model-free approach. The immediate defect resulted from the model-free design and Fuzzy Controller standardisation issues the dearth of general design methods. Eventhough the performance indices of such control systems square measure usually satisfactory, a serious downside is that the analysis of the structural properties possessed by the FCSs

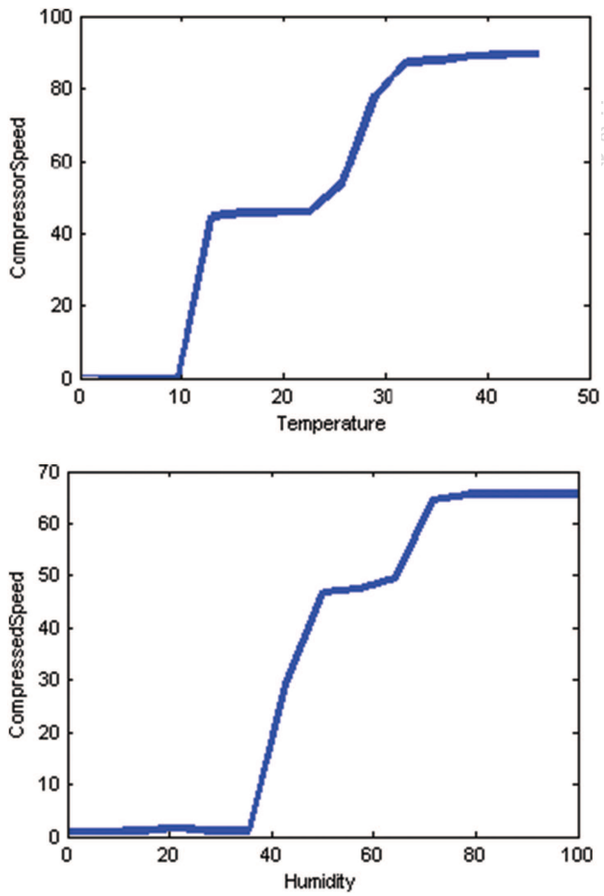


Fig. 16. Fuzzy controller response with trapezoidal membership functions for Mamdani-type FI.

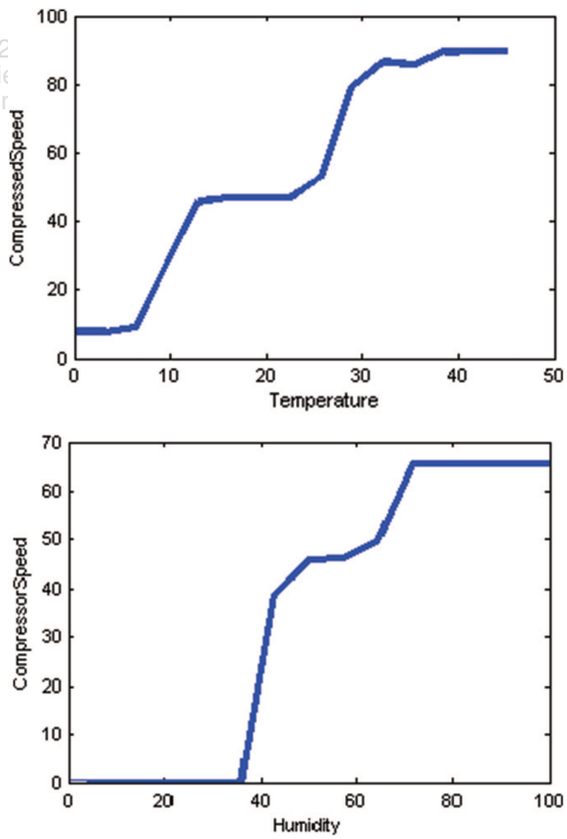


Fig. 17. Fuzzy controller response with Gaussian membership functions for Mamdani-type FIS.

as well as stability, controllability, constant sensitivity and strength. The Rule base for membership perform is shown Table I.

5. DEVELOPMENT OF SUGENO-TYPE FIS

For development of air-conditioning system using Sugeno-type model, the initial steps are same as Mamdani-type model. It additionally takes inputs from temperature Associate in Nursing humidity sensors and produces an signaling that controls the mechanical device speed. Inputs temperature and humidity have four triangular membership functions over the range of 0 °C to 45 °C and 0% to 100% respectively (as already shown in Figs. 1 and 2). The output mechanical device speed will solely be either constant or linear during this FIS, thus four membership functions for the output ar "off," "low," "medium" and "fast" that ar constant and ar shown in Table II.[9] The output in Sugeno-type FIS will solely be in vary of 0–1. The rule base for Sugeno-type FIS is same as for Mamdani-type FIS as shown in Table I.

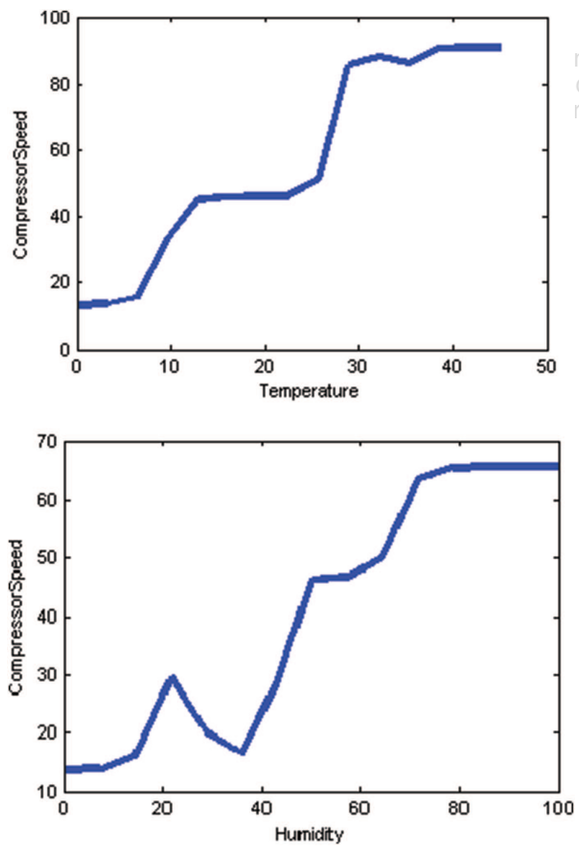


Fig. 18. Fuzzy controller response with bell shaped membership functions for Mamdani-type FIS.

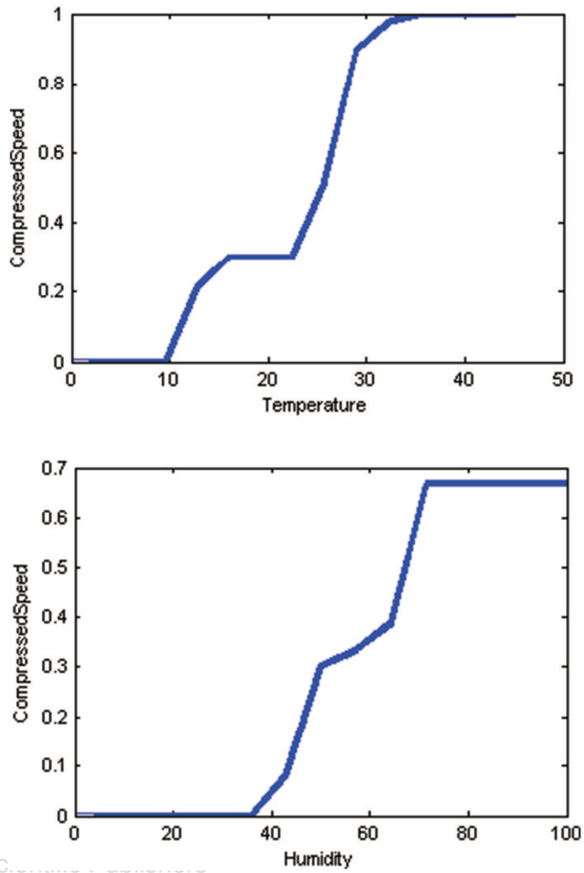


Fig. 19. Fuzzy controller response with triangular membership functions for Sugeno-type FIS.

6. RESULTS AND DISCUSSION

The plots obtained when simulating Mamdani-type of FIS for air conditioning system square measure shown in Figures 16–19. Following are the plots obtained after simulating the Sugeno-type FIS for air conditioning system (as shown in Figs. 20–22):[10]

The results obtained show that for the given application of air-conditioning system Mamdani-type FIS (as shown in Figs. 6–8) and Sugeno-type (as shown in Figs. 9–11).

FIS works equally. The only distinction detected is that in Sugeno-type FIS air-conditioning system works upto its full capability whereas in Mamdani-type FIS it doesn't work upto full capability.[11]

Membership functions will have completely different shapes. The foremost normally used shapes are triangular, trapezoidal, Gaussian and bell shaped membership functions. During this work, Fuzzy inference systems are developed for air conditioning system by considering the membership functions like triangular, trapezoidal, Gaussian and bell shaped. (Figs. 3–5, 12–15) show the spread of the various functions used for four variables.[12]

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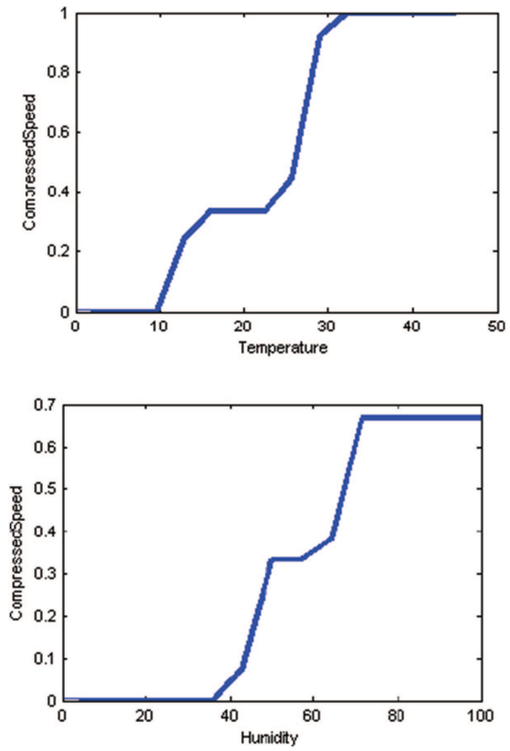


Fig. 20. Fuzzy controller response with trapezoidal membership functions for Sugeno-type FIS.

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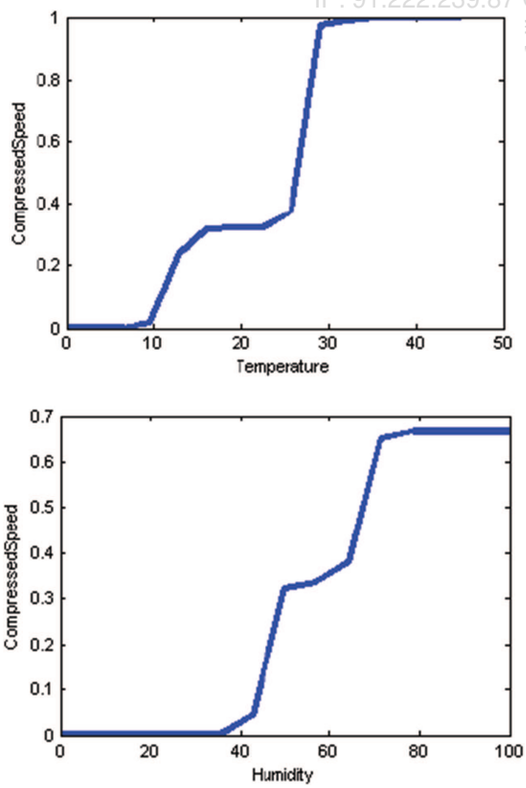


Fig. 21. Fuzzy controller response with Gaussian membership functions for Sugeno-type FIS.

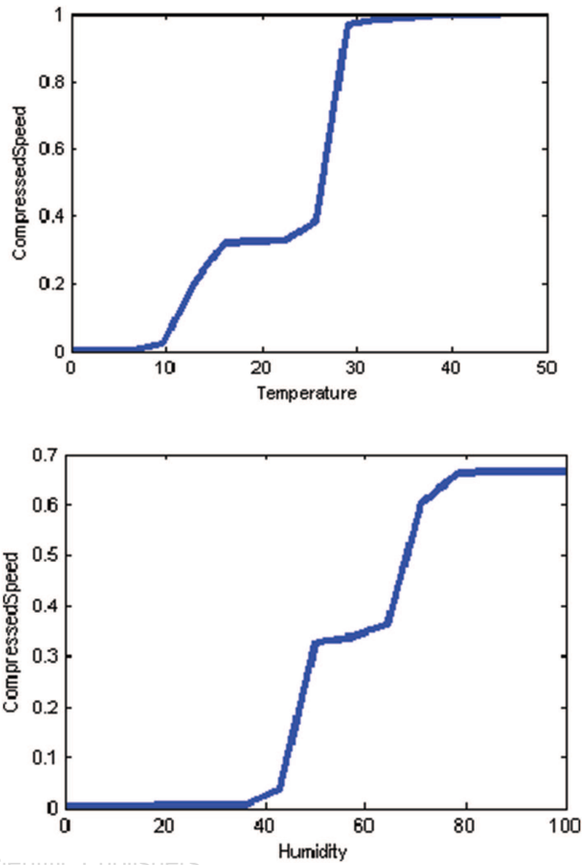


Fig. 22. Fuzzy controller response with bell shaped membership functions for Sugeno-type FIS.

7. CONCLUSION

This paper has been successfully demonstrated effect of various membership functions in the fuzzy control for air conditioning is proposed. A fully automatic air conditioning system is designed using fuzzy logic. It can be concluded from this work that for air conditioning system Mamdani-type FIS and Sugeno-type FIS performs equally however by using Sugeno-type FIS model it permits the air conditioning system to work at its full capability.[13] Although the planning of each the FIS is same however the output membership functions of Sugeno-type will solely be either constant or linear, but the simulation results showed that the triangular membership functions shows better performance compared to trapezoidal, Gaussian and bell shaped membership functions. The entire system is analyzed with FIS using MATLAB7.7/Simulink under various conditions.

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