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# Fuzzy Logic Control System for Comfortable Indoor Environment

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**Abstract:** This paper proposed fuzzy logic control system for comfortable indoor environment. The fuzzy controllers receives two crisp input values (temperature and humidity) from temperature and humidity sensors, constructs the membership functions for each variable, fire the rules and produces the output singleton values corresponding to each crisp output. The outputs of the controller include the on/off signals to the heater, fan and air con. This design model can be applied for indoor environment like office, work place, home and commercial areas. The benefit of fizzy logic control system is maintaining the system at the required state. This application of fuzzy logic would contribute in minimizing the energy wastages and saving costs.

**Keywords:** Fuzzy logic, Humidity, Rules, Temperature.

## I. INTRODUCTION

Comfortable indoor environment plays an important role in our life and can improve working capacities in work place. Several studies concerning providing safe or comfortable indoor environment have been conducted. In paper [1], Qi and Deng developed a multi input, multi output control strategy for simultaneously controlling the indoor air temperature and humidity. They used the linear quadratic Gaussian technique in designing the controller. Li et al. proposed a simulation study on the characteristics of space cooling load and indoor humidity control for residences in the subtropics using a building energy simulation program. [2] Fuzzy controller is used in this system to achieve comfortable indoor environment automatically. Fuzzy logic is based on a system of non-digital (continuous & fuzzy without crisp boundaries) set theory and rules and was introduced by Lutfi Zadieh in 1965.

It has ability to deal with vague systems and its use of linguistic variables. [3]It is a static nonlinear mapping between its inputs and outputs. Fuzzy Logic is suitable for uncertainties issues. The non-probabilistic problems are dealt with fuzzy logic. [4] It usually uses IF/THEN rules. Rules are usually expressed in the form: IF variable is set, THEN action. Fuzzy control system involves four processes: fuzzification, rules based decision making, inference mechanism and defuzzification. The fuzzy controller allows the interaction of multiple inputs to approximate the value of the output. Hence, it is largely employed in various applications. The paper presents a control system to enhance comfort in indoor environments. The proposed controller utilizes fuzzy logic to control the indoor temperature and humidity measured by temperature and humidity sensors. The controller produces output signals for heater, fan and air con. The aim of the system is to provide comfortable living space while at the same time saving energy.

## II. BASIC STRUCTURE OF THE PROPOSED SYSTEM

The basic structure of the proposed system includes fuzzy logic controller which consists of fuzzifier, inference engine connected with rule base and defuzzifier. The fuzzifier converts the crisp values into linguistics values. The linguistics values are manipulated for inference engine. [5] Rule base is built up carefully considering all possible effective situations. There are fifteen rules in the rule base. There have been incorporated two input variables: temperature and humidity. There are three outputs controlling appliances: heater, fan and air con.

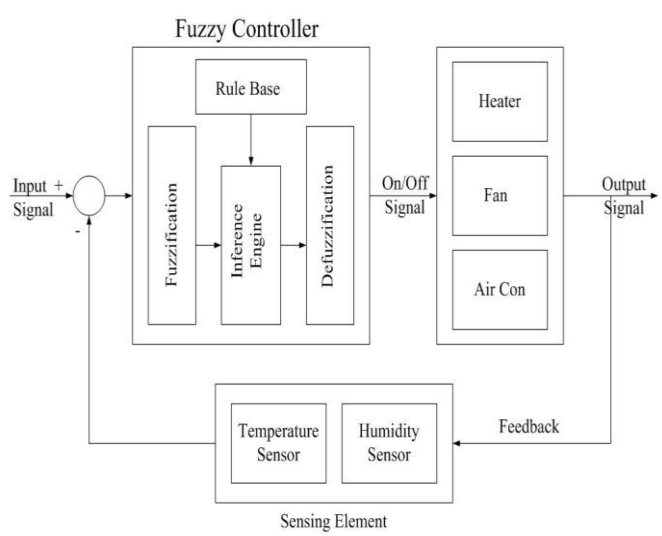



**Figure1. Block diagram of the proposed system.**

## III. FUZZY LOGIC CONTROLLER

Fuzzy logic is problem solving control system methodology and quick tracking under changing conditions. Fuzzy logic like human logic has no limits and is based on decision making methods. Therefore, to make a better decision, controlling the operation is needed which has in turn led to use fuzzy control mechanism that is based on logic. Fuzzy logic controller system does not require full knowledge of the model, whereas in other known controller this knowledge is required. The use of uncertainty tests of fuzzy systems and expert's knowledge as controls has become popular and used in many different fields of science. [6] The fuzzy control has the advantage to be robust and relatively simple to design, since it does not require the knowledge of the exact model. The fuzzy logic controller has three main parts namely: Fuzzification, Inference Engine and Defuzzification.

### A. Fuzzification

The fuzzification is the process of converting the crisp set into linguistic fuzzy sets using fuzzy membership function. The concept of linguistic variable was introduced to process the natural language. The membership function is a curvature that describes each point of membership value in the input space. In this system, the triangular membership function is used and the temperature input is determined over a scale range of 0°C to 100°C and humidity input is determined from 0% to 100%. The five fuzzy membership functions for temperature input are termed as: very cold (0-20°C), cold (10-30°C), normal (20-40°C), hot (30-50°C) and very hot (40-100°C). For humidity input, the three membership functions are: dry (0-40%), medium (20-60%) and wet (40-100%). The membership functions with their respective ranges for input variables (temperature and humidity) are shown in the Figure 2 and 3.

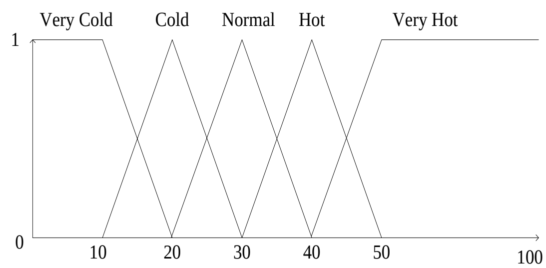



**Figure2.Membership functions and ranges for Temperature.**

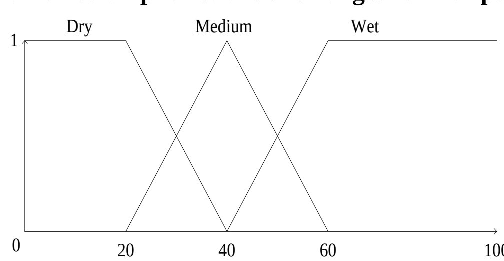



**Figure3. Membership functions and ranges for Humidity.**

Fuzzy rule base is the basic function of fuzzification. A collection of rules referring to a particular system is known as fuzzy rule base. Fuzzy rule base for the proposed system is shown in Table 1.

**TABLEI: FUZZY RULE BASE**

| INPUTS | | OUTPUTS | | |
|---|---|---|---|---|
| Temperature (°C) | Humidity (%) | Heater | Fan | Air Con |
| Very Cold | Dry | On | Off | Off |
| Very Cold | Medium | On | Off | Off |
| Very Cold | Wet | On | Off | Off |
| Cold | Dry | Off | On | Off |
| Cold | Medium | Off | Off | Off |
| Cold | Wet | On | Off | Off |
| Normal | Dry | Off | On | Off |
| Normal | Medium | Off | Off | Off |
| Normal | Wet | On | Off | Off |
| High | Dry | Off | Off | On |
| High | Medium | Off | On | Off |
| High | Wet | Off | Off | Off |
| Very High | Dry | Off | Off | On |
| Very High | Medium | Off | Off | On |
| Very High | Wet | Off | Off | On |

### A. Inference Engine

Fuzzy inference engine is an operating method that formulates a logical decision based on the fuzzy rule setting and transforms the fuzzy rule base into fuzzy linguistic output. Fuzzy linguistic descriptions are formal representations of system made through fuzzy IF-THRN rules. They encode knowledge about a system in statements of the form: IF (a set of conditions) are satisfied THEN (a set of consequents) can be inferred. There are several methods for this such as Max-Min method, Max-Dot method. Max-Min method is applied to the rules in this system. Inference engine is otherwise called as decision-making logic. [7]

### B. Defuzzification

The final step in the fuzzy logic control process is the defuzzification. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets. Several methods are available for defuzzification such as Centre of Average (COA), centroid method, centre of sums, and mean of maxima. The membership functions of the output variables are shown in Figure 4.

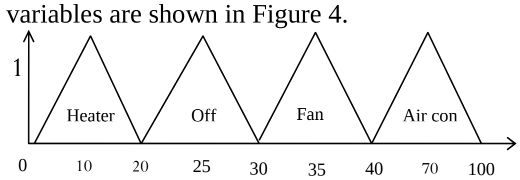



**Figure4. Membership functions for output variables.**

For defuzzification, the Centre of Gravity (COG) defuzzification method is used. This method uses the following equations to get the output.

$$\mu_i = w\left(h - \frac{h^2}{2}\right) \qquad (1)$$

Where, $\mu_i$ = Area of membership function

w = base width of output fuzzy set
h = height of output fuzzy set

$$\mu_{crispoutput} = \frac{\sum B_i \mu_i}{\sum \mu_i} \qquad (2)$$

Where, $B_i$ = center of membership function

## IV. Implementation Of Proposed System

The system flow diagram of the proposed system is as shown in Figure 5.

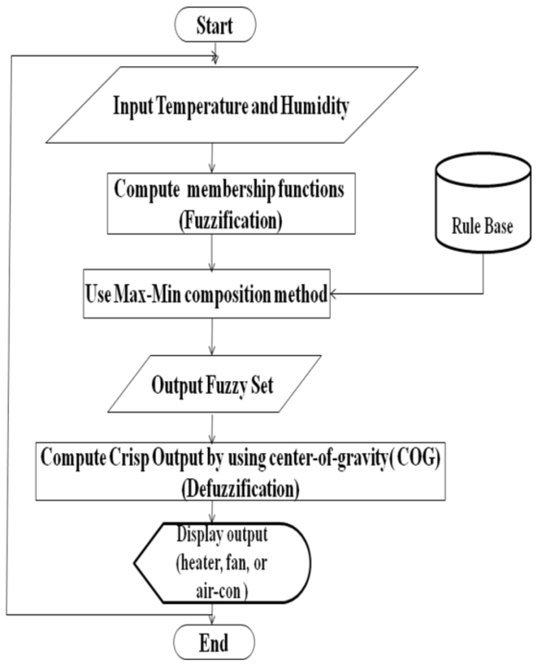



**Figure5. The System flow of the proposed system.**

In this system, temperature and humidity values are accepted as inputs for these control system. And then, it computes the membership values from these inputs and it also calculates the fuzzified rules using Max-min composition method base on training rules in Database. After that, this system defuzzified the fuzzified rules to produce the result for control system. The proposed system is implemented by using C# programming language.

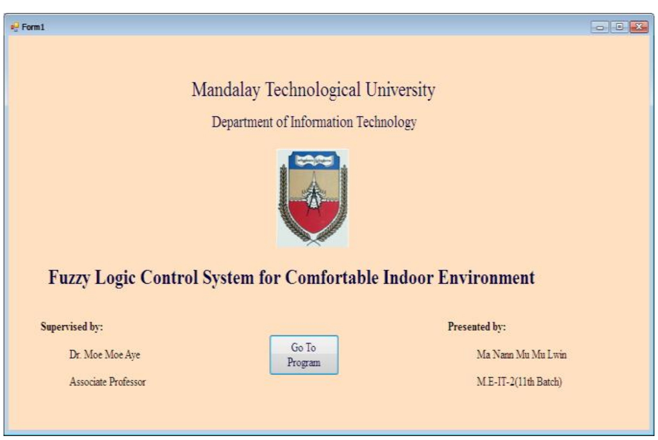



**Figure6. Home form.**

The Figure6 shows the Home form for our proposed system. We can start our proposed system by clicking the "Go To Program" button. The Figure 7(a) shows the Fuzzification form. In this form, we input the temperature value and humidity value to calculate fuzzified output as shown in Figure 7(b).

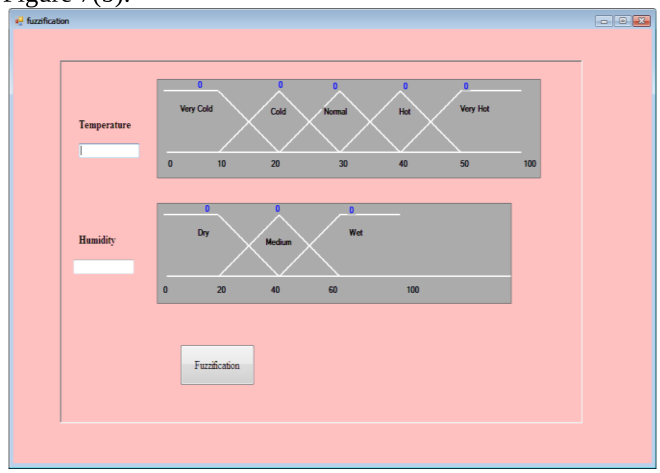



**Figure7(a). Fuzzification form.**

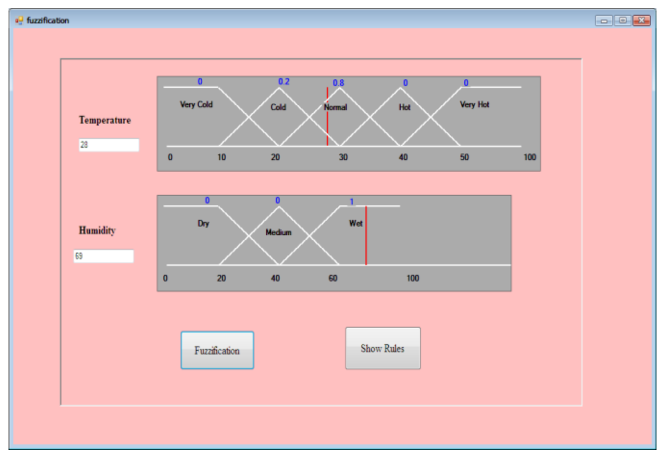



**Figure7(b). Fizzification form that shows fuzzified values.**

After calculating the fuzzified values, the "Show Rules" button will be appeared. This button shows the fuzzified rules for related values as shown in Figure 8.

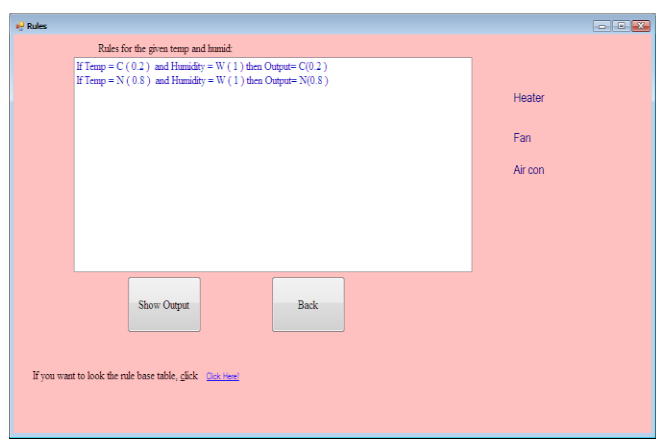



**Figure8. Fuzzified rules form.**

Finally, the system has to compute the defuzzification process to achieve the crisp output. When we click the "Show Output" button , the output for our control system is displayed in the Right side of the form. The output is the on/off state of the Heater, Fan and Air con as shown in Figure 9.

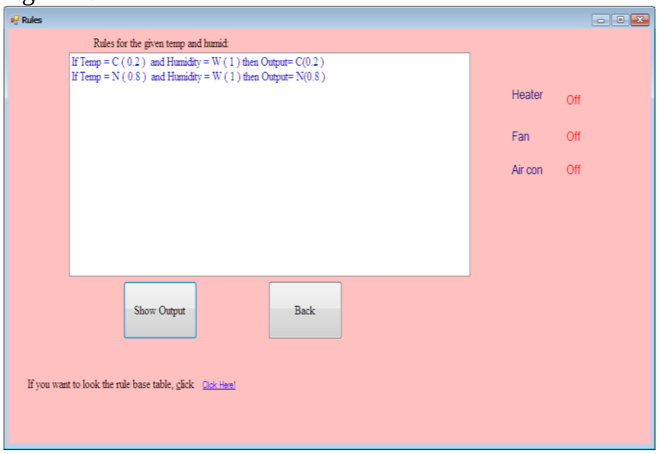
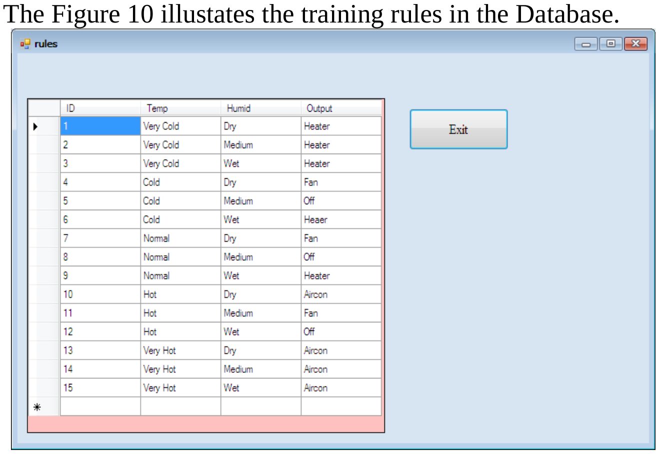



**Figure9. Show Output form.**

The Figure 10 illustates the training rules in the Database.



| ID | Temp | Humid | Output |
|---|---|---|---|
| 1 | Very Cold | Dry | Heater |
| 2 | Very Cold | Medium | Heater |
| 3 | Very Cold | Wet | Heater |
| 4 | Cold | Dry | Fan |
| 5 | Cold | Medium | Off |
| 6 | Cold | Wet | Heaer |
| 7 | Normal | Dry | Fan |
| 8 | Normal | Medium | Off |
| 9 | Normal | Wet | Heater |
| 10 | Hot | Dry | Aircon |
| 11 | Hot | Medium | Fan |
| 12 | Hot | Wet | Off |
| 13 | Very Hot | Dry | Aircon |
| 14 | Very Hot | Medium | Aircon |
| 15 | Very Hot | Wet | Aircon |



**Figure10. Rules table form.**

## V. CONCLUSION

The fuzzy logic control system for comfortable indoor environment provides the accurate control in any indoor environment. This work builds up the control management without the complexity in a processing plant of room temperature to sustain the required comfortable indoor environment. The fuzzy controller response in all experimental conditions is quite as expected. The fuzzy logic control algorithm adapts quickly to longer time delays and provides a stable response and can give more attention to various parameters. The controller presented in this paper has excellent performance and robustness properties. The proposed system design automates the appliances and contributes in better utilization of energy. It works from low humidity to high humidity and low temperature to high temperature for maintaining pleasant environment to the user satisfaction and comfort. It would enhance working capacities also. From this study, like this design, it is hoped that it can be shared some benefits of fuzzy logic to the further research.

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