1. INTRODUCTION

1.1. Problem Statement

Solve Air conditioner Controller using MATLAB Fuzzy logic tool box.

1.2. Project Idea

With the exponential increase in the use of cooling device, the air conditioning systems are becoming an essential part of our day to day life. Data suggest an exponential rise in the use of air conditioners in urban as well as rural India. With the increase in the usage of air conditioners, there is a simultaneous increase in the electrical power consumption. In this mini-project a design has been proposed considering various input parameters and applying Fuzzy Logic System to the Air Conditioner.

1.3. Theory and Concepts:

- **Fuzzy Logic:**

  Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact. Fuzzy logic was formulated by Lofti Zadeh of the University of California at Berkeley in the mid-1960s. Zadeh also formulated the notion of fuzzy control that allows a small set of 'intuitive rules' to be used in order to control the operation of electronic devices. One of the benefits of fuzzy control is that it can be easily implemented on a standard computer.

  In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Fuzzy logic imitates the logic of human thought, which is much less rigid than the calculations computer generally perform. Intelligent control strategies mostly involve a large number of inputs. The objective of using fuzzy logic has been to make the computer think like people.

Fuzzy logic can deal with the vagueness intrinsic to human thinking and natural language and recognize its nature is different from randomness. Using fuzzy logic algorithm, we could enable machines to understand and respond to vague human concept.

- **Fuzzy Inference System:**

Fuzzy Inference System is the key unit of a fuzzy logic system having decision making as its primary work. It uses the "IF…THEN" rules along with connectors "OR" or "AND" for drawing essential decision rules

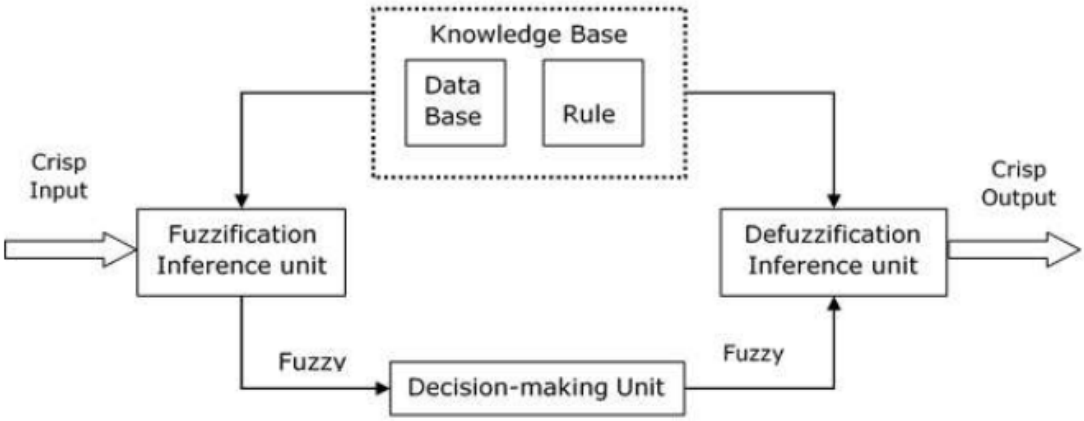

Figure 1.1 : Fuzzy Inference System

The following five functional blocks will help you understand the construction of FIS −

- **Rule Base** − It contains fuzzy IF-THEN rules.
- **Database** − It defines the membership functions of fuzzy sets used in fuzzy rules.
- **Decision-making Unit** − It performs operation on rules.
- **Fuzzification Interface Unit** − It converts the crisp quantities into fuzzy quantities.
- **Defuzzification Interface Unit** − It converts the fuzzy quantities into crisp quantities. Following is a block diagram of fuzzy interference system.

Characteristics of Fuzzy Inference System

- The output from FIS is always a fuzzy set irrespective of its input which can be fuzzy or crisp.
- It is necessary to have fuzzy output when it is used as a controller.
- A defuzzification unit would be there with FIS to convert fuzzy variables into crisp variables.

Working of FIS

The working of the FIS consists of the following steps −

- A fuzzification unit supports the application of numerous fuzzification methods, and converts the crisp input into fuzzy input.
- A knowledge base - collection of rule base and database is formed upon the conversion of crisp input into fuzzy input.
- The defuzzification unit fuzzy input is finally converted into crisp output.

Methods of FIS

Following are the two important methods of FIS, having different consequent of fuzzy rules −

- Mamdani Fuzzy Inference System
- Takagi-Sugeno Fuzzy Model (TS Method)

Mamdani Fuzzy Inference System:

This system was proposed in 1975 by Ebhasim Mamdani. Basically, it was anticipated to control a steam engine and boiler combination by synthesizing a set of fuzzy rules obtained from people working on the system.

Steps for Computing the Output

Following steps need to be followed to compute the output from this FIS −

- **Step 1** − Set of fuzzy rules need to be determined in this step.
- **Step 2** − In this step, by using input membership function, the input would be made fuzzy.

- **Step 3** − Now establish the rule strength by combining the fuzzified inputs according to fuzzy rules.
- **Step 4** − In this step, determine the consequent of rule by combining the rule strength and the output membership function.
- **Step 5** − For getting output distribution combine all the consequents.
- **Step 6** − Finally, a defuzzified output distribution is obtained.

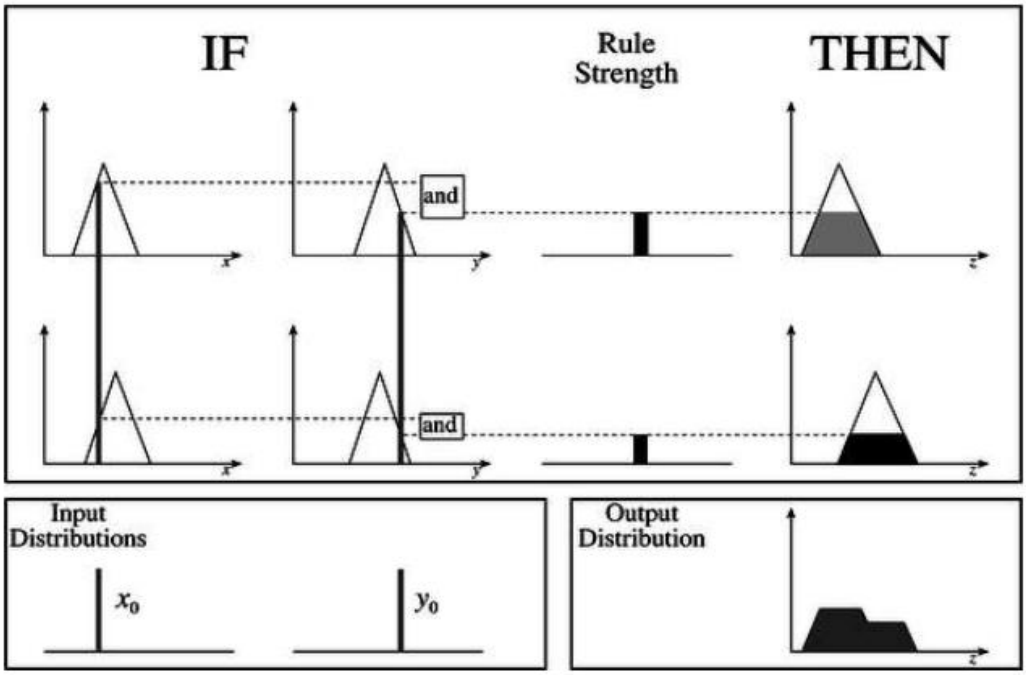

Fig 1.2 : Block diagram of Mamdani Fuzzy Interface System

Takagi-Sugeno Fuzzy Model (TS Method)

This model was proposed by Takagi, Sugeno and Kang in 1985. Format of this rule is given as −

IF x is A and y is B THEN Z = f(x,y)

Here, *AB* are fuzzy sets in antecedents and $z = f(x,y)$ is a crisp function in the consequent.

Fuzzy Inference Process

The fuzzy inference process under Takagi-Sugeno Fuzzy Model (TS Method) works in the following way −

- **Step 1: Fuzzifying the inputs** − Here, the inputs of the system are made fuzzy.
- **Step 2: Applying the fuzzy operator** − In this step, the fuzzy operators must be applied to get the output.

Comparison between the two methods

Let us now understand the comparison between the Mamdani System and the Sugeno Model.

- **Output Membership Function** − The main difference between them is on the basis of output membership function. The Sugeno output membership functions are either linear or constant.
- **Aggregation and Defuzzification Procedure** − The difference between them also lies in the consequence of fuzzy rules and due to the same their aggregation and defuzzification procedure also differs.
- **Mathematical Rules** − More mathematical rules exist for the Sugeno rule than the Mamdani rule.
- **Adjustable Parameters** − The Sugeno controller has more adjustable parameters than the Mamdani controller.

- **Applications of Fuzzy Logic Inference System**

Automotive

In automotive, fuzzy logic is used in the following areas −

- Trainable fuzzy systems for idle speed control
- Intelligent highway systems
- Traffic controls

Business

In business, fuzzy logic is used in the following areas −

- Decision-making support systems
- Personnel evaluation in a large company

Defense

In defense, fuzzy logic is used in the following areas −

- Underwater target recognition
- Automatic target recognition of thermal infrared images
- Naval decision support aids
- Fuzzy set modeling of NATO decision making

Electronics

In electronics, fuzzy logic is used in the following areas −

- Control of automatic exposure in video cameras
- Humidity in a clean room
- Air conditioning systems
- Washing machine timing
- Microwave ovens
- Vacuum cleaners

Finance

In the finance field, fuzzy logic is used in the following areas −

- Banknote transfer control
- Fund management
- Stock market predictions

Industrial Sector

In industrial, fuzzy logic is used in following areas −

- Cement kiln controls heat exchanger control
- Activated sludge wastewater treatment process control
- Water purification plant control
- Quantitative pattern analysis for industrial quality assurance
- Control of constraint satisfaction problems in structural design
- Control of water purification plants

Manufacturing

In the manufacturing industry, fuzzy logic is used in following areas −

- Optimization of cheese production
- Optimization of milk production

Marine

In the marine field, fuzzy logic is used in the following areas −

- Autopilot for ships
- Optimal route selection
- Control of autonomous underwater vehicles
- Ship steering

Medical

In the medical field, fuzzy logic is used in the following areas −

- Medical diagnostic support system
- Control of arterial pressure during anesthesia
- Multivariable control of anesthesia
- Modeling of neuropathological findings in Alzheimer's patients
- Radiology diagnoses
- Fuzzy inference diagnosis of diabetes and prostate cancer

Transportation

In transportation, fuzzy logic is used in the following areas −

- Automatic underground train operation
- Train schedule control
- Railway acceleration
- Braking and stopping

Pattern Recognition and Classification

In Pattern Recognition and Classification, fuzzy logic is used in the following areas −

- Fuzzy logic based speech recognition
- Fuzzy logic based
- Handwriting recognition
- Fuzzy logic based facial characteristic analysis
- Fuzzy image search

2. PROJECT DESIGN

2.1. Hardware and Software requirements

Operating System – Windows 7/8/10

Toolbox – MATLAB Fuzzy Logic Toolbox

Hardware – Intel core i3/i5/i7 processor with 4GB RAM

2.2. Input Variables

Parameter	Status	Unit
Target temperature	Very Cold, Cold, Warm, Hot, Very Hot	16 to 32 degree Celsius
Actual room temperature	Very Cold, Cold, Warm, Hot, Very Hot	16 to 32 degree Celsius
Humidity	Dry, Refreshing, Comfortable, Humid	10% to 70%

2.3. Output Variables

Parameter	Status	Unit
Fan speed	Minimum, Slow, Medium, Fast, Maximum	16 to 32 degree Celsius
Compressor speed	Minimum, Slow, Medium, Fast, Maximum	16 to 32 degree Celsius
Fin direction	Away, Towards	10° (towards user) 80° (away from user)
Operation	Air Condition (AC), Dehumidifier	-

2.4. Rule-Base :

1. If (Target_Temp is Very_Cold) and (Actual_Room_Temp is Very_Hot) and (Humidity is Dry) then (Fan_Speed is Maximum)(Compressor_Speed is Slow)(Fin_Direction is Towards)(Operation is Air_conditioner)
2. If (Target_Temp is Very_Cold) and (Actual_Room_Temp is Very_Hot) and (Humidity is Comfartable) then (Fan_Speed is Maximum)(Compressor_Speed is Medium)(Fin_Direction is Towards)(Operation is Air_conditioner)
3. If (Target_Temp is Cold) and (Actual_Room_Temp is Hot) and (Humidity is Comfartable) then (Fan_Speed is Fast)(Compressor_Speed is Medium)(Fin_Direction is Towards)(Operation is Air_conditioner)
4. If (Target_Temp is Cold) and (Actual_Room_Temp is Warm) and (Humidity is Comfartable) then (Fan_Speed is Fast)(Compressor_Speed is Medium)(Fin_Direction is Towards)(Operation is Air_conditioner)
5. If (Target_Temp is Cold) and (Actual_Room_Temp is Hot) and (Humidity is Humid) then (Fan_Speed is Fast)(Compressor_Speed is Medium)(Fin_Direction is Away)(Operation is Dehumidifier)
6. If (Target_Temp is Warm) and (Actual_Room_Temp is Warm) and (Humidity is Humid) then (Fan_Speed is Medium)(Compressor_Speed is Maximum)(Fin_Direction is Away)(Operation is Dehumidifier)
7. If (Target_Temp is Hot) and (Actual_Room_Temp is Cold) and (Humidity is Refreshing) then (Fan_Speed is Minimum)(Compressor_Speed is Slow)(Fin_Direction is Away)(Operation is Air_conditioner)
8. If (Target_Temp is Hot) and (Actual_Room_Temp is Very_Cold) and (Humidity is Refreshing) then (Fan_Speed is Minimum)(Compressor_Speed is Slow)(Fin_Direction is Away)(Operation is Air_conditioner)
9. If (Target_Temp is Very_Hot) and (Actual_Room_Temp is Cold) and (Humidity is Comfartable) then (Fan_Speed is Minimum)(Compressor_Speed is Slow)(Fin_Direction is Away)(Operation is Air_conditioner)
10. If (Target_Temp is Cold) and (Actual_Room_Temp is Cold) and (Humidity is Humid) then (Fan_Speed is Slow)(Compressor_Speed is Maximum)(Fin_Direction is Towards)(Operation is Dehumidifier)

11. If (Target_Temp is Warm) and (Actual_Room_Temp is Cold) and (Humidity is Humid) then (Fan_Speed is Slow)(Compressor_Speed is Fast)(Fin_Direction is Away)(Operation is Dehumidifier)
12. If (Target_Temp is Very_Cold) and (Actual_Room_Temp is Very_Cold) and (Humidity is Comfartable) then (Fan_Speed is Medium)(Compressor_Speed is Medium)(Fin_Direction is Towards)(Operation is Air_conditioner)
13. If (Target_Temp is Cold) and (Actual_Room_Temp is Warm) and (Humidity is Refreshing) then (Fan_Speed is Fast)(Compressor_Speed is Slow)(Fin_Direction is Towards)(Operation is Air_conditioner)
14. If (Target_Temp is Very_Cold) and (Actual_Room_Temp is Cold) and (Humidity is Dry) then (Fan_Speed is Fast)(Compressor_Speed is Minimum)(Fin_Direction is Towards)(Operation is Air_conditioner)
15. If (Target_Temp is Very_Cold) and (Actual_Room_Temp is Warm) and (Humidity is Refreshing) then (Fan_Speed is Maximum)(Compressor_Speed is Slow)(Fin_Direction is Towards)(Operation is Air_conditioner)
16. If (Target_Temp is Very_Cold) and (Actual_Room_Temp is Hot) and (Humidity is Comfartable) then (Fan_Speed is Maximum)(Compressor_Speed is Medium)(Fin_Direction is Towards)(Operation is Air_conditioner)
17. If (Target_Temp is Hot) and (Actual_Room_Temp is Warm) and (Humidity is Humid) then (Fan_Speed is Medium)(Compressor_Speed is Fast)(Fin_Direction is Away)(Operation is Dehumidifier)
18. If (Target_Temp is Hot) and (Actual_Room_Temp is Warm) and (Humidity is Humid) then (Fan_Speed is Medium)(Compressor_Speed is Fast)(Fin_Direction is Away)(Operation is Dehumidifier)
19. If (Target_Temp is Warm) and (Actual_Room_Temp is Very_Hot) and (Humidity is Humid) then (Fan_Speed is Fast)(Compressor_Speed is Maximum)(Fin_Direction is Towards)(Operation is Dehumidifier)
20. If (Target_Temp is Very_Hot) and (Actual_Room_Temp is Very_Hot) and (Humidity is Comfartable) then (Fan_Speed is Medium)(Compressor_Speed is Fast)(Fin_Direction is Away)(Operation is Dehumidifier)
21. If (Target_Temp is Hot) and (Actual_Room_Temp is Very_Hot) and (Humidity is Comfartable) then (Fan_Speed is Fast)(Compressor_Speed is Fast)(Fin_Direction is Towards)(Operation is Air_conditioner)

22. If (Target_Temp is Cold) and (Actual_Room_Temp is Warm) and (Humidity is Humid) then (Fan_Speed is Fast)(Compressor_Speed is Fast)(Fin_Direction is Towards)(Operation is Dehumidifier)
23. If (Target_Temp is Cold) and (Actual_Room_Temp is Hot) and (Humidity is Dry) then (Fan_Speed is Fast)(Compressor_Speed is Minimum)(Fin_Direction is Towards)(Operation is Air_conditioner)
24. If (Humidity is Dry) then (Fan_Speed is Medium)(Compressor_Speed is Slow)(Fin_Direction is Away)(Operation is Dehumidifier)
25. If (Target_Temp is Cold) and (Actual_Room_Temp is Very_Hot) and (Humidity is Humid) then (Fan_Speed is Maximum)(Compressor_Speed is Maximum)(Fin_Direction is Towards)(Operation is Dehumidifier)
26. If (Humidity is Dry) then (Fan_Speed is Medium)(Compressor_Speed is Minimum)(Fin_Direction is Towards)(Operation is Dehumidifier)
27. If (Humidity is Refreshing) then (Fan_Speed is Medium)(Compressor_Speed is Slow)(Fin_Direction is Towards)(Operation is Dehumidifier)
28. If (Humidity is Comfartable) then (Fan_Speed is Medium)(Compressor_Speed is Medium)(Fin_Direction is Towards)(Operation is Dehumidifier)
29. If (Humidity is Humid) then (Fan_Speed is Fast)(Compressor_Speed is Maximum)(Fin_Direction is Towards)(Operation is Dehumidifier)

2.5 Membership Functions:

- Triangular Membership Function
- Gaussian Membership Function
- Trapezoidal Membership Function

3. RESULTS AND DISCUSSION

3.1. Screen Shots

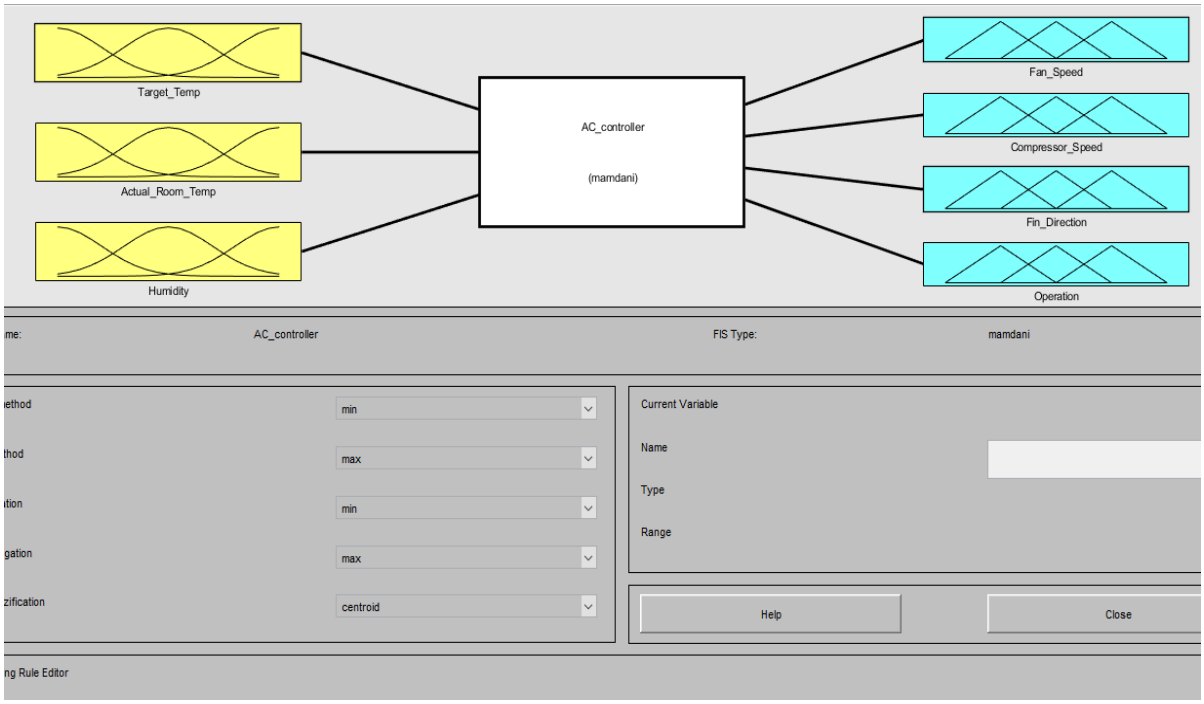

Fig 3.1 : Fuzzy Logic Designer

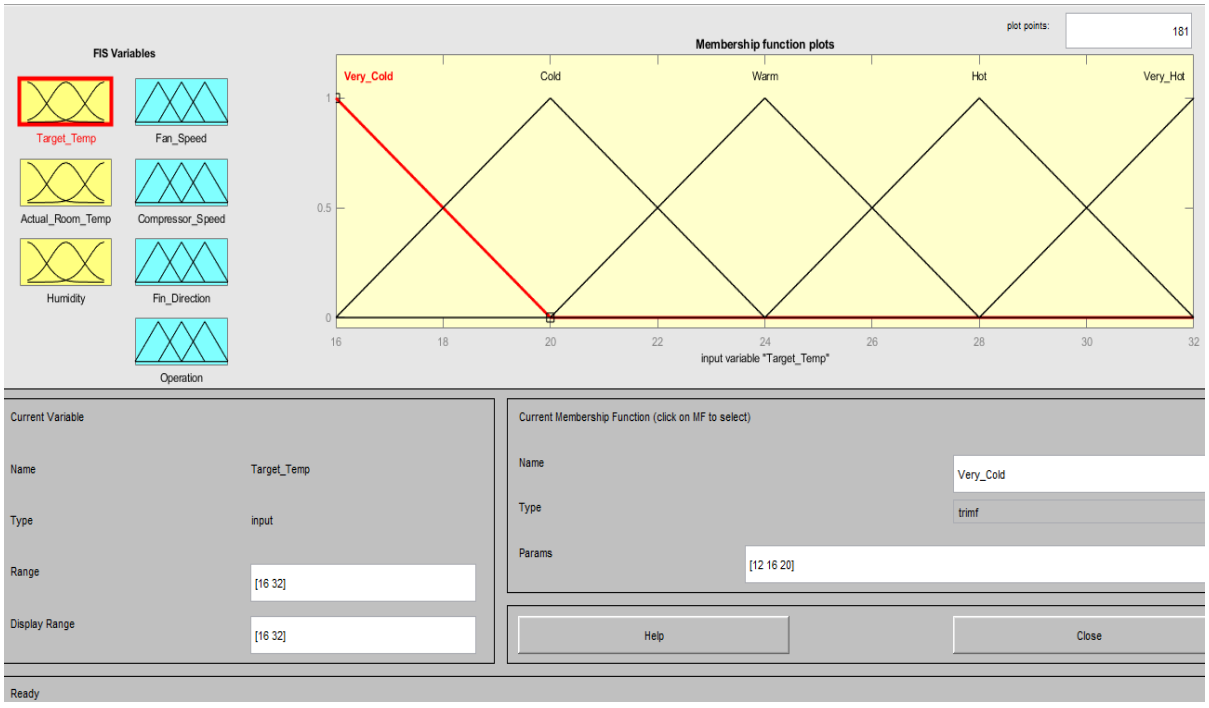

Fig 3.2 : Membership Functions

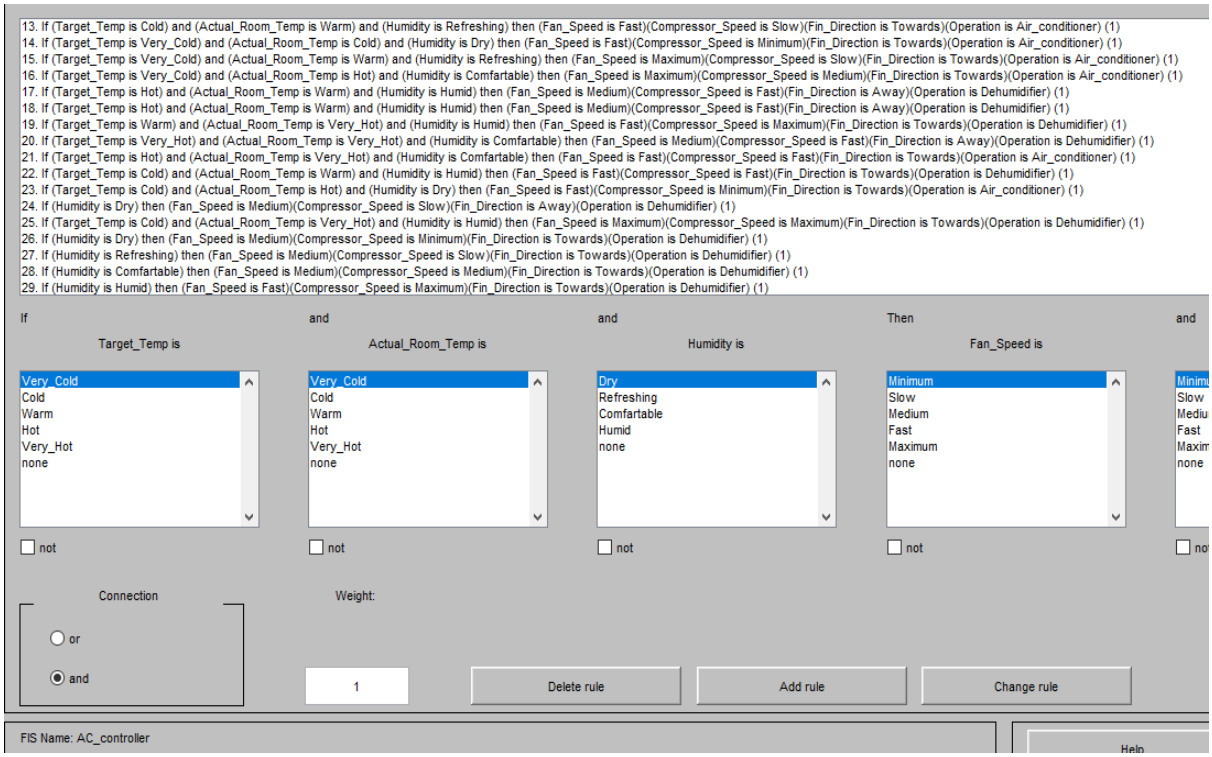

Fig 3.3 : Fuzzy Rule Editor

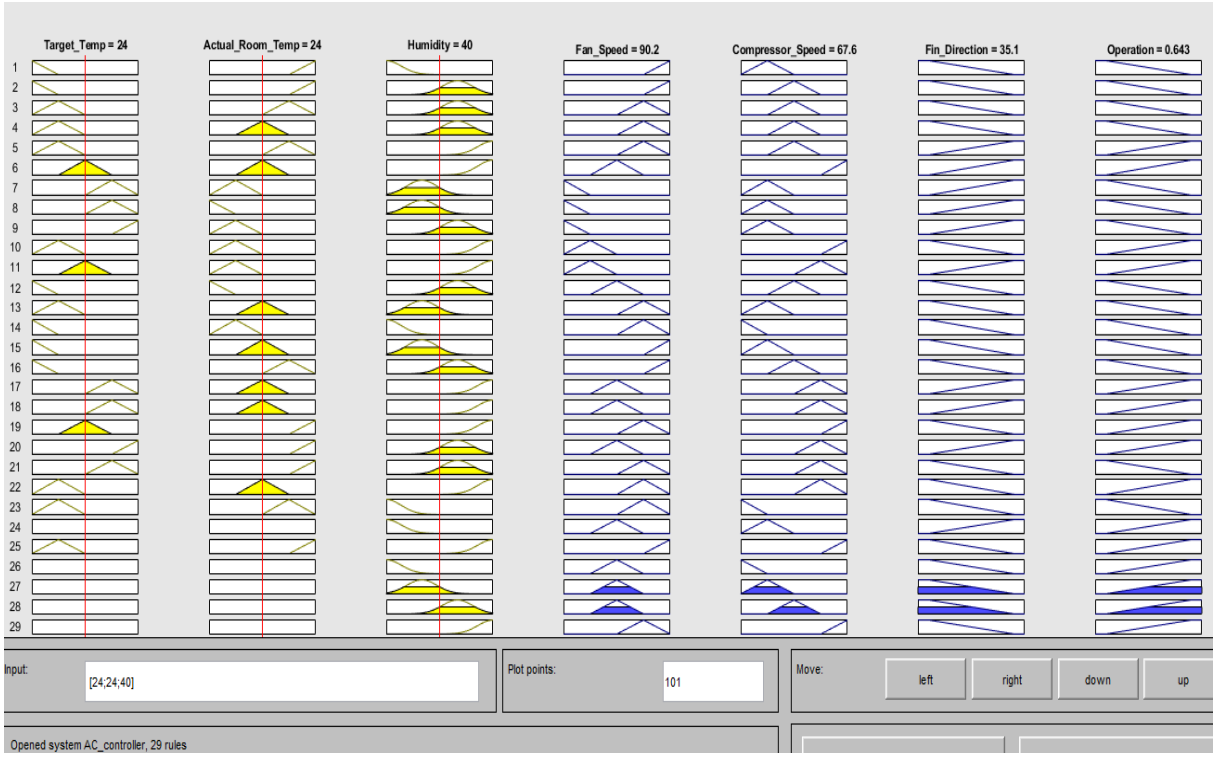

Fig 3.4 : Fuzzy Rule Viewer

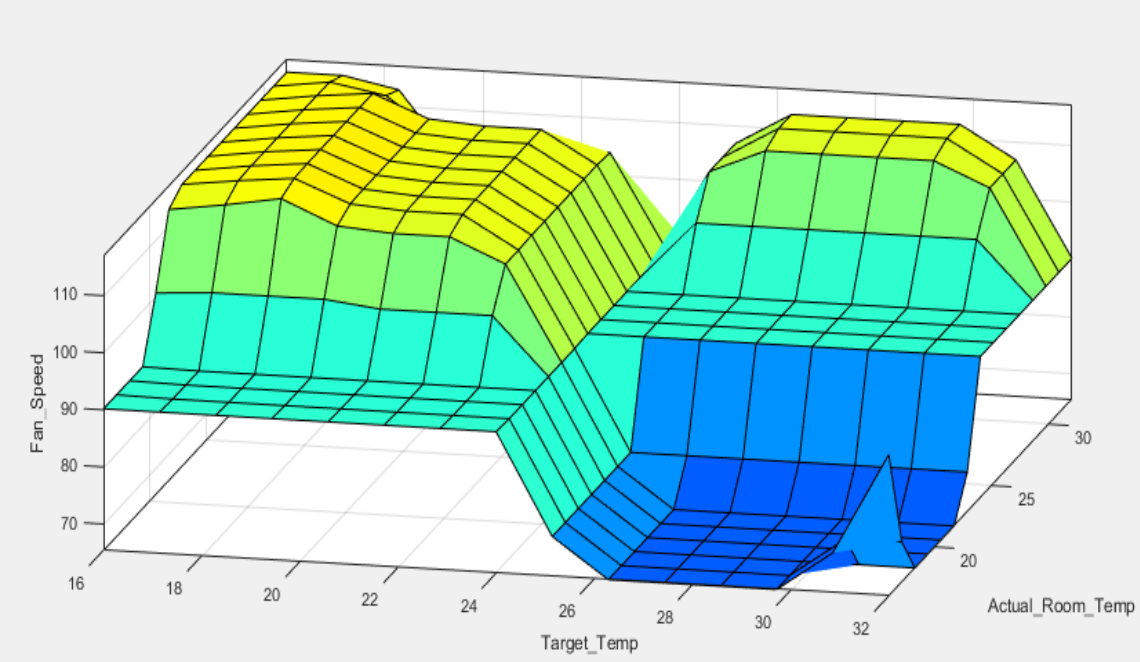

Fig 3.5 : Surface Viewer

CONCLUSION

Previously the Air-Conditioning systems which were used to simply cool the rooms now can perform a variety of functions. By adding intelligence to the Air-Conditioning system we do not have to worry about the cooling process. The analysis clearly maps out advantage of fuzzy logic in dealing with problems that are difficult to study analytically yet are easy to solve intuitively in terms of linguistic variables. In case of the Air-Conditioning system, fuzzy logic helped solve a complex problem without getting involved in intricate relationships between physical variables. Intuitive knowledge about input and output parameters was enough to design an optimally performing system. With most of the problems encountered in day to day life falling in this category, like washing machines, vacuum cleaners, etc, fuzzy logic is sure to make a great impact in human life. In future we will come up with a device that implements the Fuzzy Logic controller in an embedded system which can be used for increasing the efficiency of Air Conditioners.

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