**WOLKITE UNIVERSITY**

**College of Engineering and Technology**

**Department of Electrical and Computer Engineering**

# DESIGN AND CONTROL OF AUTONOMOUS AIR CONDITIONING SYSTEM USING FUZZY LOGIC CONTROLLER


Prepared by:

Almaz W/mariam [ENGR/110/07]

Bilen Girma [ENGR/254/07]

Mekdelawit Tatek[ENGR/730/07]

Advisor: Mr. Berhanu Dagim


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# DECLARATION

We, the undersigned, declare that this project, ”DESIGN AND CONTROL OF AUTONOMOUS ROOM AIR CONDITIONING SYSTEM”, is our own work. This work has not been submitted earlier either to this university or to any other institute for the partial fulfillment of the requirement of a course of study. All the sources of the materials used by our work are properly referred.

| Authors Name | Signature | Date |
|---|---|---|
| 1. Almaz W/mariam | _______________ | ___________ |
| 2. Bilen Girma | _______________ | ___________ |
| 3. Mekdelawit Tatek | _______________ | ___________ |

It is approved that this final-year project report has been written in compliance with the formatting rules laid down by the department of the university. This project has been submitted for examination with my approval as a university advisor.

| Name of advisor | Signature |
|---|---|
| Mr. Berhanu Dagim | |

# ABSTRACT

Air conditioning is a process of removing heat and moisture from the interior of an occupied space to improve the comfort occupants. This project aims to design and control fuzzy logic based autonomous room air cooling system. The rule base receives two crisp input values from temperature and humidity sensors, divides the universe of discourse into regions with each region containing two fuzzy variables, fires the rules, and gives the output singleton values corresponding to each output variable. Two defuzzifiers are used to control the actuators; cooler fan and water pump. MATLAB-simulation is used to achieve the designed goal and the results obtained from the simulation were found correct according to the design model. Since this project uses fuzzy logic controller it has an advantage in providing a great and successful controlling action that compensates difficult nonlinear characteristics. The simulation result show that the overall system output performance can be improved using the proposed fuzzy logic governor, the fuzzy logic controller resulted less percentage overshoot (0.496%), settling time (0.5) and less rise time (345.37).

Keyword: fuzzy logic controller, MATLAB-simulation

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# CHAPTER ONE

# Introduction

## 1.1 Background

The basic concept behind air conditioning is to have been applied in ancient Egypt, where reeds were hung in windows and were moistened with trickling water. The evaporation of water cooled the air blowing through the window, though this process also made the air more humid (also beneficial in a dry desert climate). Other techniques in medieval Persia involved the use of cisterns and wind towers to cool buildings during the hot season. Modern air conditioning emerged from advances in chemistry during the 19th century, and the first large-scale electrical air conditioning was invented and used in 1902 by Willis Havilland Carrier. the first modern electrical air conditioning unit was invented by Willis Carrier in Buffalo, New York. After graduating from Cornell University, Carrier, a native of Angola, New York, found a job at the Buffalo Forge Company. While there, Carrier began experimenting with air conditioning as a way to solve an application problem for the Sackett-Wilhelms Lithographing and Publishing Company in Brooklyn, New York, and the first "air conditioner", designed and built in Buffalo by Carrier, began working on 17 July 1902.

Designed to improve manufacturing process control in a printing plant, Carrier's invention controlled not only temperature but also humidity. Carrier used his knowledge of the heating of objects with steam and reversed the process. Instead of sending air through hot coils, he sent it through cold coils (ones filled with cold water). The air blowing over the cold coils cooled the air, and one could thereby control the amount of moisture the colder air could hold. In turn, the humidity in the room could be controlled. The low heat and humidity helped maintain consistent paper dimensions and ink alignment. Over time, air conditioning came to be used to improve comfort in homes and automobiles as well. Residential sales expanded dramatically in the 1950s.

Air conditioning is the process whereby not only cooling but also the condition of air, as defined by its temperature and moisture content, is changed.

Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favorable conditions. More generally, air conditioning can refer to any form of technological cooling, heating, ventilation, or disinfection that modifies the condition of air.

An air conditioner is the device (often referred to as air con, AC or A/C, and not to be confused with the abbreviation for alternating current) is a major or home appliance, system, or mechanism designed to change the air temperature and humidity within an area (used for cooling and sometimes heating depending on the air properties at a given time). The cooling is typically done using a simple refrigeration cycle, but sometimes evaporation is used, commonly for comfort cooling in buildings and motor vehicles. This project is done based on cooling concept of air conditioner.

The main objective of an air conditioning system is to fulfill the requirements in terms of air quality (temperature, humidity and air purity degree) to create the comfort and suitable conditions for living and working in an air conditioned environment. This is achieved by a combination of basic air processing, different options for managing air and using the related elements of automation and control laws.

Modern processing systems are heavily dependent on automatic control systems. The control automation has become essential for machines and processes to run successfully for the achievement of consistent operation, better quality, reduced operating costs, and greater safety. The control system design, development and implementation need the specification of plants, machines or processes to be controlled. A control system consists of controller and plant, and requires an actuator to interface the plant and controller. The behavior and performance of a control system depend on the interaction of all the elements. The dynamical control systems design, modeling and simulation in local and distributed environment need to express the behavior of quantitative control system of multi-input and multi-output variables control environment to establish the relation between actions and consequences of the control strategies [1]. Computational Intelligence (CI) is a field of intelligent information processing related with different branches of computer sciences and engineering. The fuzzy systems are one paradigm of

CI. The contemporary technologies in the area of control and autonomous processing are benefited using fuzzy sets [2]. The user based processing capability is an important aspect of fuzzy systems taken into account in any design consideration of human centric computing systems. The human centricity plays a vital role in the areas of intelligent data analysis and system modeling [3]. The elements of fuzzy sets belong to varying degrees of membership or belongingness. Fuzzy sets offer an important and unique feature of information granules. A membership function quantifies different degrees of membership. The higher the degree of membership A (x), the stronger is the level of belongingness of this element to A. Fuzzy sets provide an ultimate mechanism of communication between humans and computing environment [4]. The fuzzy logic and fuzzy set theory deal with nonprobabilistic uncertainties issues. The fuzzy control system is based on the theory of fuzzy sets and fuzzy logic [5]. Previously a large number of fuzzy inference systems and defuzzification techniques were reported. These systems/techniques with less computational overhead are useful to obtain crisp output. The crisp output values are based on linguistic rules applied in inference engine and defuzzification techniques [6]-[7]. The efficient industrial control with new techniques of fuzzy algorithm based on active rule selection mechanism to achieve less sampling time ranging from milliseconds in pressure control, and higher sampling time in case of temperature control of larger installations of industrial furnaces has been proposed [8]. The development of an air condition control system based on fuzzy logic with two inputs and one output using temperature and humidity sensors for feedback control, and two control elements for cooling and humidity, and formulated fuzzy rules for temperature and humidity has been achieved. To control the room temperature, the controller reads the room temperature after every sampling period [9]. This proposed design work of Autonomous Room Cooling System is the application of fuzzy logic control system consisting of two input variables: Temperature and Humidity, and two output variables: Cooler fan speed and Water pump speed used in a processing plant of room cooler to maintain the required cooling environment.

## 1.2. Problem of statement

Since our environmental temperature increase due to so many factors we try to solve this increment of temperature by design an automatic air conditioner system to settle the increment of temperature to its standard value in order to bring human life in a comfortable way of life.

The Automatic Air conditioning controller is really important not only to control the temperature but also to monitor and adjust temperature, humidity, pressure etc., without much operator involved in the process. As a result of this we decrease the increment of temperature.

First requires the measuring of the temperature /house who we are attempting to control and also to maintain the target temperature.

There are various types of controller in the market such as on/off, proportional and PID in this project, fuzzy logic controller has been chosen as the controller.

Frequent of adjusting the fan or the temperature mode (thermostat) by users in the same room may affect the frequent on/off of the compressor of an air conditioner that contributes to the surge of energy consumption. To avoid this interference, an automatic control technique is needed. Instead of adjusting the thermostat frequently, the fans speed of the air-conditioner can be controlled automatically to provide a comfortable condition to the indoor temperature whilst the air compressors remain on/off.

## 1.3. Objective of project

### 1.3.1. General objective

- The main objective of this project is to design and control air conditioning system using fuzzy logic control.

### 1.3.2. Specific objective

- ✓ To study about air cooling system.
- ✓ To validate the result from simulation (by MATLAB) through experimental.
- ✓ To investigate the performance of fuzzy controller.

- ✓ To develop good knowledge on intelligent controller.

## 1.4. Scope of the project

As we have noticed at the beginning the main aim of the project is to design and control room air conditioning system. The limitation of the entire project is divided into two. First part of the project involves the design of fuzzy logic algorithm which is a simplified algorithm that used to design the fuzzifier, inference engine, rule base and defuzzifier for the autonomous room air cooling system according to the control strategy of the processing plant to achieve the quantity and quality of the desire needs to maintain the room environment. The second part involves the development of Simulink diagram using MATLAB to validate the system.

## 1.5. Significance of the project

- This kind of system is used to improve comfort, energy efficiency and security.
- This kind of systems is particularly useful for the disabled or elderly, improving the life quality and avoiding special aid expenses.
- A healthy home creation (without contaminant materials)
- Home life span increases
- To control the condition of the room automatically

## 1.6. Project overview

The entire project is composed of six chapters, each covering a section of the work as summarized below:

Chapter one: gives about a brief introduction to autonomous room air conditioning system, and answers why we have gone for this project, what the objectives, what advantages can we get from the project and its project scope.

Chapter two: covers an extensive literature review of previous works on fuzzy logic based air conditioning system.

Chapter three: Methodology and system block diagram: In this chapter brief description about architecture and interfacing of the devices being used are proposed as well as the mathematical model used for the system

Chapter four: covers the detailed design of the system and the overall integrated system or main projects results.

Chapter five: result and discussion

Chapter six: Conclusions and recommendations: This chapter concludes the entire work performed during the project and Points out some few recommendations.

# CHAPTER TWO

## Literature review

In previous works that we have referred we have discussed different cooling systems. Few of them are [1] The Automatic control for air conditioning system using Programmable Logic Control PLC (LOGO plc), this is a thesis paper which is proposed by MEKELE university graduating class students in 2005E.C. The Automatic control for air conditioning system is conceptually designed based on Programmable Logic Control (PLC) system which is called LOGO plc. The advantage of PLC system is that it allows online monitoring continually and updates or modification can be performed interactively. This Automatic mode is applied to the air conditioner to avoid the frequent interruption or adjustment of the fan speed or temperature set point by user ‘s normal practice which has contributed to the surge of energy consumption due to the frequent on/off of the compressor. [2] The automatic control of air conditioning system using microcontroller proposed in 2010 E.C by Wolkite university GC students.[3] Automatic Cooling System of Water-Cooled Compressor it uses PLC controller to maximize the process efficiency, avoiding the operator alienation and keeps it safe trough automated system with PLC logic. [4] Cooling water flow control realized with systems based on fuzzy mechanism, this research proposed a solution based on fuzzy mechanisms for controlling the flow of cooling water on the first zone of the secondary cooling of steel. For this purpose, a fuzzy system with three input variables and three output variables was designed, the proposed system was tested and validated by simulation made in MATLAB Simulink based on actual data collected from the continuous casting process. Here we are room cooler using fuzzy logic controller. It consists of two crisp input values from temperature and humidity sensors and three defuzzifiers are used to control the actuators; Fan1 (cooler fan) and water pump. This work will help in improves the autonomous room cooling system using fuzzy logic. MATLAB simulation is used to improve the performance of the designed model.

# CHAPTER THREE

# Methodology and system block diagram

## 3.1 introduction

This chapter describes that methodologies, overall block diagram and operating system of our project, component description, and the mathematical model of our system in order to model our system, we have to follow the following steps, first find data and literature form different sources the evaluate the data, then model the plant and design controller for the system.

## 3.2. Methodologies

There are few stages that will be involved in order to work out the aimed objectives in this project. The project was beginning by discussion the project with our advisor. After finding write objectives, problem and other related issues, the finding is done doing some literature review.

In general for this thesis project work we follow the following methodologies.

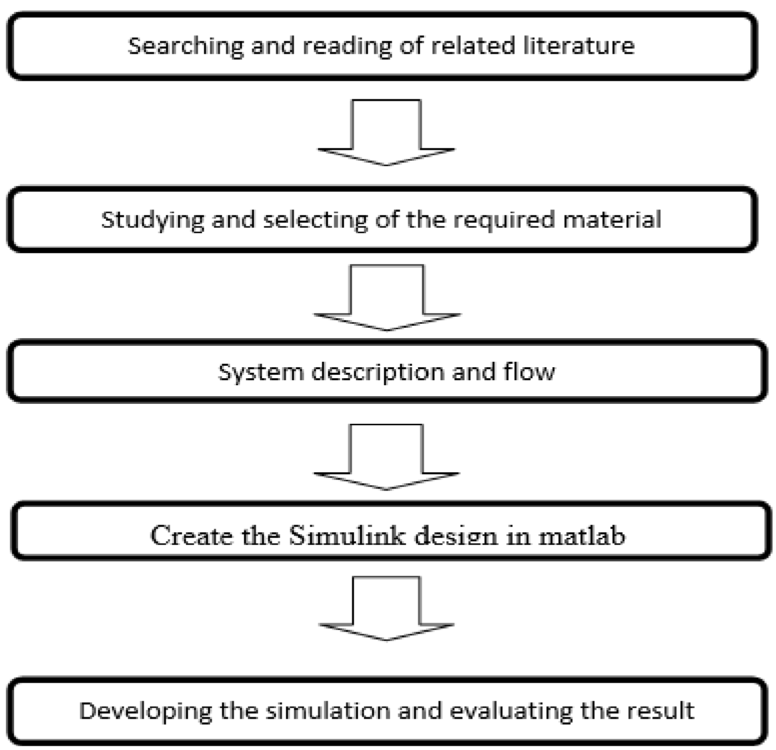



Figure 3.1 methodologies

## 3.3. System block diagram

The basic structure of the proposed model of autonomous water room cooler consists of room air cooler with fuzzy logic control system. The room cooler mounted in a room has cooler fan, a water pump to spread water on its boundary walls of grass roots or wooden shreds. Humidity and temperature sensors used to monitor the environment of room are mounted in the room. The sensors with amplification and voltage adjustment unit are connected with the two fuzzifiers of the fuzzy logic control system. Three outputs of defuzzifiers: cooler fan speed control, water pump speed control and room exhaust fan speed control are connected through actuators.

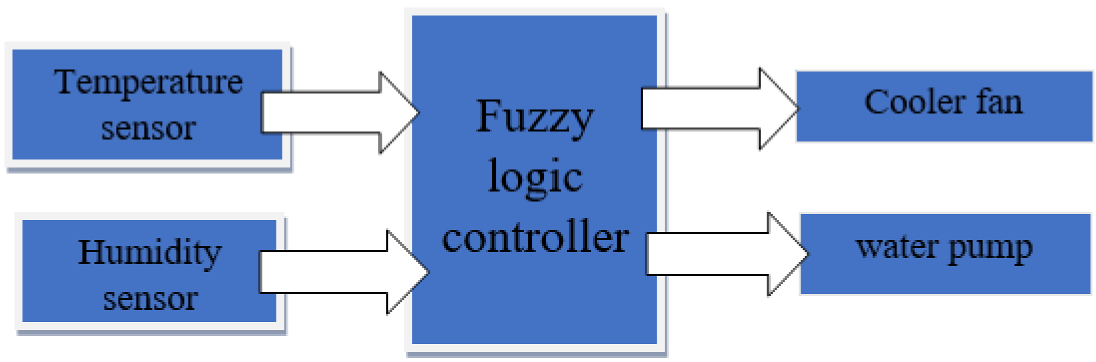



Figure 3.2 system block diagram

The block diagram consists of temperature sensor, humidity sensor, fuzzy logic controller, cooler fan and water pump. Most components functions can be categorized into three categories:

- Input
- Output
- Control

**Input Functions**

Input functions are mostly performed by components called sensors. Sensors can be anything from a simple on/off switch to a capacitive proximity switch to a complex audio/video recognition system.

**Humidity sensor**

A system that is sensed by humidity sensor, whose electrical characteristics changes according to the amount of humidity. Humidity refers to the amount of wetness or water vapor in the soil. When it is just about to rain and there's a lot of water vapor in the air, this is an example of a time when the humidity level is high.

The most common type of humidity sensor uses what is called capacitive measurement. This system relies on electrical capacitance, or the ability of two nearby electrical conductors to create an electrical field between them. The sensor itself is composed of two metal plates with a nonconductive polymer film between them. The film collects moisture from the humidity, and the moisture causes minute changes in the voltage between the two plates. The changes in voltage are converted into digital readings showing the amount of moisture in the humidity.

Figure 3.3 HC 20 Humidity sensor

HC201 is the ideal solution for large volume cost-effective applications in humidity climate control. This sensor is;

- For the range of 20-90% RH, linear approximation is possible,
- Errors will be lower than ± 2% RH.

**Temperature sensor** (LM35)

The most common type of temperature is LM35 sensor. They are:-

- ✓ Are inexpensive.
- ✓ Easily obtainable.
- ✓ Easy to use and adaptable.
- ✓ Can have reasonable output voltages.
- ✓ Are temperature sensitive resistors.

The temperature sensor that is used is LM 35 sensor which is type of thermistor. The LM 35 series are; Integrated circuit temperature sensors whose output voltage is linearly proportional to the Celsius temperature. The LM 35 thus has an advantage over linear temperature sensors Calibrated in Kelvin, as the user is not required to subtract a large constant. This is also suitable for remote applications. This also has a very low impedance output. If the temperature of the processing zone is above/below the set point, the heater is switched OFF/ON accordingly. Thus the appropriate control action takes place with the help of LM 35 sensor.

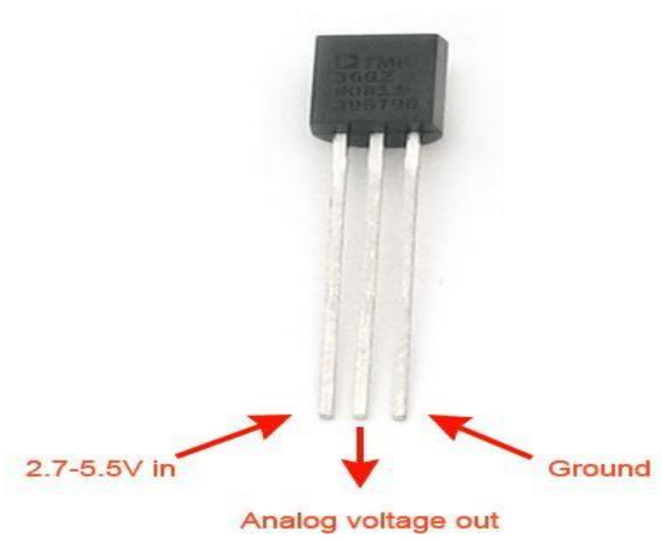



Figure 3.4 LM35 sensors

**Output functions**

Output functions are mostly performed by components called actuators. Actuators use a signal from the controller system to change the state of an object in the controlled environment (e.g. switching AC power to the circuit feeding the light bulbs, moving an object).

Some examples of actuators:

- Electro-mechanical switches ( relays )
- Electronic controllers: (Power switches , Motor controllers)
- Mechanical actuators: (Motor , Pneumatic actuator , Linear actuator)

**An actuator** is something that converts energy into motion. It also can be used to apply a force. An actuator typically is a mechanical device that takes energy — usually energy that is created by air, electricity or liquid — and converts it into some kind of motion. That motion can be in virtually any form, such as blocking, clamping or ejecting. Actuators typically are used in manufacturing or industrial applications and might be used in devices such as motors, pumps, switches and valves.

To get an actuator to do something useful in an automatic air conditioning system, most of the time it has to be equipped with extra mechanical/electric systems. The output function is thus being performed by a combination of a basic actuator in conjunction with some additional systems. An electric motor is an electromechanical device that converts electrical energy to mechanical energy. This mechanical energy is used for, for example, rotating a pump impeller, fan or blower, driving a compressor, lifting materials etc. Electric motors are used athome (mixer, drill, and fan) and in industry. Electrical motors are used for powering of different pups and fans.

**Pumps**

Pumps are used to move or raise fluids. A fire pump is a part of a fire sprinkler system's water supply and can be powered by electric, diesel or steam. The pump intake is either connected to the public underground water supply piping, or a static water source (e.g., tank, reservoir, lake). The pump provides water flow at a higher pressure to the sprinkler system risers and hose standpipes. In our project Fire pumps are powered by an electric motor.

A heat pump is a device that transfers thermal energy from a source to a sink that is at a higher temperature than the source. Thus, heat pumps move thermal energy in a direction which is opposite to the direction of spontaneous heat flow. The heat pump uses some form of low entropy energy to accomplish the desired transfer of thermal energy from source to sink.

A heat pump can provide either heating or cooling of a given conditioned-space, depending upon whether the surrounding environment is cooler or warmer than the conditioned-space.

In heating and air conditioning (HVAC) applications, the term heat pump usually refers to easily reversible vapor-compression refrigeration devices that are optimized for high efficiency in both directions of thermal energy transfer.

**Fan**

Fans can be thought of as low pressure air pumps that utilize power from a motor to output a volumetric flow of air at a given pressure. A propeller converts torque from the motor to increase static pressure across the fan rotor and to increase the kinetic energy of the air particles.

**Fuzzy controller**

According to the oxford dictionary, the word intelligent is derived from intellect, which is the faculty of knowing, reasoning and understanding. Intelligent behavior is therefore the ability to reason, plan and learn, which is in turn requires access to knowledge.

Artificial intelligent is a b**y-**product of the information technology revolution and is an attempt to replace human intelligent with machine intelligence. An artificial intelligent control system combines the techniques from the field of artificial intelligent with those of control engineering to design autonomous system that can sense, reason, and plan, learn and act in an intelligent manner. Such a system should be able to achieve sustained desired behavior under conditions of uncertainty, which include.

(1) Uncertainty in plant models

(2) Unpredictable environmental changes

(3) Incomplete, inconsistent or unreliable sensor information

(4) Actuator mal function.

The term ‘‘intelligent control’’ has a more general meaning and addresses more general control problems. That is, it may refer to systems which cannot be adequately described by a differential/difference equations framework but require other mathematical models, as for example, discrete event system models. More often, it treats control problems, where a qualitative model is available and the control strategy is formulated and executed on the basis of a set of linguistic rules. Overall, intelligent control techniques can be applied to ordinary systems and more important to systems whose complexity defies conventional control methods.

There are three basic approaches to intelligent control: knowledge-based expert systems, fuzzy logic, and neural networks. All three approaches are interesting areas of research and development. For this research fuzzy logic controller designed.

**Logic**

Logic is the science of reasoning. Symbolic or mathematical logic has turned out to be powerful computational paradigm. Not only symbolic logic help in the description of events in the real world but has also turn out to be an effective tool for inferring or deducing information from a given set of facts.

**Fuzzy versus Crisp**

Consider the query "Is water colorless?" The answer to this is a definite yes/true or no/false as warranted by the situation. If "yes/true" is accorded a value of 1 and "no/false" is accorded value of 0, this statement results in a 0/1 type situation. Such a logic which demands a binary (0/1) type of handling is termed crisp in the domain of fuzzy set theory. Thus statement such as "temperature is 32 $^{0}$C", "the running time of program is 4 seconds" are examples of crisp situations.

On the other hand consider the statement, "is Abebe honest?" The answers to this query need not to be definite "yes" or "no". Considering the degree to which one know Abebe, a variety of answers spanning a range such as "extremely honest", "extremely dishonest", "honest at times", "very honest" could be generated. If for instance, "extremely honest" were to be accorded a value of 1, at the high end of spectrum of value "extremely dishonest" a value of 0 at the low end of the spectrum then "honest at the times" and "very honest" could be assigned value of 0.4 and 0.85 respectively. So the situation is that it can accept values between 0 and 1. Such a situation is termed as fuzzy.

**Fuzzy logic**

An objective of fuzzy logic has been to make computers think like people. Fuzzy logic can deal with the vagueness intrinsic to human thinking and natural language and recognizes that its nature is different from randomness. Using fuzzy logic algorithms could enable machines to understand and respond to vague human concepts such as hot, cold, large, small, etc. It also could provide a relatively simple approach to reach definite conclusions from imprecise information.

Fuzzy logic has the advantage of modeling complex, nonlinear problems linguistically rather than mathematically and using natural language processing (computing with words).

**Fuzzy Set Theory**

**Classical sets**

A set is defined as a collection of objects that may share certain characteristics. For example, one may define a set of positive integers, a set of students with passing grades, and a set of honest politicians. Each individual object is referred to as an element or member of the set. In a classical set an object x is either a member of a given set A (expressed as $x \in A$) or not a member (expressed as $x \notin A$); partial membership is not allowed.

There are numerous ways to define a set:

- One may specify the properties of its elements. For example,

  A = {x|x is an odd number <10}

- One may list all the members of the set. For example,

  A = {1, 3, 5, 7, 9}

- One may use a formula to define the set. For example,

  A = {xi = xi + 1, i = 1... 5, where xi = 1}

**Membership function**

- a membership function, μ, can be used to define a set.

  $\mu A(x) = 1$ if $x \in A$, and

  $\mu A(x) = 0$ if $x \notin A$ for all values of x.

Let all the numbers under consideration, i.e. the universe of discourse, be defined as

{1, 2, 3, 4, 5, 6, 7, 8, 9, 10}.

Then, the set of odd numbers can be expressed as

{(1,1), (2,0), (3,1), (4,0), (5,1), (6,0), (7,1), (8,0), (9,1), (10,0)}.

Where each member of the universe of discourse is associated with a membership value in the form (#, μ). The numbers 1, 3, 5, 7, and 9 are associated with μ = 1 because they form the set of odd numbers extracted from the universe of discourse. This method of defining a set can be easily extended to define a fuzzy set by allowing partial membership.

**Universal Set**

The set that consists of all the elements of interest for a particular application (the universe of discourse) is referred to as the universal set. It is the mother of all sets; any set that is not a universal set is a subset. One may write $A \subset I$ to mean that a set A (any set) is actually a subset of the universal set I.

**Basic Concepts of Fuzzy Sets**

A fuzzy set is a set where degrees of membership between 1 and 0 are allowed; it allows partial membership. Fuzzy sets can thus better reflect the way intelligent people think. For example, an intelligent person will not classify people as either friends or enemies; there is a range between these two extremes. Not recognizing that there are degrees in every trait can lead to erroneous decisions. Vague human expressions such as tall, hot, cold, etc. can be expressed by fuzzy sets of the form

A = {(x, μA(x)) $x \in X$} Where X represents the universe of discourse and μA(x) assumes values in the range from 1 to 0.

Let the values of temperature in °C under consideration be

T = {0, 5, 10, 15, 20, 25, 30, 35, 40}.

Then, the term hot can be defined by a fuzzy set as follows

HOT = {(0, 0), (5, 0.1), (10, 0.3), (15, 0.5), (20, 0.6), (25, 0.7), (30, 0.8), (35, 0.9), (40, 1.0)}.

This fuzzy set reflects the point of view that 0 °C is not hot at all, 5, 10, and 15 °C are somewhat hot, and 40 °C is indeed hot. Another person could have defined the set differently.

**Fuzzy Sets Properties**

**Empty fuzzy set**

A fuzzy set is referred to as empty if and only if the value of the membership function is zero for all possible members under consideration. $A=\emptyset$ if $\mu A(x) = 0 \; \forall \; x \in X$.

**Universal fuzzy Set**

A fuzzy set is universal if and only if the value of the membership function is one for all members under consideration.

**Operations on Fuzzy Sets**

The three basic logic operations, they are the operations most commonly used in engineering applications

**Complement**

The absolute complement of a fuzzy set A is denoted by $\bar{A}$ and its membership function is defined by: $\mu \bar{A}(x) = 1 - \mu A(x)$ for all $x \in X$.

**Union**

The union of two fuzzy sets A and B is a fuzzy set whose membership function is defined by

$\mu A \cup B (x) = \max [\mu A(x), \mu B(x)]$

**Intersection**

The intersection of two fuzzy sets A and B is a fuzzy set whose membership function is defined by $\mu A \cap B (x) = \min [\mu A(x), \mu B(x)]$

**Fuzzification**

Fuzzification is the operation of transforming a crisp set to a fuzzy set, or a fuzzy set to a fuzzier set. The operation translates crisp input or measured values into linguistic concepts. This, in a way, is similar to what people may do in numerous situations to reach a decision. For example, if one is told that the temperature is going to be 10 °C, one translates this crisp input value into a linguistic concept such as mild, cold, or warm according to one's inclination, then reaches a decision about the need to wear a jacket or not. If one fails to fuzzify (for example, due to lack of familiarity with the Celsius temperature scale) then the decision process cannot continue or a possibly erroneous decision would be reached. So, you have been fuzzifying all along (without knowing it) whenever you made correct decisions.

**Classical Reasoning**

In classical binary logic, reasoning is based on two complementary mechanisms: deduction (modus ponens) and induction (modus tollens). Deduction is used to obtain conclusions by means of forward inference and induction is used to deduce causes by means of backward inference. The two mechanisms are contrasted in Table 2.1. In that table *A* and *B* are crisp sets and the symbol → means implies

Table 3-1 Deduction and Induction

| | Deduction | Induction |
|---|---|---|
| Rule | IF x is A → y is B | IF x is A → y is B |
| Premise | X is A | Y is not B |
| Conclusion | Y is B | X is not A |

In other words, given the rule: IF x is A, THEN y is B and the observation that "x is A", one concludes by deduction that: "y is B". In mathematical shorthand: $(p \wedge (p \rightarrow q)) \rightarrow q$

Given the same rule but the observation that "y is not B", one concludes by induction that: "x is not A". In mathematical shorthand :$( q \wedge (p \rightarrow q)) \rightarrow p$

**Fuzzy Reasoning**

Fuzzy reasoning is based on inference rules of the form IF <premise>, THEN <consequence> as is the case in classical logic, but fuzzy sets, rather than crisp sets, are used. Fuzzy sets define linguistic variables and hence fuzzy inference rules can model a system linguistically. Fuzzy algorithms are mathematically equivalent to fuzzy relations and fuzzy inference is equivalent to fuzzy composition.

There are numerous ways that have been put forward to express an inference rule.

A direct, simple inference rule takes the form:

IF *x* is *A*, THEN *y* is *B, Where A* and *B* are fuzzy sets.

If the number of rules is large it becomes more convenient to employ a fuzzy relations approach. The IF/THEN rules are converted to fuzzy relations, and then fuzzy composition is used to infer conclusions. The conversion from IF/THEN rules to fuzzy relations could be defined in more than one way. A simple method is given by: $R = A \rightarrow B = A \times B$

An inference rule could have more than one proposition. For example, a rule of inference with two propositions would take the form: if x is A, and y is B, then z is C where A, B, and C are fuzzy subsets of X, Y, and Z, respectively.

The rule may be written as: $A \text{ and } B \rightarrow C$

A fuzzy algorithm has several rules, such as

Rule 1: IF $x$ is $A_1$, THEN $y$ is $B_1$

Rule 2: IF $x$ is $A_2$, THEN $y$ is $B_2$, then up to rule n

Rule n: IF $x$ is $An$, THEN $y$ is $Bn$

This n-rule system can be converted to n relations: $R_1$, $R_2$... $Rn$. These relations can be combined into one relation, $R$, using fuzzy intersection operations or fuzzy union operations depending on how the rules are perceived to be connected.

$R = R_1 \cup R_2 \ldots \cup R_n$, or

$R1 = R_1 \cap R_2 \ldots \cap R_n$

**Fuzzy Logic Controller and Design**

Basic block diagram of fuzzy logic controller is as shown under.

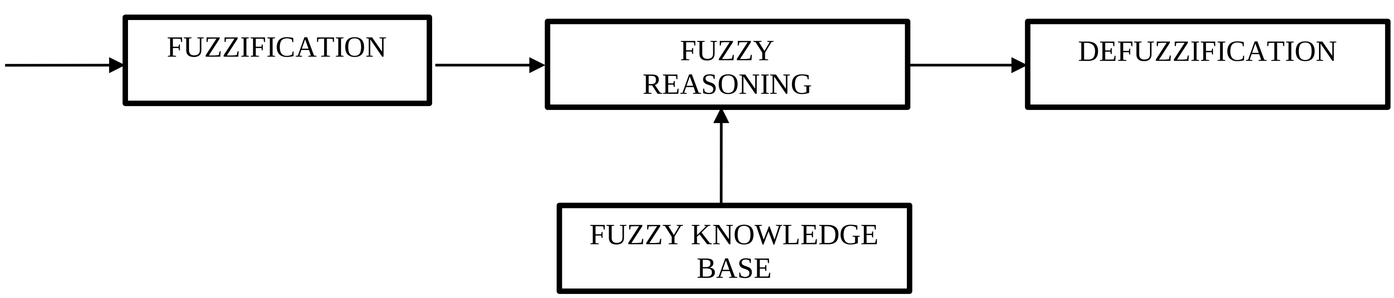



Figure 3.5 Basic structure of fuzzy logic controller

The main building units of an FLC are a fuzzification unit, a fuzzy logic reasoning unit, a knowledge base, and a defuzzification unit. Defuzzification is the process of converting inferred fuzzy control actions into a crisp control action.

In the design of a fuzzy logic control system it is assumed that:

- a solution exists.
- input and output variables can be observed and measured.
- an adequate solution (not necessarily an optimum one) is acceptable.
- a linguistic model can be created based on the knowledge of a human expert.

The basic configuration of Fuzzy Logic Controller (FLC) consists of four main parts

(i) Fuzzification

(ii) Knowledge base

(iii) Decision-Making logic and

(iv) Defuzzification

The functions of the above modules are described below.

**(i) The Fuzzification:**

(a) Measure the values of input variables

(b) Performs a scale mapping that transforms the range of values of input variables into corresponding universe of discourse.

(c) Performs the function of fuzzification that converts input into suitable linguistic values, which may be, **viewed** labels of fuzzy sets.

**(ii) The Knowledge Base:**

It consists of data base and linguistic control rule base.

(a) The database provides necessary definitions, which are used to define linguistic control rules and fuzzy data, manipulation in an, FLC.

(b) The rule base characterizes the control goals and control policy of the domain experts by means of set of linguistic control rules.

**(iii) The Decision Making Logic:**

It is the most important part of FLC; it has the capability of simulating human decision making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic.

**(iv) The Defuzzification:**

(a) A scale mapping which converts the range of values of input variables into corresponding universe of discourse.

(b) Defuzzification, which yields a non-fuzzy, control action from an inferred fuzzy control action.

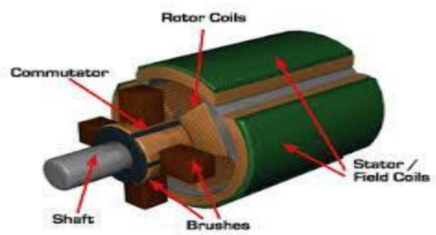
There are seven methods used for defuzzifying the fuzzy output functions. They are

1. Max-membership principle,
2. Centroid method,
3. Weighted average method,
4. Mean–max membership,
5. Centre of sums,
6. Bisector of area, and
7. First of maxima or last of maxima

## 3.4 Mathematical modeling of the system

### 3.4.1 Mathematical model for the plant

DC motor: - is an electrical machine which converts electrical energy into mechanical energy.




There are five major types of dc motors in general use:

1. The separately excited dc motor
2. The shunt dc motor
3. The permanent-magnet dc motor
4. The series dc motor
5. The compounded dc motor

We chose separately excited dc motor since it has a constant speed though its starting torque is not high. Therefore, it is suitable for constant speed drive, where high starting torque is not required such as pumps, blowers, fan, belt or chain conveyor etc.

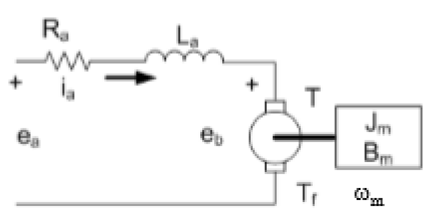



Figure 3.6 circuit diagram of DC motor

Various parameters of separately exited DC motor are as follows:

$Ea$=armature voltage(V)

$Ra$=armature resistance(Ω)

$La$= armature inductance(H)

$Ia$=armature current

$Eb$=back emf(V)

$Tm$=motor torque(Nm)

$\omega$=angular speed(rad/sec)

$\Theta$ =angular position of rotor shaft(rad)

$Jm$ =motor moment of inertia(kgm2)

$Kf$ =windage torque coefficient($^{Nms}/_{rad}$)

$Ke$=torque constant of motor($^{Nm}/_{A}$)

$Kb$ =back emf constant

$Ea$ (t)= $Ra\ Ia$ (t) + $La$ dis(t)/dt+ $Eb$(t) (3.1)

$Eb$(t)= $Kb\ \omega$(t) (3.2)

$Tm$=$KtIa$(t) (3.3)

$Tm$= $Jmd\omega(t)/dt$+ $Kf\omega(t)$ (3.4)

From equation (3.1) and (3.2) we get:

$$Ea(t)= Raia(t) + \frac{Ladis(t)}{dt} + Kb\omega(t) \tag{3.5}$$

$$Keia(t) = \frac{Jmd\omega(t)}{dt} + Kf\omega(t) \tag{3.6}$$

Laplace transform of equation (3.5) and (3.6) are given as:

$$Ea(s) = RaIa(s) + LaIa(s)s + KbW(s) \tag{3.7}$$

$$KeIa(s) = JmW(s)s + KfW(S) \tag{3.8}$$

From equation (3.7)

$$KbW(s) = Eb(s) \tag{3.9}$$

$$Ea(s) = RaIa(s) + LaIa(s)s + Eb(s)$$

$$Ea(s) = Ia(s)[Ra + Las] + Eb(s)$$

$Ea(s) - Eb(s) = Ia(s)[Ra + Las]$

$Ia(s) = Ea(s - Eb(s)[1/Ra + Las]$ (3.10)

From equation (3.8)

$Tm(s) = ktIa(s)$ (3.11)

$Tm(s) = JmW(s)s + KfW(S)$

$Tm(s) = W(s)[Jms + Kf]$

$Tm(s)/[Jms + KF] = W(s)$ (3.12)

$$G(S) = Ke[1/Ra + Las][1/Jms + Kf]$$

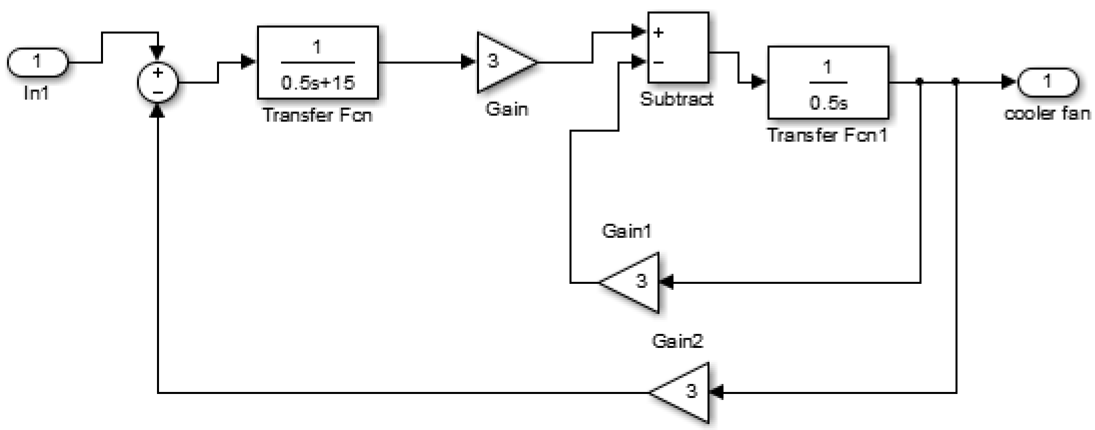



Figure 3.7 Simulink model of DC motor

### 3.4.2. Mathematical relationship between temperature and velocity.

The mathematical relationship between temperature and velocity is given by the following expression. For certain gases, the average velocity of gas particle is a function of the temperature as shown below:

$$V = \sqrt{3RT/m} \qquad (3.13)$$

Taking both sides square

$$V^2 = 3RT/m$$

$$T = V^2m/3R$$

# CHAPTER FOUR

# Controller Design

## 4.1. Design of the fuzzy logic controller

Present thesis describes Fuzzy logic control based autonomous room air conditioning system. We take the room temperature and humidity as an input for fuzzy interference system. The output control signal of Fuzzy is control signal for speed control of cooler fan and water pump. This control signal drives the Dc motor.

The following steps are applied to design the fuzzy logic controller.

- First all the information about the system is collected.
- The control elements are identified to apply fuzzy logic.
- Input and output variables for the fuzzy logic controller are identified.
- Universe of discourse is defined for input and output.
- The fuzzy sets and the corresponding membership function shape are determined.
- The rule table is defined.

The proposed fuzzy logic based controller for our system is based on Mamdani fuzzy inference system (FIS), most commonly used fuzzy methodology [10]. Fuzzy inference system consists of an input stage, a processing stage, and an output stage [11]. The input stage maps the inputs to the appropriate membership functions and degree of membership. The processing stage invokes appropriate rules and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined results back into a crisp control output value.

The first step in the developing the automatic air conditioner using fuzzy logic controller is to select the variables that well be important in choosing an effective control action. The variables are known as the conditions or the antecedent variables. Two condition variables are readily identified as being important in the system. These are:

- Humidity
- Temperature

The basic structure of the proposed model of autonomous water room cooler consists of room air cooler with fuzzy logic control system. The room cooler mounted in a room has cooler fan, a water pump to spread water on its boundary walls of grass roots or wooden shreds. The sensors with amplification and voltage adjustment unit are connected with the two fuzzifiers of the fuzzy logic control system. Two outputs of defuzzifiers: cooler fan speed control and water pump speed control are connected through actuators.

This simplified design algorithm is used to design the fuzzifier, inference engine, rule base and defuzzifier for the autonomous room air cooling system according to the control strategy of the processing plant to achieve the quantity and quality of the desire needs to maintain the room environment. This design work uses five triangular membership functions equally determined over a scale range of 0°C to 40°C for the temperature input and 0% to 100% relative humidity inputs.

### 4.1.1. The FIS Editor

We have defined two Inputs for the Fuzzy Controller. One is room temperature and the other one is humidity. Both these Inputs are applied to the Rule Editor [6]. According to the Rules written in the Rule Editor the controller takes the action and governs the opening of the cooler fan and water pump which is the Output of the controller. It may be shown as:

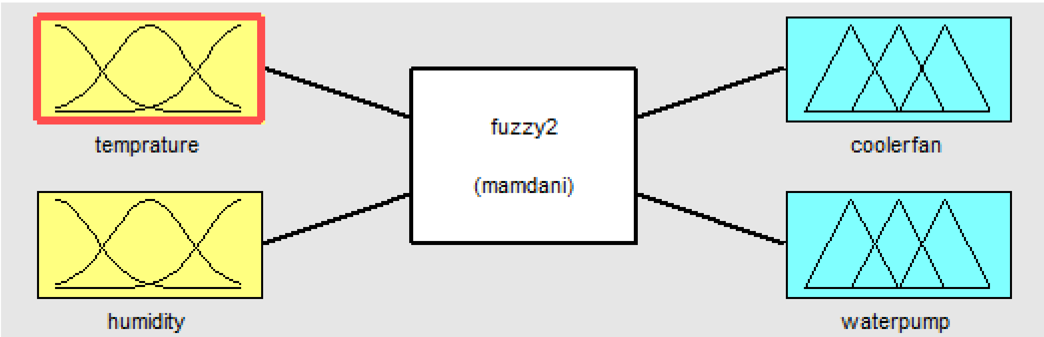



Figure 4.1 mamdani type controller

### 4.1.2 The membership function

**Input Variables**

The type of membership function used in this thesis is triangular because of simplicity to understand. Then the following seven triangular membership functions have been identified and applied.

Table 4.1 membership function and ranges of input variable temperature

| Membership function | Ranges |
|---|---|
| Very cold | [0 5 10] |
| Cold | [5 10 15] |
| Cool | [10 15 20] |
| Normal | [15 20 25] |
| Warm | [20 25 30] |
| Hot | [25 30 35] |
| Very hot | [30 35 40] |

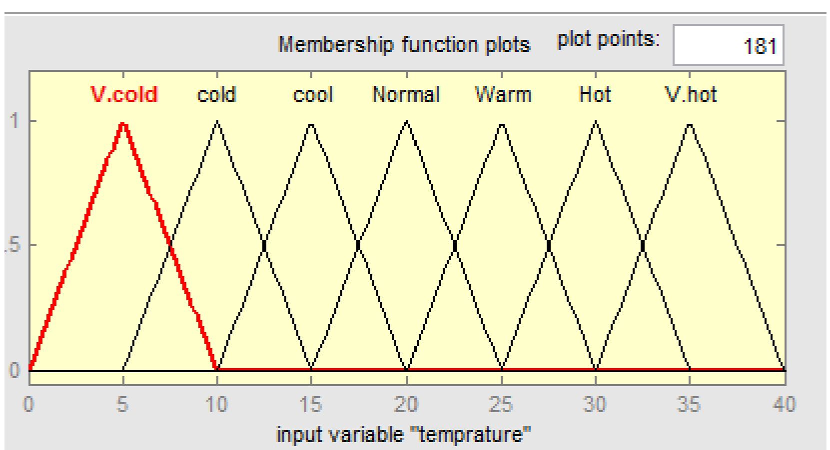



Figure 4.2 membership function for temperature

Table 4.2 membership function and ranges of input variable humidity

| Membership function | Ranges |
|---|---|
| Very dry | [0 12.5 25] |
| Dry | [12.5 25 37.5] |
| Not too dry | [25 37.5 50] |
| Moist | [37.5 50 62.5] |
| Not too wet | [50 62.5 75] |
| Wet | [62.5 75 87.5] |
| Very wet | [75 87.5 100] |

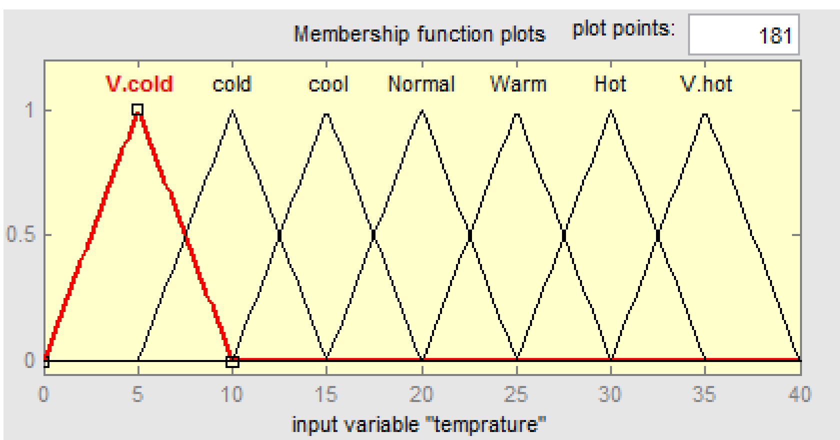



Figure 4.3 membership function for humidity

**Output Variable**

The output variable identified here is the cooler fan and water pump.

Table 4.3 output variables membership function

| Membership function | Ranges | Speed of cooler fan | Speed of water pump |
|---|---|---|---|
| MF1 | [0 12.5 25] | Stop | Stop |
| MF2 | [12.5 25 37.5] | Very low | Very low |
| MF3 | [25 37.5 50] | Low | Low |
| MF4 | [37.5 50 62.5] | Medium | Medium |
| MF5 | [50 62.5 75] | Not too high | Not too high |
| MF6 | [62.5 75 87.5] | High | High |
| | [75 87.5 100] | Very high | Very high |

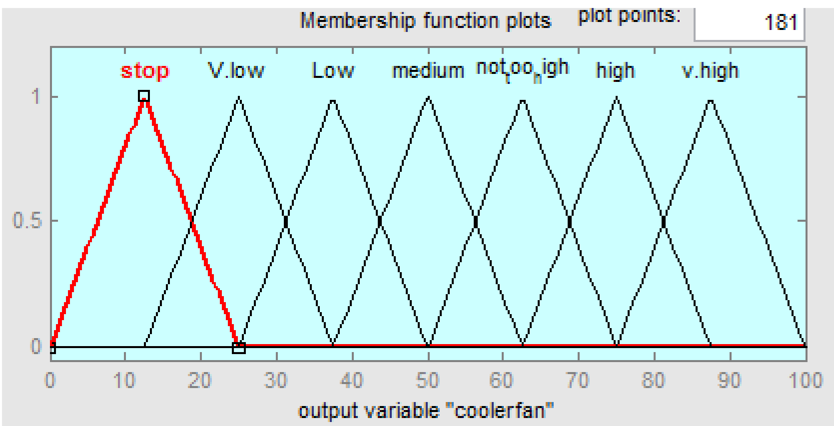



Figure 4.4 membership function for cooler fan

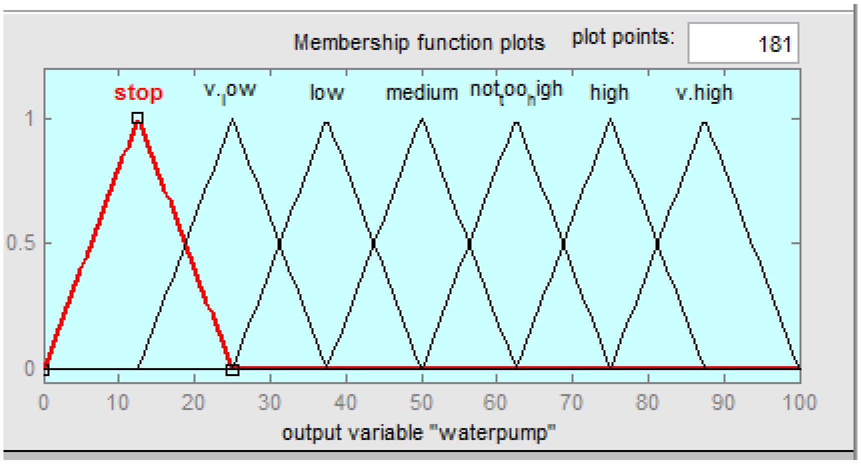



Figure 4.5 membership function for water pump

### 4.1.3 Rule viewer

Fuzzy control rules can be considered as the knowledge of an expert in any related field of application. The fuzzy rule is represented by a sequence of if-then, leading to algorithms describing what action or output should be taken in terms of the currently observed information, which includes both inputs and feedback if a closed-loop control system is applied.

**Fuzzy Inference Rule for the Proposed Controller**

In this study, input and output membership functions are same and seven segment triangular membership functions are used as stated earlier. Since each input has seven membership functions, the number of fuzzy based rules is forty-nine and they are presented in Table (4-2) it consists of 49 rules Working of fuzzy logic controller is based on 49 rules. The fuzzy rules are generally IF and THEN statements combined by AND aggregation. These rules can be placed in form of table below here error and cumulative error are two inputs of fuzzy logic controller**.**

Table 4.4 total number of rules

| Inputs | | Outputs | |
|---|---|---|---|
| **Temperature(◦c)** | **Humidity %** | **Speed of cooler fan** | **Speed of Water pump** |
| **v.cold** | **v.dry** | **stop** | **High** |
| **v.cold** | **Dry** | **Stop** | **High** |
| **v.cold** | **Not to dry** | **Stop** | **Not to high** |
| **v.cold** | **Moist** | **Stop** | **Stop** |
| **v.cold** | **Not too wet** | **Stop** | **Stop** |
| **v.cold** | **Wet** | **Stop** | **Stop** |
| **v.cold** | **v.wet** | **Stop** | **Stop** |
| **Cold** | **v.dry** | **Stop** | **High** |
| **Cold** | **Dry** | **Stop** | **High** |
| **Cold** | **Not too dry** | **Stop** | **Not too high** |
| **Cold** | **Moist** | **Stop** | **Stop** |
| **Cold** | **Not too wet** | **Stop** | **Stop** |
| **Cold** | **Wet** | **Stop** | **Stop** |
| **Cold** | **v.wet** | **Stop** | **Stop** |
| **Cool** | **v.dry** | **stop** | **High** |
| **Cool** | **Dry** | **Stop** | **High** |
| **Cool** | **Not too dry** | **Stop** | **Not too high** |
| **Cool** | **Moist** | **Stop** | **Stop** |
| **Cool** | **Not too wet** | **Stop** | **Stop** |
| **Cool** | **Wet** | **Stop** | **Stop** |
| **Cool** | **v.wet** | **Stop** | **Stop** |
| **Normal** | **v.dry** | **Stop** | **High** |
| **Normal** | **Dry** | **Stop** | **High** |

| | | | |
|---|---|---|---|
| **Normal** | **Not too dry** | **Stop** | **Not too high** |
| **Normal** | **Moist** | **Stop** | **Stop** |
| **Normal** | **Not too wet** | **Stop** | **Stop** |
| **Normal** | **Wet** | **Stop** | **Stop** |
| **Normal** | **v.wet** | **Stop** | **Stop** |
| **Wet** | **v.dry** | **Medium** | **High** |
| **Wet** | **Dry** | **Medium** | **High** |
| **Wet** | **Not too dry** | **Medium** | **Not too high** |
| **Wet** | **Moist** | **Medium** | **Stop** |
| **Wet** | **Not too wet** | **Medium** | **Stop** |
| **Wet** | **Wet** | **Medium** | **Stop** |
| **Wet** | **v.wet** | **Medium** | **Stop** |
| **Hot** | **v.dry** | **High** | **High** |
| **Hot** | **Dry** | **High** | **High** |
| **Hot** | **Not to dry** | **High** | **Not too high** |
| **Hot** | **Moist** | **High** | **Stop** |
| **Hot** | **Not too wet** | **High** | **Stop** |
| **Hot** | **Wet** | **High** | **Stop** |
| **Hot** | **v.wet** | **High** | **Stop** |
| **v.hot** | **v.dry** | **v.high** | **High** |
| **v.hot** | **Dry** | **V.high** | **High** |
| **v.hot** | **Not too dry** | **v.high** | **Not too high** |
| **v.hot** | **Moist** | **v.high** | **Stop** |
| **v.hot** | **Not too wet** | **V.high** | **Stop** |
| **v.hot** | **Wet** | **v.high** | **Stop** |
| **v.hot** | **v.wet** | **v.high** | **Stop** |

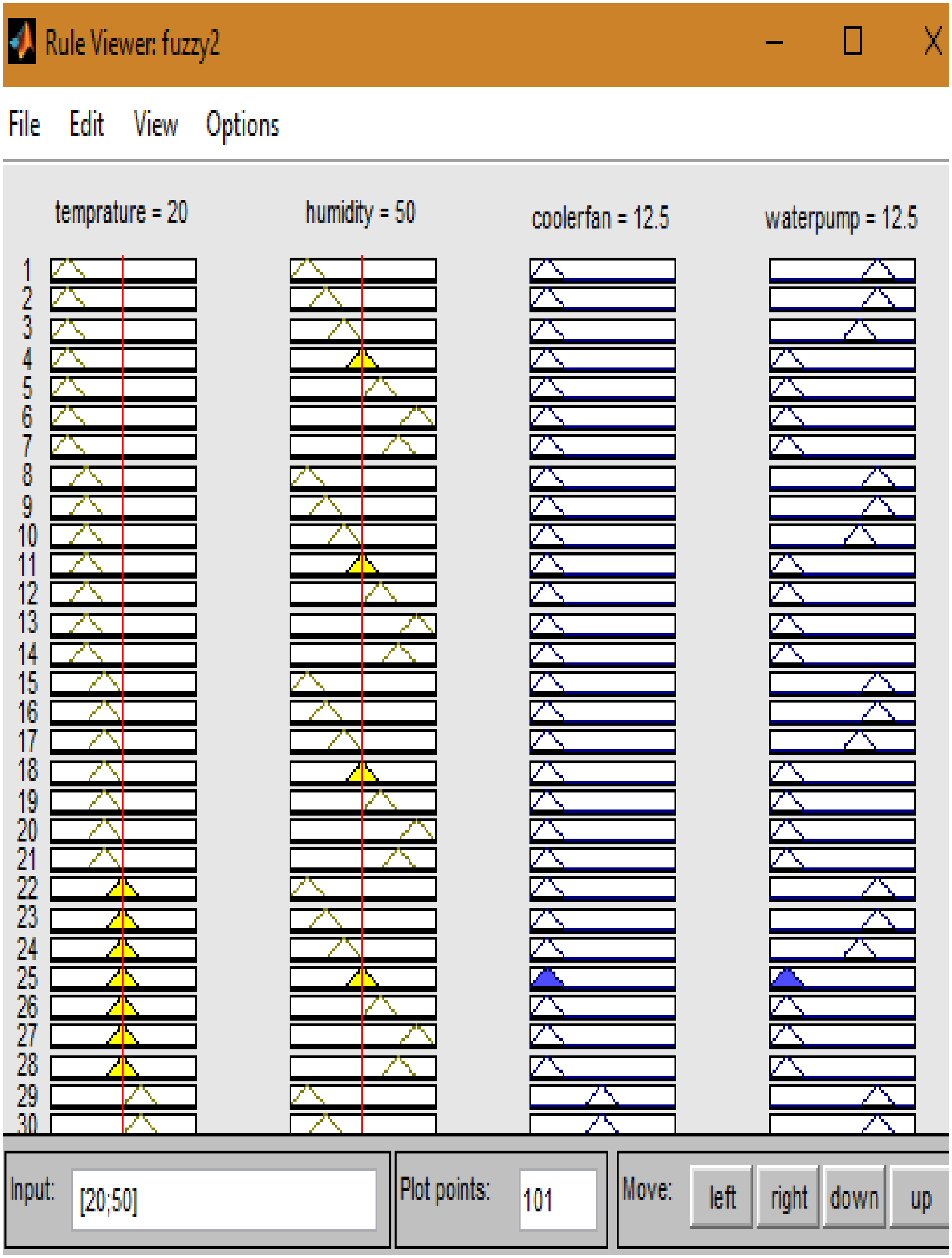
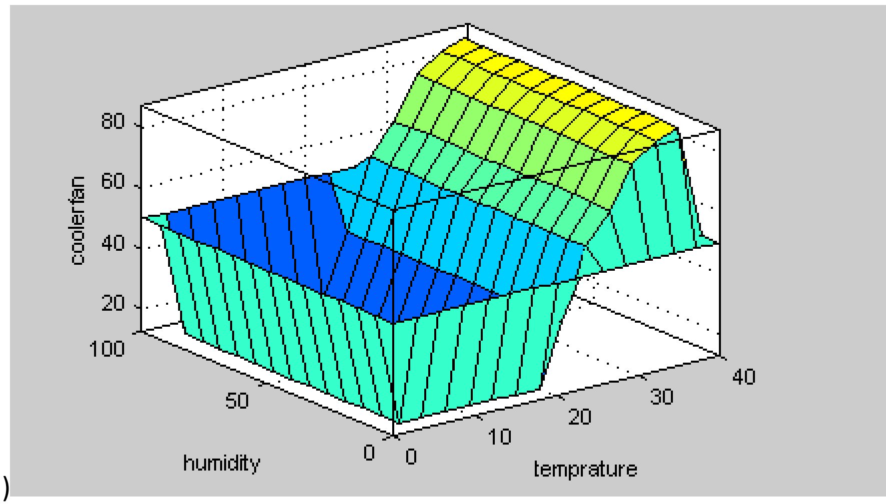



Figure 4.6 rule viewer

### 4.1.4 Defuzzification

A Defuzzification is the process of producing the crisp control action from the output of the fuzzy control action**.** The last step in the fuzzy inference process is defuzzification; the final output of a fuzzy system has to be a crisp number. The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number.

### 4.1.5 Surface viewer

(a)


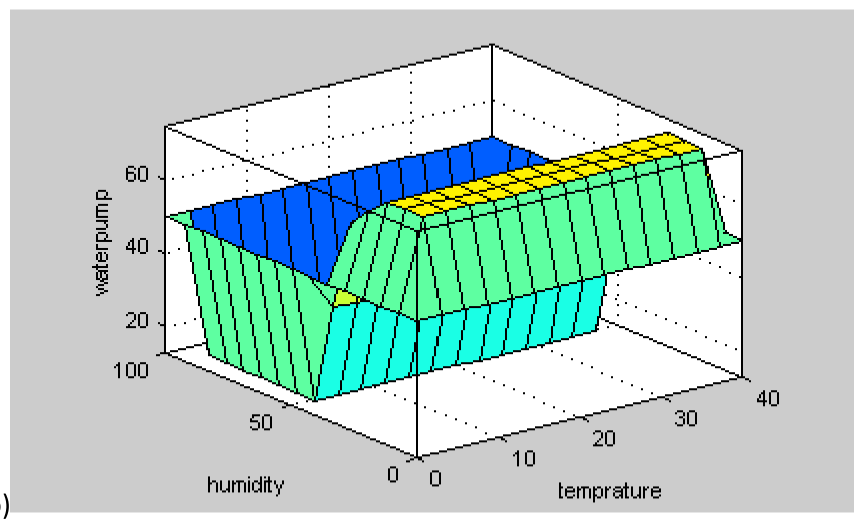

(b)



Figure 4.7 (a) shows surface viewer of cooler fan and (b) shows surface viewer water pump

## 4.2. **Overall MATLAB Simulink design of the system**

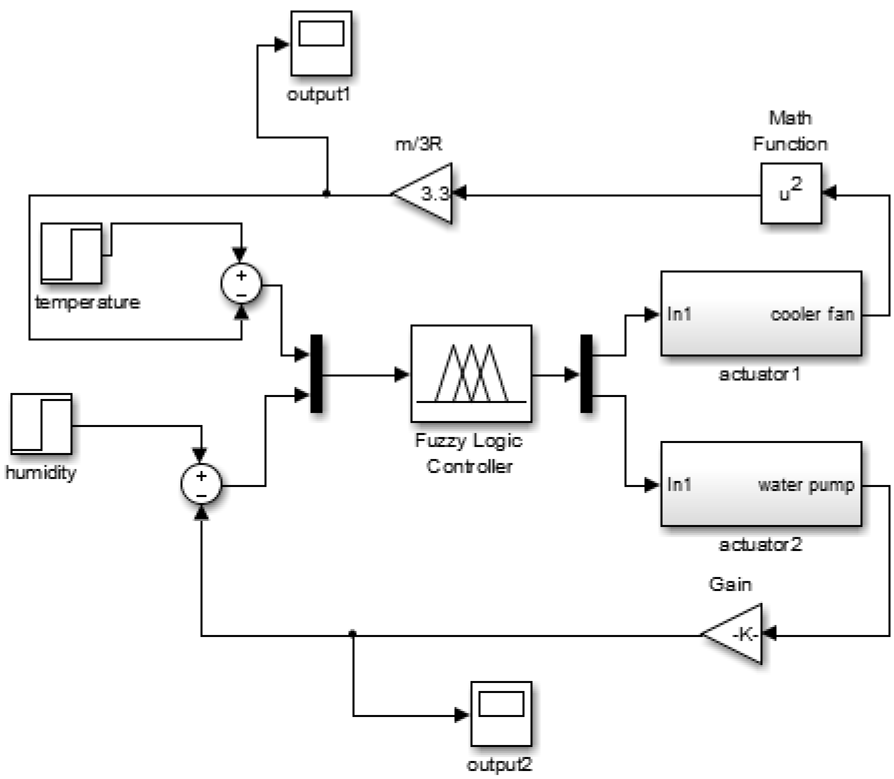



Figure 4.8 simulink diagram of the system

As shown in the above MATLAB Simulink we use a constant source to drive it and as a set point system inputs. Then the output reading of the system feed backed to the system and compared to that of the set point. Then the fuzzy logic controller makes decision based on the rule bases on it and then it sends output command to the actuator.

# CHAPTER FIVE

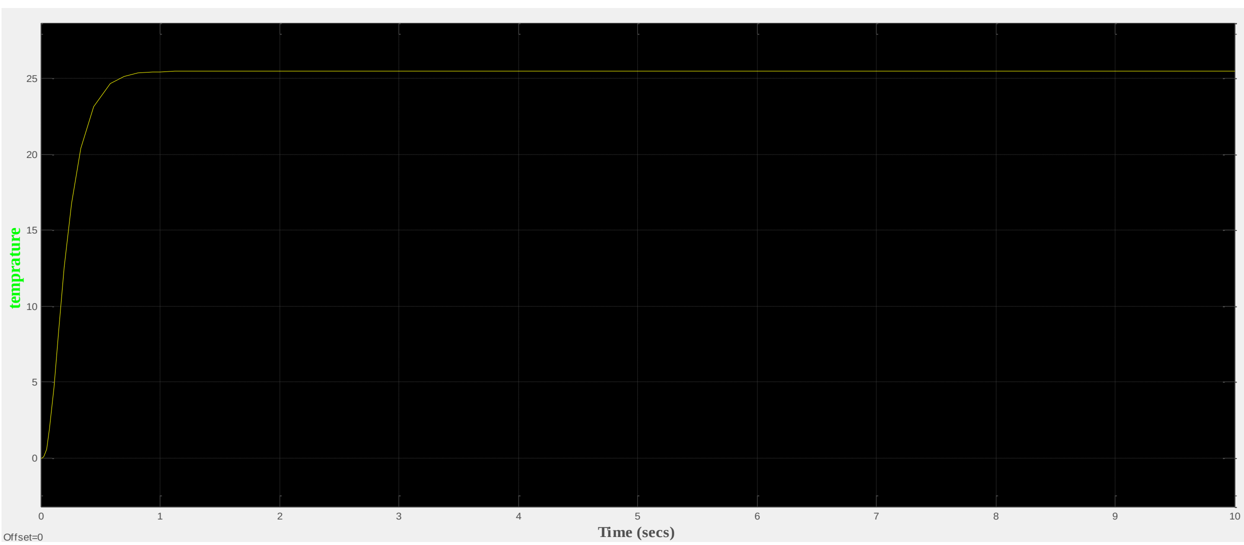
## Simulation Results and Discussion

### 5.1. Introduction

This chapter presents simulation results obtained from tests performed for the autonomous room air conditioning system using Matlab Simulink with different type of controller. The Simulink model shown in bellow is used to carry out simulation studies and analyze the performance of controller.

### 5.2. Simulation result

To demonstrate the effectiveness of the proposed method, simulation is carried out using MATLAB Simulink



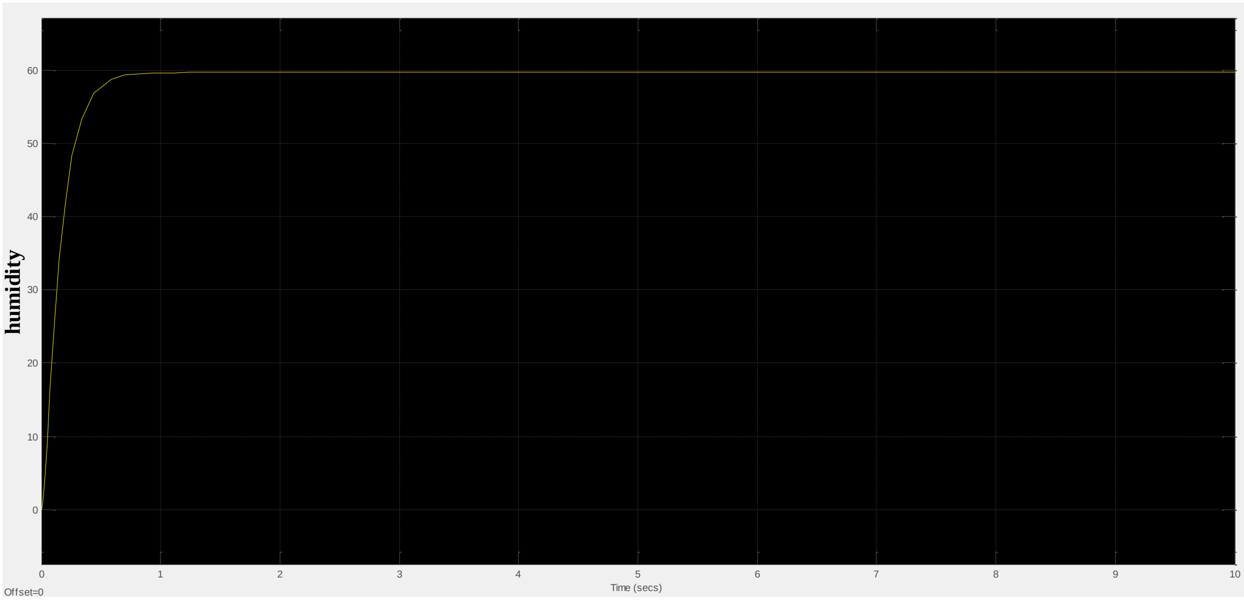



Figure 4.9 response of the system

## 5.3. Discussion

The simulation result show that the overall system output performance can be improved using the proposed fuzzy logic governor, the fuzzy logic controller resulted less percentage overshoot (0.496%), settling time (0.5) and rise time (345.37).

As expected, FLC provide good performance in terms of oscillations and overshoot in the absence of a prediction mechanism. Comparing to other control systems fuzzy systems indicated that the fuzzy logic controller significantly reduced overshoot and steady state error. So we can conclude that fuzzy logic controller is an effective controller, especially for the non-linear dynamic systems its appropriate selection.

# CHAPTER SIX

## Conclusion and recommendation

### 6.1 Conclusion

This project paper deals with the design and control of fuzzy logic based autonomous room air conditioning. It is an automated system with automatic feature that is used to condition the air inside the room despite the variation in the weather condition in a good accurate and reliable manner. So the system has got faster execution time and is more efficient and ease in operation.

### 6.2 Recommendation

Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favorable conditions. More generally, air conditioning can refer to any form of technological cooling, heating, ventilation, or disinfection that modifies the condition of air.

Since we were focusing on cooling function of air conditioning system, we couldn’t show the work of the heating function. so for future work we recommend that the forms of technological cooling, heating, ventilation, or disinfection that modifies the condition of air should be considered as part of the system.

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