DEVELOPMENT OF CONTROLLER BASED ON FUZZY AND PID FOR MECANUM WHEEL ROBOT

ADDZRULL HI-FI SYAM BIN AHMAD JAMIL

A project report submitted in partial fulfillment of the
requirement for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
University Tun Hussein Onn Malaysia

JUNE 2013

ABSTRAK

Roda *Mecanum* meningkatkan keupayaan sistem untuk bergerak serta-merta daripada apa-apa konfigurasi dalam arah yang dikehendaki. Kebelakangan ini, disebabkan pergerakan fleksibel, roda *Mecanum* telah digunakan dalam aplikasi yang luas ke atas reka bentuk konvensional. Robot berasaskan roda *Mecanum* umumnya di pasang tiga roda atau empat roda pada sesuatu robot direka berdasarkan kestabilan untuk bekerja di ruang kerja. Dari segi kawalan robot, penyelidik telah membangunkan algoritma kawalan yang berbeza seperti pengawal PI, pengawal PID dan pengawal logik kabur untuk lulus isyarat kawalan untuk mencapai kelajuan motor yang stabil. Walau bagaimanapun, sistem yang sedia ada masih mempunyai masalah dari segi masa tindak balas, keteguhan dan peratusan kesilapan. Oleh itu, dalam penyelidikan ini, pengawal kabur-PID bagi roda Mecanum telah dibangunkan dalam bentuk Antara Muka Pengguna grafik (GUI). Model simulasi roda *Mecanum* telah direka dengan menggunakan Matlab / Simulink platform. Di mana, empat model roda *Mecanum* telah direka dengan memasangkan ia pada DC motor dan setiap motor dikawal oleh individu-kabur pengawal PID. Model pengawal kabur-PID telah dibangunkan dengan cara ia menggunakan kesilapan dan perubahan pada keluaran motor DC sebagai input . Enjin inferens logik kabur menggunakan keahlian segi tiga input fungsi dan input *fuzzzyfied* dianalisis menggunakan Mamdani jenis algoritma. Di samping itu, keluaran *defuzzified* dan isyarat kawalan dihantar ke loji kuasa DC. Sistem yang dicadangkan mempunyai kadar prestasi yang lebih baik berbanding dengan algoritma kawalan yang sedia ada. Model logik mudah kabur berasaskan telah dibangunkan untuk mengawal arah roda Mecanum. Robot yang menggunakan roda Mecanum telah di reka melalui simulasi dan hasilnya secara ringkas diterangkan di dalam bab-bab seterusnya tesis ini.

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF SYMBOLS AND ABBREVIATION

FLC	- Fuzzy Logic Controller
FL	- Fuzzy Logic
MATLAB	- MATrix LABoratory
MF	- Membership Function
F	- Force applied to cart
M	- Mass of cart
m	- Mass of pendulum
B	- Viscous Friction Coefficient
Kt	- Torque Constant
Kb	- Back Emf Constant
Jw	- Angle
Jm	- Rotor Inertia
kg	- Kilogram
$Nm^{-1}s^{-1}$	- Newton meter per second
m	- Meter
i	- DC Motor Current
N/kg	- Newton per kilogram
$\dot{x}$	- Velocity
$\dot{\theta}$	- Angular velocity
F_x	- Force in x-axis

F_y - Force in y-axis

V - Voltage

rpm - Revolutions per minute

ZMP - Zero Moment Point

DC - Direct current

ADC - Analog-to-Digital Converter

I/O - Input/Output

FET - filed effect transistors

EMF - Electromagnetic Field

A/D - Analog/Digital

Abstract

Mecanum wheel robots are used to describe the ability of a system to move instantaneously in desired direction from any configuration. In recent years, mecanum wheel have been used in vast applications over a conventional design due to its flexible mobility, foreseen as performing difficult tasks in congested environment with static and dynamic obstacles and narrow aisles. The mecanum wheel based robots are generally three wheeled or four wheeled in assembly; designed based on the stability to work in the workspace. In terms of robot control, researchers have developed different control algorithm such as PI controller, PID controller and fuzzy logic controller to pass a control signal to achieve a steady speed of the motor. Although, the existing systems still have problems in terms of time response, robustness and percentage of error. The diverse knowledge sources are essential for good performances in solving real world control system problems. Thus in this research work, a Graphical user interface (GUI) simulation model of a simple mecanum wheel robot using fuzzy-PID controller has been developed. The simulation model of the mecanum wheel has been designed using Matlab/Simulink platform. In which, the mecanum wheel model has been designed with DC motor assembly where the problem of anisotropy are considered. Similarly, four mecanum wheel models has been designed with DC motor and each motor is controlled by individual fuzzy-PID controller. The fuzzy-PID controller model has been developed in such a way that it uses the error and change in error of the DC motor plant as it's input. The fuzzy inference engine uses the triangular membership function inputs and the fuzzzyfied input in analyzed using mamdani type algorithm. Further, the output is defuzzified and a control signal is passed to the DC power plant. The proposed system has a better performance rate when compared with the existing control algorithms with reduced overshoot and settling time. Also, a simple fuzzy logic based model has been developed to control the direction of the mecanum wheel robot. The mecanum wheel robot has been validated through simulation and the results are briefly explained in subsequent chapters of this thesis.

CHAPTER 1

INTRODUCTION

1.1 Preamble

The mecanum wheel or Ilon wheel is one design for a wheel with a series of rollers attached to its circumference. Mecanum wheel is based on the principle of a central wheel with a number of rollers placed at an angle around the periphery of the wheel which can move in any direction. In recent years, the mecanum wheels have been used in robotics, in industry, and in logistics due to their mobility in narrow spaces and crowded environments foreseen with static and dynamic obstacles. Recent applications in mecanum wheel based robots are becoming more demanding every day due to its additional maneuverability and efficiency. These features are gained at the expense of increased mechanical complexity and increased complexity in control. Demanding applications require precise dynamical model in order to allow for precise locomotion. Dynamical simulation models are also essential to study limitations of current mechanical configurations and to allow for further enhancements both at controllers level and at mechanical configuration level. The study of fuzzy-PID controller for mecanum wheel robot is important as it can be used in many applications like narrow spaces or crowded environments such as warehouses, hospitals, elderly care facilities.

Thus in this research work, it is proposed to develop simulink model of a simple mecanum wheel robot using fuzzy PID controller. In order to develop the mecanum wheel model, simple methods are to be proposed to analyze the problem of anisotropy of mecanum wheel robot, simulink model of the mecanum wheel system with DC motor assembly are modeled according to the four wheel structure. Further, it is proposed to develop and enhance the fuzzy PID controller to improve the performance of the mecanum wheel robot with longitudinal symmetry and simulative experiments will be carried out. The developed system will be tested for validating the results in real experimental runs. The outcome of this study will be a simple mecanum wheel robot simulator which provides the structure of the robot control system, including the choice of drive motor, speed control, drive circuit, and it provides an initial step to develop a mechanical configuration of a mecanum wheel robot that can be used in any static obstacle, dynamic obstacle or narrow aisles.

1.2 Problem Statement

The proposed mecanum wheel robot using fuzzy-PID controller has been influenced from the literature as the robot has more stable and effective performance in congested environment and the control algorithm using fuzzy-PID can be used to reduce the percentage of error and settling time. Some of the problem identifications considered in this research study are discussed below. They are,

1. The mecanum wheel mobile platform has the advantages over the conventional mobile one in terms of mobility particularly in congested environments, for example, factories, offices, hospitals and elderly care facilities. The special wheels and structure are needed for the mobile robot to have the omni-directional maneuverability. Three wheel structure using ‘Omni-wheel’ and four wheel structure using ‘Mecanum wheel’ are the representative examples of the omni-directional platforms. Especially, the omni-directional mobile platform with Mecanum wheels is used in case of requiring the stability of movement like as the fork lift, the wheelchair and so on.
2. The problem encounter when dealing with DC motor is the lag of efficiency and losses. In order to eliminate this problem, controller is introduce to the system. There’s few type of

controller but in this project, PID controller is chosen as the controller for the DC motor. This is because PID controller helps get the output, where we want it in a short time, with minimal overshoot and little error.

3. In speed control system, PID controller sometimes cannot accurate for this application because of nonlinear properties. Therefore, the fuzzy logic controller is proposed to overcome the problem of PID controller. Fuzzy logic controller has ability to control the nonlinear system cause of the algorithm is concentrate by emulating the expert and implemented in language.
4. As for machines, having a high overshoot is an undesired condition since the starting current is very high. Thus, control methodology such as fuzzy PID is used to limit the maximum overshoot as weel as to reduce the starting current of the machine.

1.3 Objectives

The main objective of this project is to develop a Fuzzy-PID controller model for a mecanum wheel robot. The mecanum wheel of the robot is driven by a DC motor. This project also focuses on the speed control of DC motor using fuzzy-PID controller. This project also embarks on the following sub objectives:

1. To identify and assemble the mecanum wheels each connected to a DC motor for mecanum wheel robot using MATLAB/Simulink environment.
2. To develop and enhance the simulation model of fuzzy PID controller to control the DC motor model assembly.
3. To analysis and validate the developed mecanum wheel robot in terms of time response, robustness and percentage of error.

1.4 Scope of this project

The scope of the project are:

1. Understanding the DC motor control background, analysing the problem and investigate the fuzzy PID controller theory which has been applied to the DC motor system.
2. Design and implementation of the control algorithm is carried by fuzzy PID logic controller.
3. Implement fuzzy PID logic controller on the DC motor control by using MATLAB/Simulink environment.

1.5 Thesis Organization

This thesis encapsulates the following five Chapters.

Chapter 1 presents an introduction to the mecanum wheel, fuzzy logic controller and PID cpntrollers. This Chapter also discusses the motivation towards the research, a clear understanding over the problem and the objectives of the research work.

Chapter 2 reviews the state of the art methods of fuzzy-PID controller models, DC motor plant with mecanum wheel methods. Existing methodologies available for the speed control of DC motor for various loads are also briefly studied. This chapter also reveals the experimental methods used in design and development of mecanum wheel robot and the speed control of DC motor using Fuzzy-PID controller.

Chapter 3 is devoted to the design and development of the fuzzy-PID controller for mecanum wheel robot and the experimental methods. The design methods involved in the fuzzy inference system design with fundamental properties are further investigated. The design methods involved in choosing the PID controller models also briefly discussed. This Chapter also discusses the simulation model of the fuzzy-PID controller using the error and change in error of the proposed

DC motor power plant. Rest of the Chapter is dedicated to the result and analysis procedures and discussions.

Chapter 4 summarizes the results of the proposed speed control of DC motor power plant. This Chapter compares the results of the fuzzy controller, PID controller and the combination of the fuzzy_PID controller for the mecanum wheel robot developed in this research work. This Chapter also highlights the objectives met in this research and moreover concludes the thesis and provides views for further research in this area.

1. MOTIVATION AND LITERATURE REVIEW

Mecanum wheel was designed and invented in Sweden, in 1975, by Bengt Ilon, an engineer with the Swedish company Mecanum AB [1]. Mecanum wheel is based on the principle of a central wheel with a number of rollers placed at an angle around the periphery of the wheel. The first mobile robot with Mecanum wheels (named “Uranus”), was designed and constructed in Carnegie Mellon University [2 & 3]. It had not a suspension system, which is absolutely necessary if the ground is not completely flat. In recent years there has been much research on the development of mobile robot based using four mecanum wheels [4]. Due to the feature of mecanum wheels, maximum velocity and acceleration that a robot can achieve are varying respectively in different direction, which is called anisotropy of omnidirectional robot [5-7].

Since Fuzzy Logic Controller (FLC) can mimic human behavior,many reasearchers applied FLC to control either wheel mobile robot .A thorough literature overview was done on the usage of FLC as applied to the various DC motor system. Ho-Hoon Lee and Sung-Kun cho proposed a new fuzzy logic anti swing control for industrial three dimensional overhead cranes.How ever, PID controller still approached for position control which is based on model controller [8]. Yodyium and Mo-Yuen work (2000) implement Dc Motor speed control by using fuzzy logic controller.The design of the motor is same to other motor and result are shown both loaded and unloaded condition.The controller is cheap as it required only small amount of components and easily improved to adaptive fuzzy controller.The controller provide good performance and compact size and low cost [9]. Abdullah I. Al-Odienat and Ayman A. Al-Lawama (2008) proposed Fuzzy logic controllers (FLC’s) have the following advantages over the conventional controllers: they are cheaper to develop, they cover a wider range of operating conditions, and they are more readily customizable in natural language terms. A self-organizing fuzzy controller can automatically refine an initial approximate set of fuzzy rules. Application of PI-type fuzzy controller increases the quality factor [10].

M. de Villiers and Prof. G. Bright (2010) develope a control model for Mecanum wheels. Available control models used in robotics are based on a simplification which defines the contact point of the wheel on the ground as the point in the centre of the wheel, which does not vary. This limits the smoothness of motion of a vehicle employing these wheels and impacts the efficiency of locomotion of vehicles using Mecanum wheels. The control model proposed accounts for the fact that the contact point in fact changes position down the axle of the wheel as the angle roller moves on the ground. Taking this into consideration makes control of the wheels more predictable and accurate [11 - 13].

Florentina Adascaliţei and Ioan Doroftei (2011) concerning practical applications for mobile robotic platforms based on special wheels (Mecanum wheel) is presented. Mobile robots equipped with four Mecanum wheels have the omnidirectional property, which means, they have the ability to move instantaneously in any direction, from any configuration. Therefore, compared to conventional platforms, these vehicles possess multiple advantages in terms of their mobility in narrow spaces or crowded environments. They have the ability to easily perform certain tasks in congested environments foreseen with static obstacles, dynamic obstacles or narrow areas. Hence the resulting needs to create this kind of robotic platforms to satisfy the requirements of various fields, such as: industrial, military, naval, medical and last but not least, the educational field [14 - 16].

H´elder P. Oliveira, Armando J. Sousa, A. Paulo Moreira and Paulo J. Costa (2011) created a model for a mobile omni-directional robot with 4 wheels. The derived model is non-linear but maintains some similarities with linear state space equations. Friction coefficients are most likely dependent on robot and wheels construction and also on the weight of the robot. The model is derived assuming no wheel slip as in most service robotic applications. The test ground is smooth and carpeted. Experience data was gathered by overhead camera capable of determining position and orientation of the robot with good accuracy [17 & 18].

From the literature survey, it is well defined there is a need in simulation system which can be provide a basis for developing a mecanum wheel robot in both controllers level and at mechanical configuration level. Thus in this research work, in order to identify the mecanical configuration of a mobile robot, it is proposed to study and develop a meacanum wheel assembly connected with a DC motor. Further, to control the DC motor, it is also proposed to develop and enhance the fuzzy PID controller with robust features.

The outcome of this research work will be a Graphical User Interface (GUI) software for mecanum wheel robot model which provides the structure of the robot control system, including the choice of drive motor, speed control, drive circuit and can be used in any static and dynamic obstacle.

CHAPTER 3

This chapter presents the fuzzy PID control system for the development of mecanum wheel robot. Simple Fuzzy PID controller has been developed using Matlab Simulink simulation platform. The development of fuzzy inference system with two in put such as error and change error also design. Further, the development of dc motor plant with mecanum wheel model has been briefly discussed. Also, the simulation of each model has been presented.

3.1 Dc Motor Speed Modeling

To perform the simulation of the mecanum wheel robot using the controlling system, an appropriate model needs to be represented by DC motor circuit diagram as shown in Figure 3.1

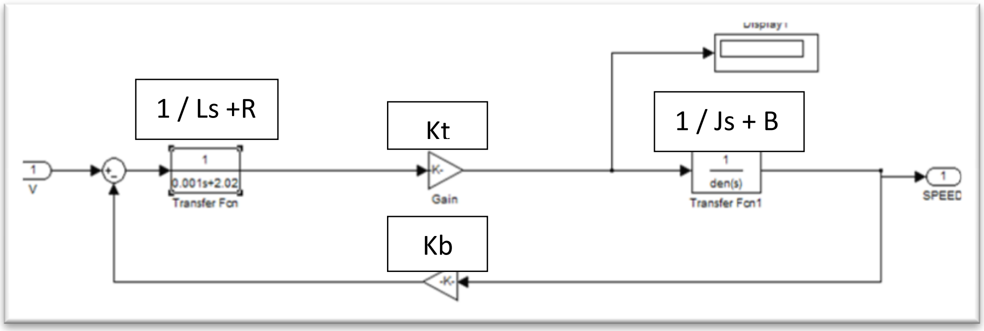


Figure 3.1: Dc Motor Plant

Table 3.1: Physical System Parameters.

Physical quantity	Symbol	Numerical Value	Units
Inductance	La	1.21^-3	H
Resistance	Ra	2.02	Ω
Back-emf constant	Kb	0.0164	Vs/rad

Torque Constant	Kt	0.0164	Nm/A
Viscous Friction Coefficient	B	13.02^-6	Nms/rad
1 MecanumWheel Inertia	Jw	8.375^-3	kgm²
Rotor inertia	Jm	9.55^-3	kgm²

Total Inertia = Jw + Jm = (8.375^-3) + (9.55^-3) = 17.925^-3

Power = 7 Watts, Speed = 7000 rpm(max), Rotor inertia = 9.55^-3 kgm²

W = 2π (7000) / 60 = 733.04 rad/s

Torque constant :

K = V / W = 12 / 733 = 0.0164 Vs/rad

Rotor inetia :

T = P / W =7 / 733.04 = 9.55^-3 kgm²

i = T / K = 9.55^-3 / 0.016 = 0.582 amp

K * i = dw/dt + bW

Steady state I and W stable , dw/dt = 0

b = (0.0164 * 0.582) / 733.04 = 13.02 ^-6

3.2 Proposed Controller For Dc Motor

The structure of the purposed controller for macanum wheel robot is shown in figure 3.2.The purposed controller consists of fuzzy PID controller for speed control in the completed closed loop system.

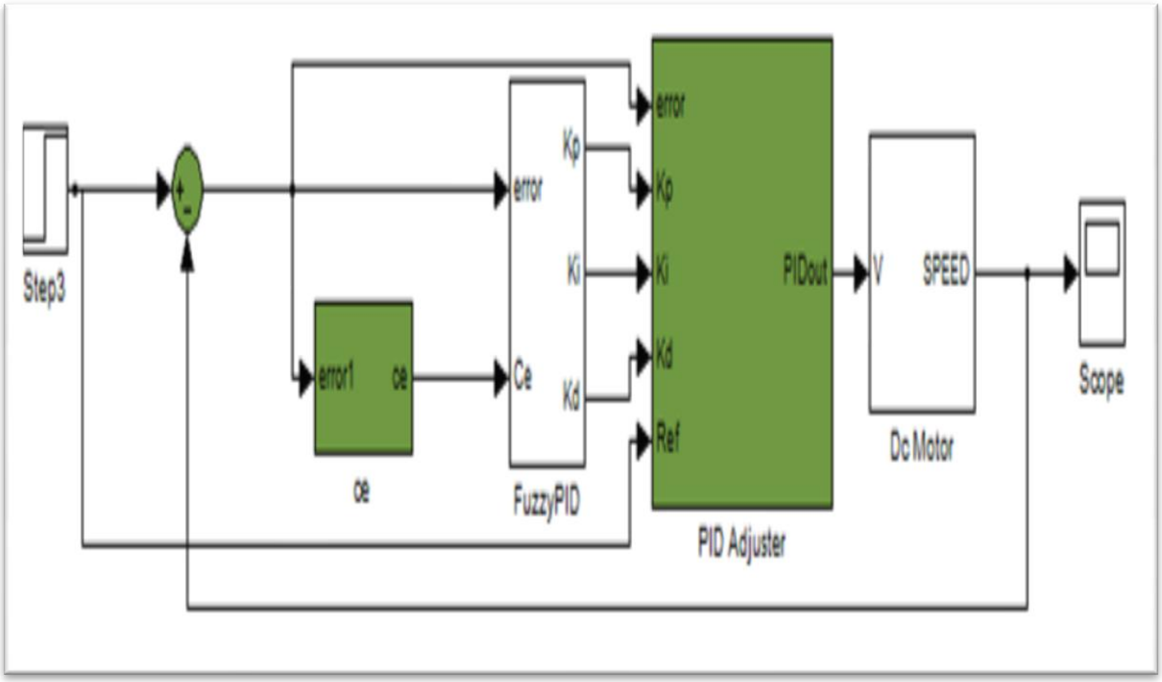


Figure 3.2: Block Diagram Of Fuzzy Pid Controller

The fuzzy PID controller consist of few blocks of Simulink. There are change error block ,Fuzzy PID block and PID Adjuster block. The steps Simulink source block is assume as a dc voltage input for the motor. Error and change error signal will be go inside the fuzzy system input. From that , fuzzy will make up the decision to choose the Kp ,Ki and Kd value to suite the system. The fuzzy had two inputs and tree out put.Out put from fuzzy will go through the PID adjuster block. The result that had been makeup from the fuzzy will be run inside this block. PID Adjuster block will be give the Kp , Ki, and Kd value to the Dc motor block system.

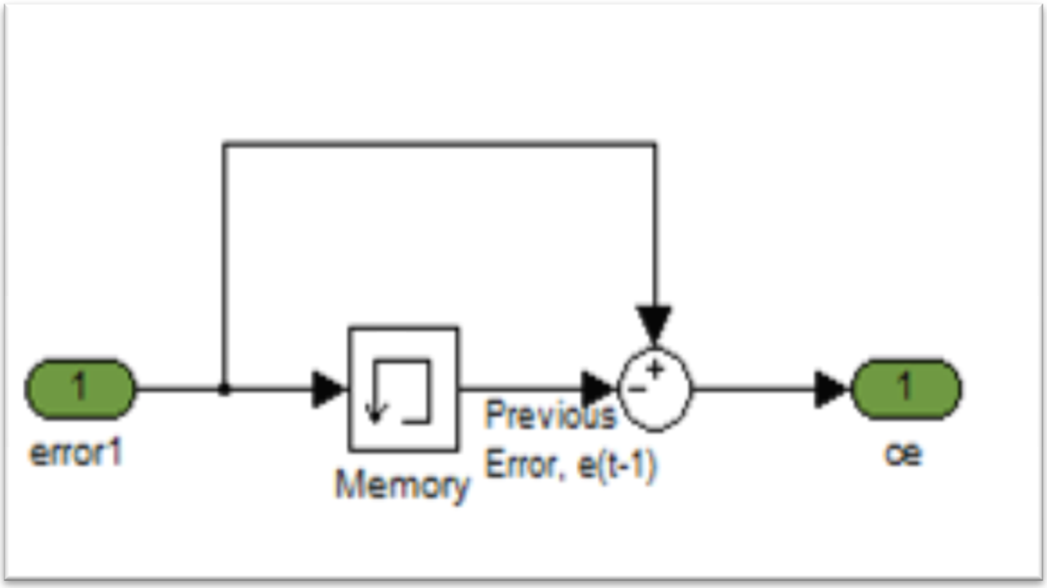


Figure 3.3: Change Error Block Diagram

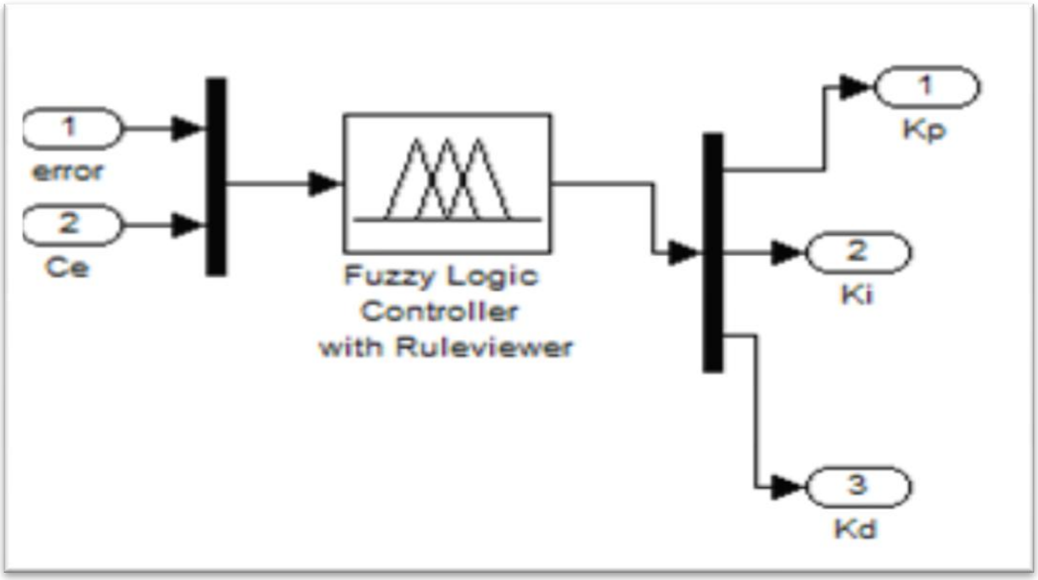


Figure 3.4: Fuzzy Block Diagram

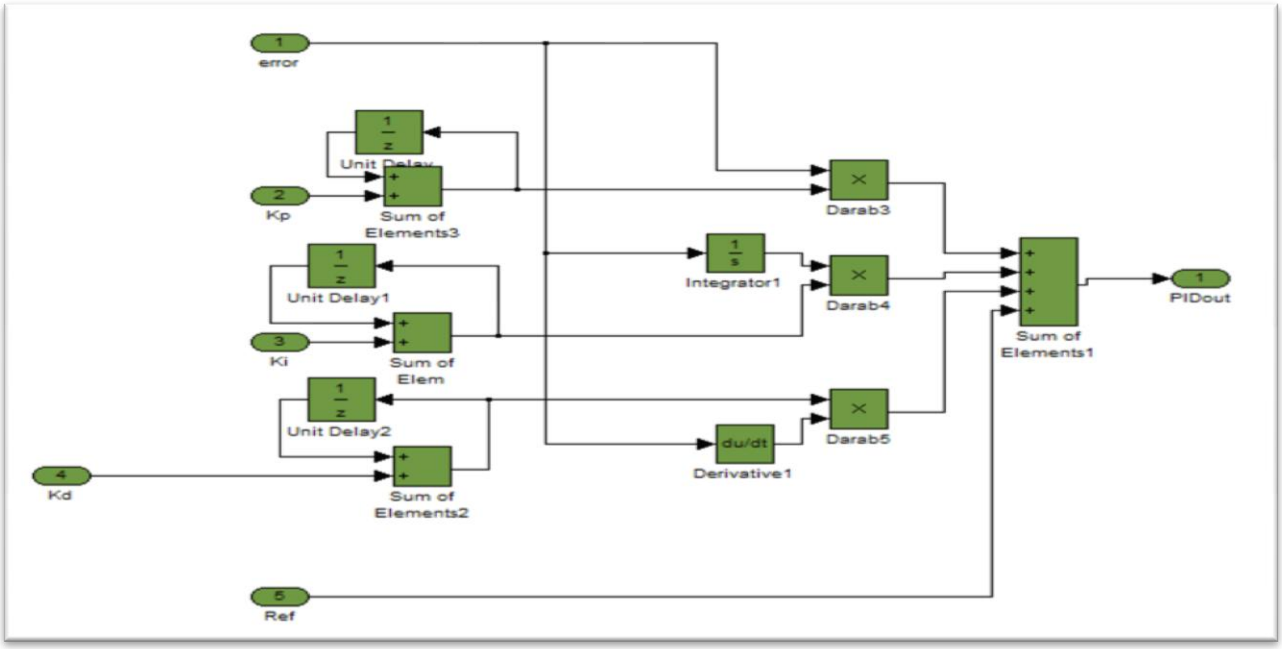


Figure 3.5: PID Adjuster block diagram

3.3 Self-Tuning Fuzzy PID Controller

Self-tuning fuzzy PID controller means that the three parameters *Kp*, *Ki* and *Kp* of PID

controller are tuned by using fuzzy tuner [25], [26].Hence, it is automatically tune the PID parameters. The structure of the self-tuning fuzzy PID controller is shown in Figure 3.7.

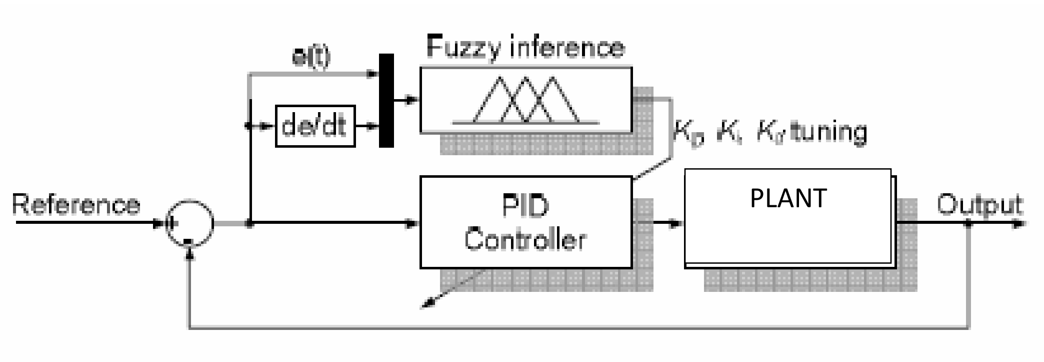


Figure 3.6: Structure of self-tuning fuzzy PID controller

The e(t) is the error between desired set point and the output, de(t) is the derivation of error. The fuzzy inference will tuned PID parameters, which provide a nonlinear mapping from the error and derivation of error to PID parameters.

3.4 Design of Self-Tuning Fuzzy PID Controller

Base to the fuzzy structure, there are two inputs to fuzzy inference error e(t) and derivative of error de(t), and three outputs for each PID controller parameters respectively Kp, Ki and Kd. Fuzzy inference block of the controller design is shown in Figure 9 below.

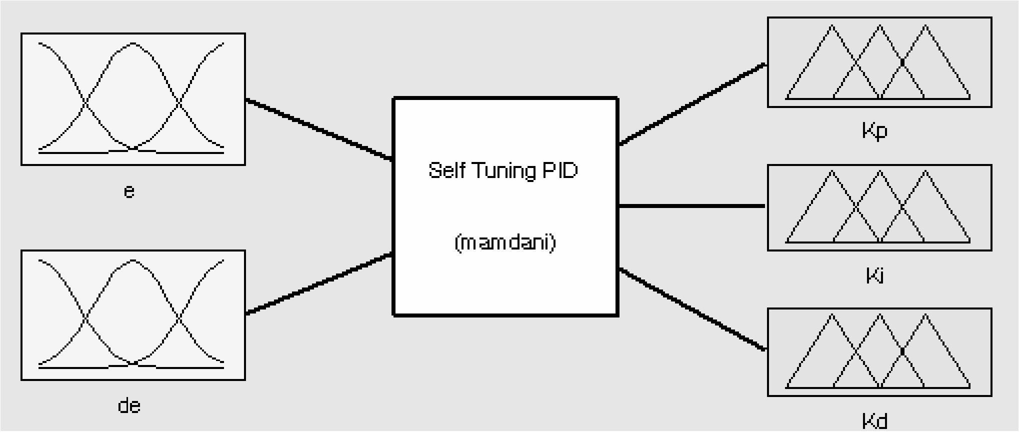


Figure 3.9 : Fuzzy inference block

Relationships between KP, KI and KD and important response characteristics, of which these three are most useful. Use KP to decrease the rise time, KD to reduce the overshoot and settling time and KI to eliminate the steady-state error.

3.5 Fuzzy Logic Controller Design

A basic structure of fuzzy logic controller system block diagram for position control is clearly shown in Figure 3.4. fuzzy logic controller input variables involves receiving the error signal and change of error. These variables evaluate the fuzzy control rules using the compositional rules of inference and the appropriately computed control action is determined by using the defuzzification [17]. The essential steps in designing the fuzzy logic controller of this system are illustrated in Figure 3.5

3.6 Fuzzification

Fuzzification is a process of producing a fuzzy input on the base of a crisp one. It involves the conversion of the input and output signals into a number of fuzzy represented values (fuzzy sets). Figure 3.6 below describes the input and output variables that are used in this system.

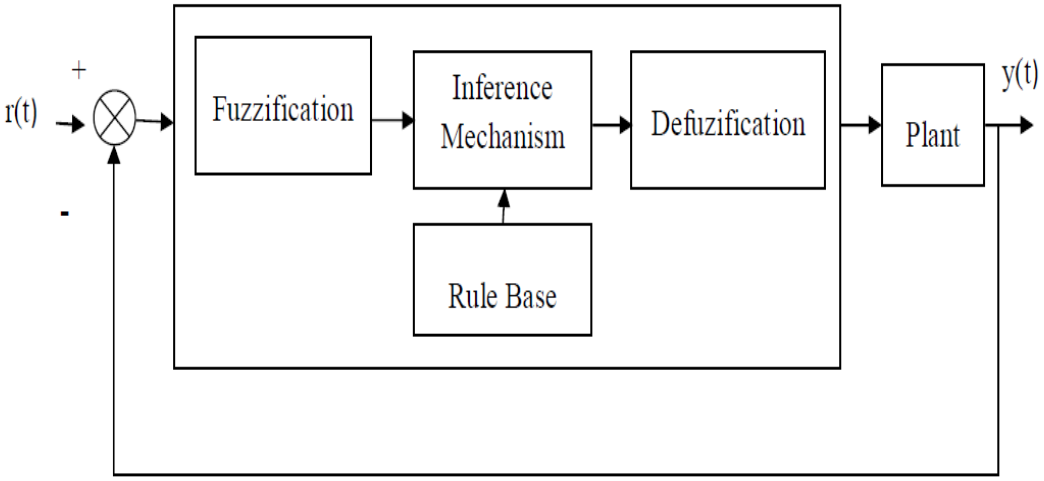


Figure 3.7: Structure Of Fuzzy Logic Controller System

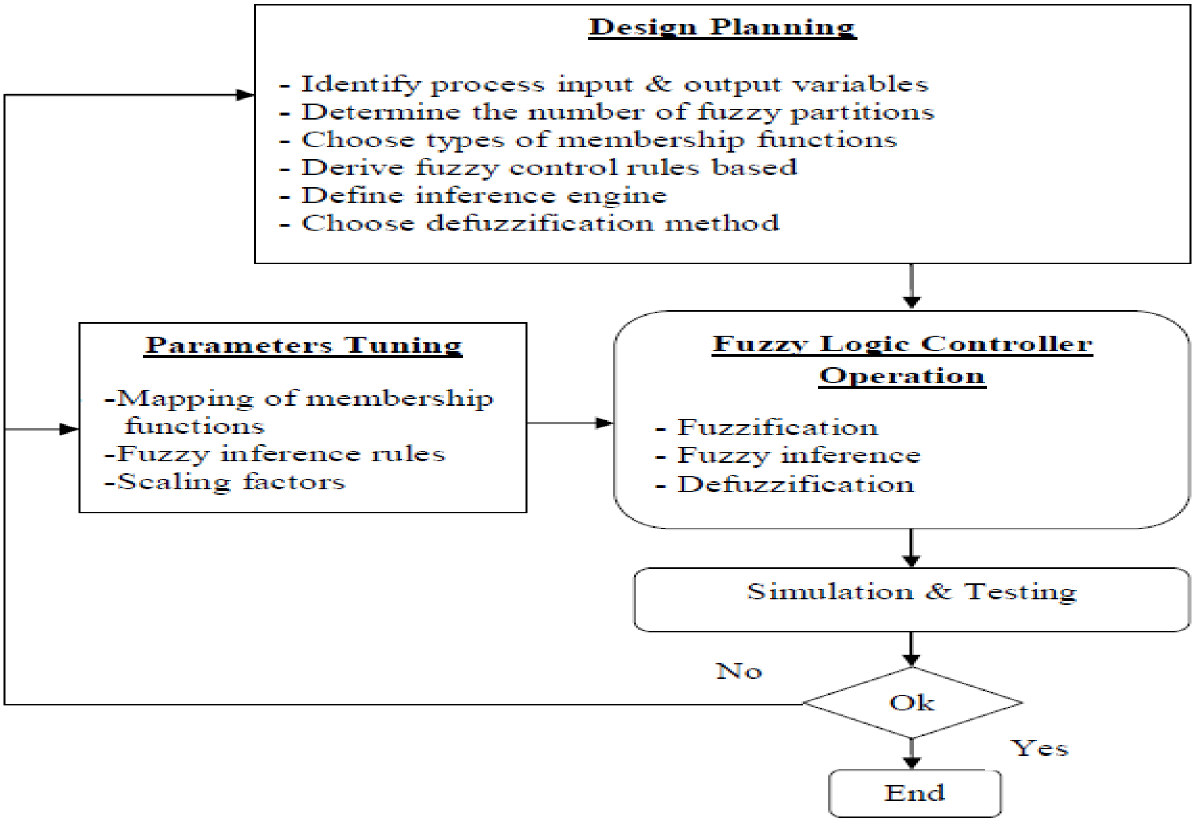


Figure 3.8: Design Procedure Of The Fuzzy Logic Controller

3.7 Fuzzification

Fuzzification is a process of producing a fuzzy input on the base of a crisp one. It involves the conversion of the input and output signals into a number of fuzzy represented values (fuzzy sets). Figure 3.9 below describes the input and output variables that are used in this system.

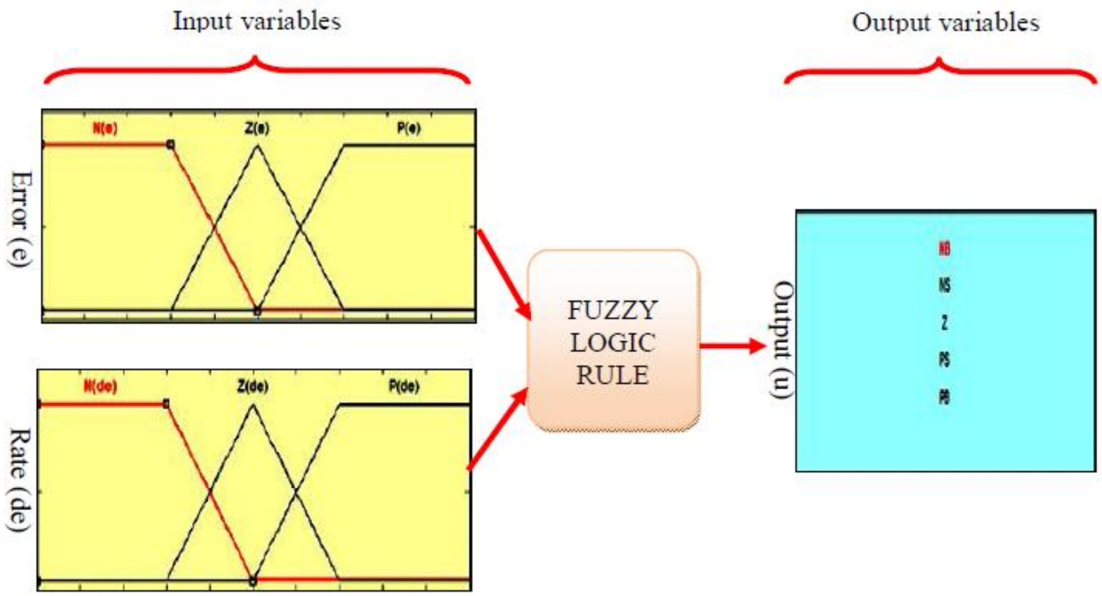


Figure 3.9: Membership function for input and output of fuzzy logic controller

(i) Input variables:

Error (e) Quantized into 3 membership function: Negative L NL(e), Negative Medium NM(e), Negative High NH(e), Zero Z(e), Positive Low PL(e), Positive Medium PM(e) and Positive High PH(e). Input variables FUZZY LOGIC RULE Output variables Error (e) Rate (de) Output (u)

Rate (de) Quantized into 3, membership function: Negative L NL(e), Negative Medium NM(e), Negative High NH(e), Zero Z(e), Positive Low PL(e), Positive Medium PM(e) and Positive High PH(e).

(ii) Output variables:

Output Quantized into 3 membership function: Positive Low PL(e), Positive Medium PM(e) and Positive High PH(e).

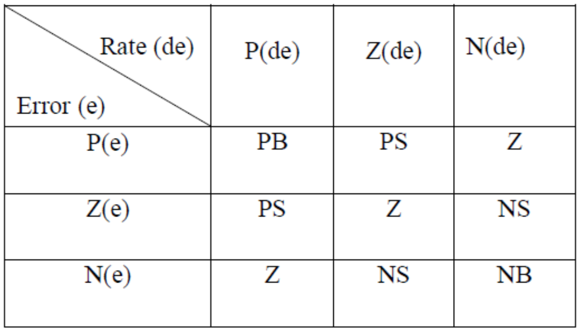
3.8 : Inference engine

Inference engine is defined as the Software code which processes the rules, cases, objects or other type of knowledge and expertise based on the facts of a given situation. When there is a problem to be solved that involves logic rather than fencing skills, we take a series of inference steps that may include deduction, association, recognition, and decision making. An inference engine is an information processing system (such as a computer program) that systematically employs inference steps similar to that of a human brain.

3.9 Rule Base

The basic function of the rule based is to represent the expert knowledge in a form of if-then rule structure. The fuzzy logic can be derived into combination of input (3 × 3). The rule table of fuzzy logic controller as listed in Table 3.2

Table 3.2: Rule table of fuzzy logic controller (3 × 3)



Rate (de) Error (e)	P(de)	Z(de)	N(de)
P(e)	PB	PS	Z
Z(e)	PS	Z	NS
N(e)	Z	NS	NB

The fuzzy logic control rules based on Table 3.2 are:

1) IF Error(e) is N(e) AND Rate(de) is P(de) THEN Output(u) is Z(u)

2) IF Error(e) is Z(e) AND Rate(de) is P(de) THEN Output(u) is PS(u)

3) IF Error(e) is P(e) AND Rate(de) is P(de) THEN Output(u) is PB(u)

4) IF Error(e) r is N(e) AND Rate(de) is Z(de) THEN Output(u) is NS(u)

5) IF Error(e) is Z(e) AND Rate(de) is Z(de) THEN Output(u) is Z(u)

6) IF Error(e) is P(e) AND Rate(de) is Z(de) THEN Output(u) is PS(u)

7) IF Error(e) is N(e) AND Rate(de) is N(de) THEN Output(u) is NB(u)

8) IF Error(e) is Z(e) AND Rate(de) is N(de) THEN Output(u) is NS(u)

9) IF Error(e) is P(e) AND Rate(de) is N(de) THEN Output(u) is Z(u)

Table 3.3 Rule Base For The Fuzzy Pid Control System

ERROR		CE		
		H	M	L
	H	KP(H),KI(H),KD (H)	KP(H),KI(H),KD(M)	KP(H),KI(H),KD(L)
	M	KP(M),KI(M),KD (H)	KP(M),KI(M),KD (M)	KP(M),KI(M),KD (L)
	L	KP(L),KI(M),KD (H)	KP(L),KI(L),KD (M)	KP(L),KI(L),KD (L)

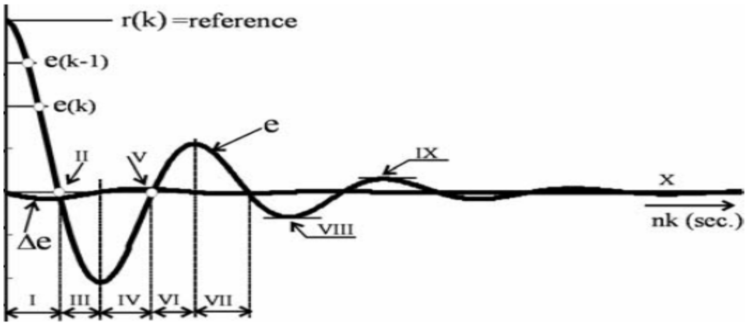


Figure 3.10: Error And Change Error Graph To Find The Fuzzy Rule

This simple rule is applied as follows to determine the sign of Δu.

<u>At region I :</u> e=’ + ’ and Δe=’ – ‘. The error is positive and decreasing toward zero. Therefore, Δu is set to positive to reduce the error.
<u>At region II :</u> e=’ 0 ’ and Δe=’ – ‘. The error is zero, but is getting away and increasing in negative direction. Therefore, a negative Δu is assigned to reduce the error.
<u>At region III :</u> e=’ – ’ and Δe=’ – ‘. The error is negative and increasing. Therefore, Δu is still required to be negative to reduce the error toward zero.
<u>At region IV :</u> e=’ – ’ and Δe=’ + ‘. The error is still negative, but decreasing. Therefore, negative Δu is kept on to reduce the negative error.
<u>At region V :</u> e=’ 0 ’ and Δe=’ + ‘. The error is zero, but increasing in positive direction. Therefore, a positive Δu is applied to increase the controlled output so that the voltage error is reduced.
<u>At region VI :</u> e=’ + ’ and Δe=’ + ‘. The error is positive and increasing. A positive value for Δu will be suitable to reduce the error.

<u>At region VII :</u> A repeat of region I.
<u>At region VIII :</u> e=’ – ’ and Δe=’ 0 ‘. The error is negative and constant since there is no change. Therefore a negative value for Δu should be assigned to decrease the error.
<u>At region IX :</u> e=’ + ’ and Δe=’ 0 ‘. The error is positive and constant. Therefore a positive Δu is required to reduce the error.
<u>At region X:</u> e=’ 0 ’ and Δe=’ 0 ‘. The error is both zero and constant. Therefore Δu is set to zero since no change is required for the control signal.

3.10 : Defuzzification

The reverse of Fuzzification is called Defuzzification. The use of Fuzzy Logic Controller (FLC) produces required output in a linguistic variable (fuzzy number). According to real world requirements, the linguistic variables have to be transformed to crisp output. There are many defuzzification methods but the most common methods are as follows [11]:

1) Center of gravity (COG)
2) Bisector of area (BOA)
3) Mean of maximum (MOM)

3.11 : Center of gravity (COG)

For discrete sets COG is called center of gravity for singletons (COGS) where the crisp control value is the center of gravity of the fuzzy set is calculated as follows:

$$u_{COGS} = \frac{\sum_i \mu_c(x_i)x_i}{\sum_i \mu_c(x_i)}$$

Where xi is a point in the universe of the conclusion (i=1, 2, 3…) and μc (xi) is the membership value of the resulting conclusion set. For continuous sets summations are replaced by integrals.

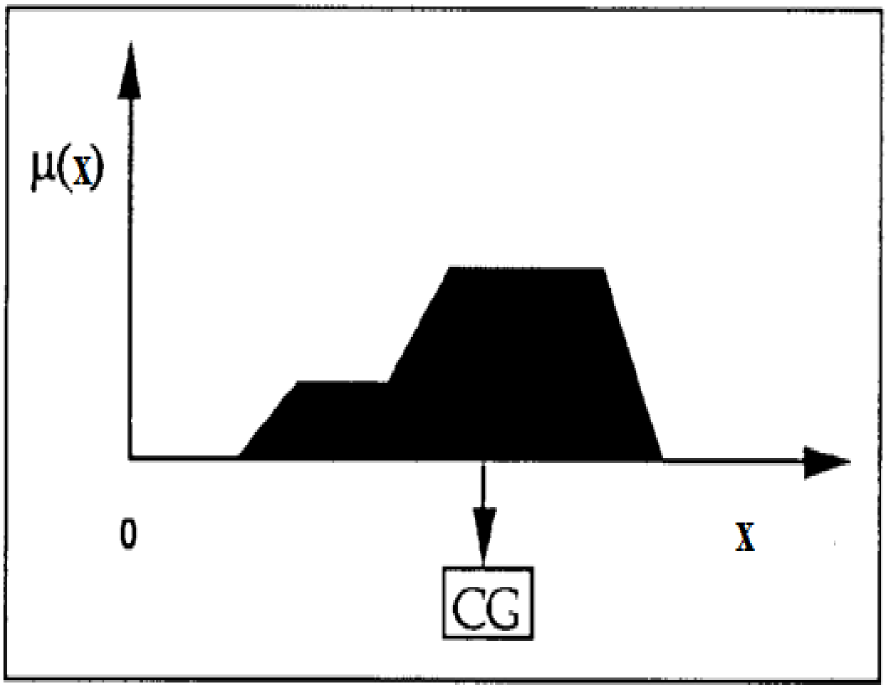


Figure 13: Illustration of center of gravity method

3.11 Voltage controller

The dc motor will be rotate clock wise if positive voltage given, but will rotate anti clockwise after received negative voltage. Here the voltage controller had been create to give certain voltage to the four dc motor. There are six basic motion had been test in this task.

i. Forward – all four wheels rotate forward
ii. Backward – all four wheel rotate back ward
iii. Right slide – wheel 1 and 4 back ward, wheel 2 and 3backward
iv. Left slide – wheel 1 and 4 forward, wheel 2 and 3 back ward
v. Clock wise – wheel 1 and 3 forward, wheel 2 and 3 back ward
vi. Counter-clockwise – wheel 1 and 3 backwards, wheel 2 and 4 forward

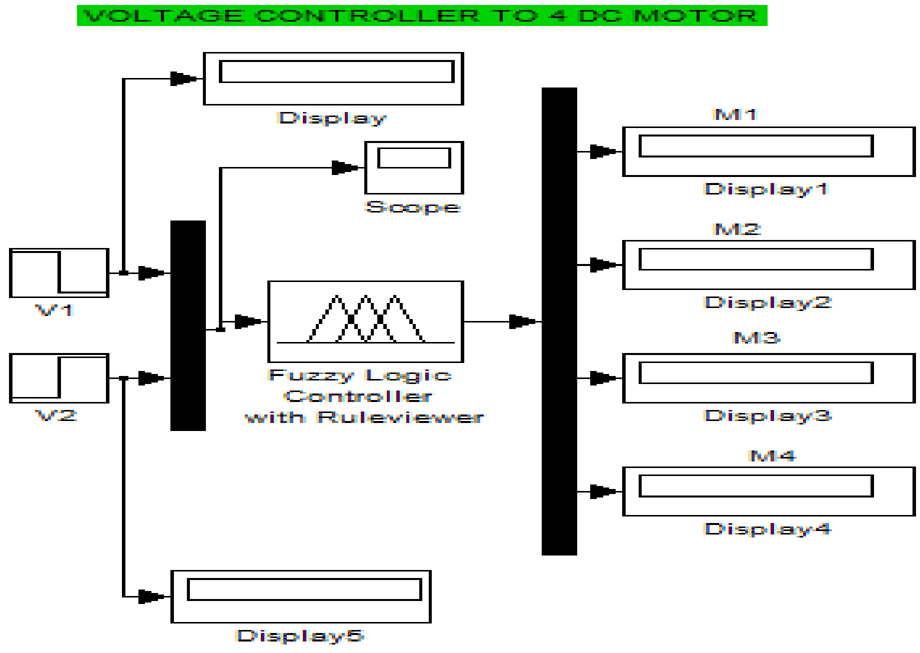


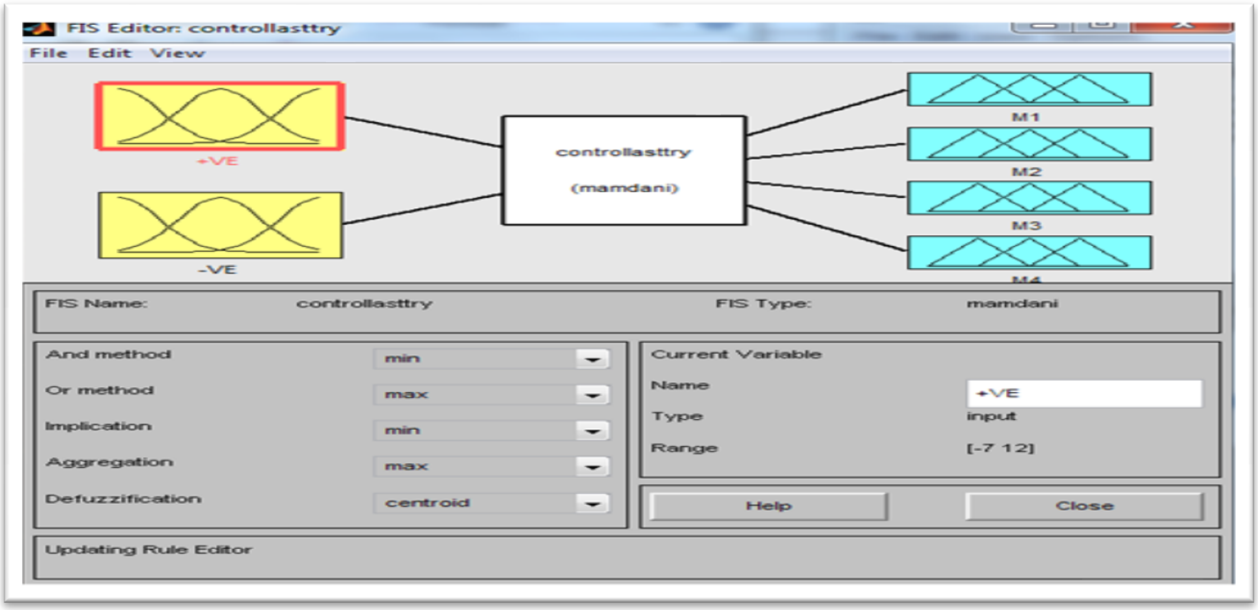
Figure 14: Four Dc Motor Controller

Table 3.3 : Controller Output Four Dc Motor

V1	V2	M1	M2	M3	M4	MOTIONS
12V	0V	12V	12V	12V	12V	FORWARDS
6V	-6V	-6V	6V	6V	-6V	RIGHT SLIDE
1V	1V	6V	-6V	6V	-6V	CLOCK WISE
0V	-12V	-12V	-12V	-12V	-12V	BACK WARDS
-6V	6V	6V	-6V	-6V	6V	LEFT SLIDE
-1V	-1V	-6V	6V	-6V	6V	ANTI-CLOCK WISE

There are six mumdani rule had been made to perform the result on Table 3.3

i. If (+VE is hp) then (M1 is ph)(M2 is ph)(M3 is ph)(M4 is ph) (1)
ii. If (-VE is nh) then (M1 is nh)(M2 is nh)(M3 is nh)(M4 is nh) (1)
iii. If (+VE is mp) and (-VE is nm) then (M1 is nm)(M2 is pm)(M3 is pm)(M4 is nm) (1)
iv. If (+VE is nm) and (-VE is pm) then (M1 is pm)(M2 is nm)(M3 is nm)(M4 is pm) (1)
v. If (+VE is zp) and (-VE is pz) then (M1 is pm)(M2 is nm)(M3 is pm)(M4 is nm) (1)
vi. If (+VE is zn) and (-VE is nz) then (M1 is nm)(M2 is pm)(M3 is nm)(M4 is pm) (1)



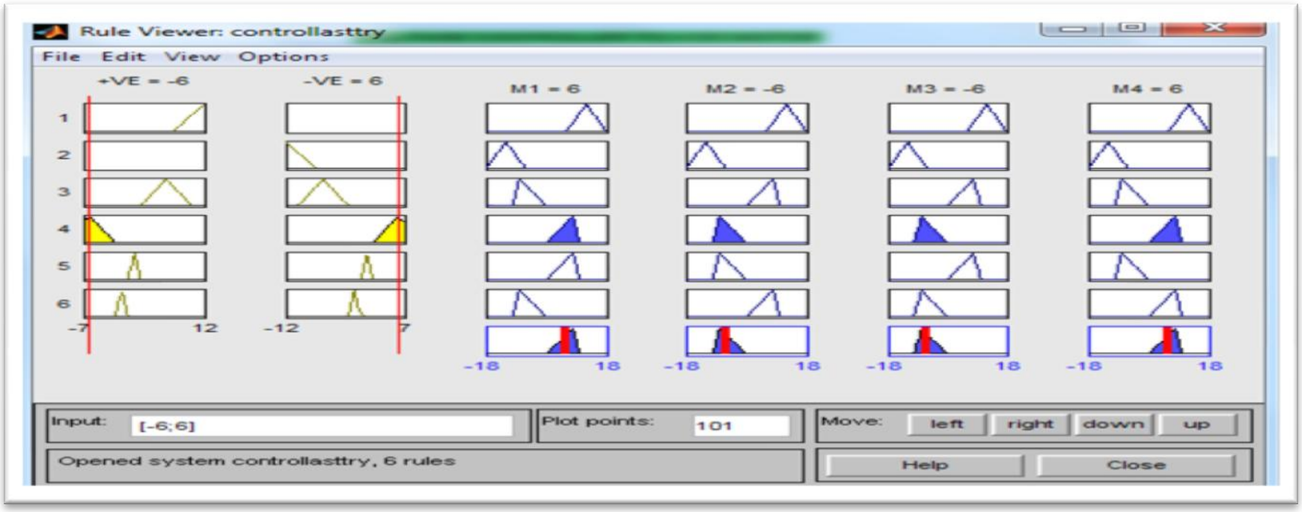
FIS Name: controllasttry
FIS Type: mamdani

And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid

Current Variable
Name: +VE
Type: input
Range: [-7 12]

Updating Rule Editor

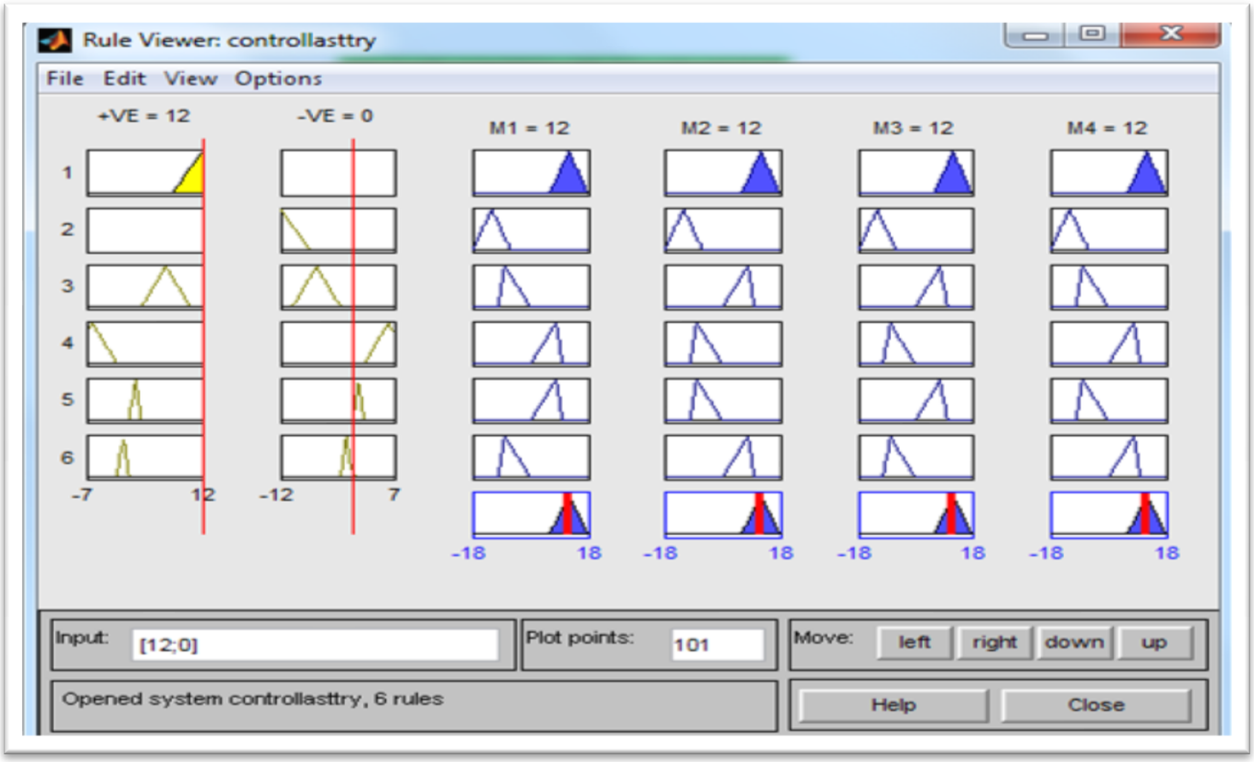
Figure 15 : Fuzzy Fis Editor



Input: [-6;6]
Plot points: 101

Opened system controllasttry, 6 rules

Figure 16 : rule viewer V1 = -6 ; V2 = 6



+VE = 12

-VE = 0

M1 = 12

M2 = 12

M3 = 12

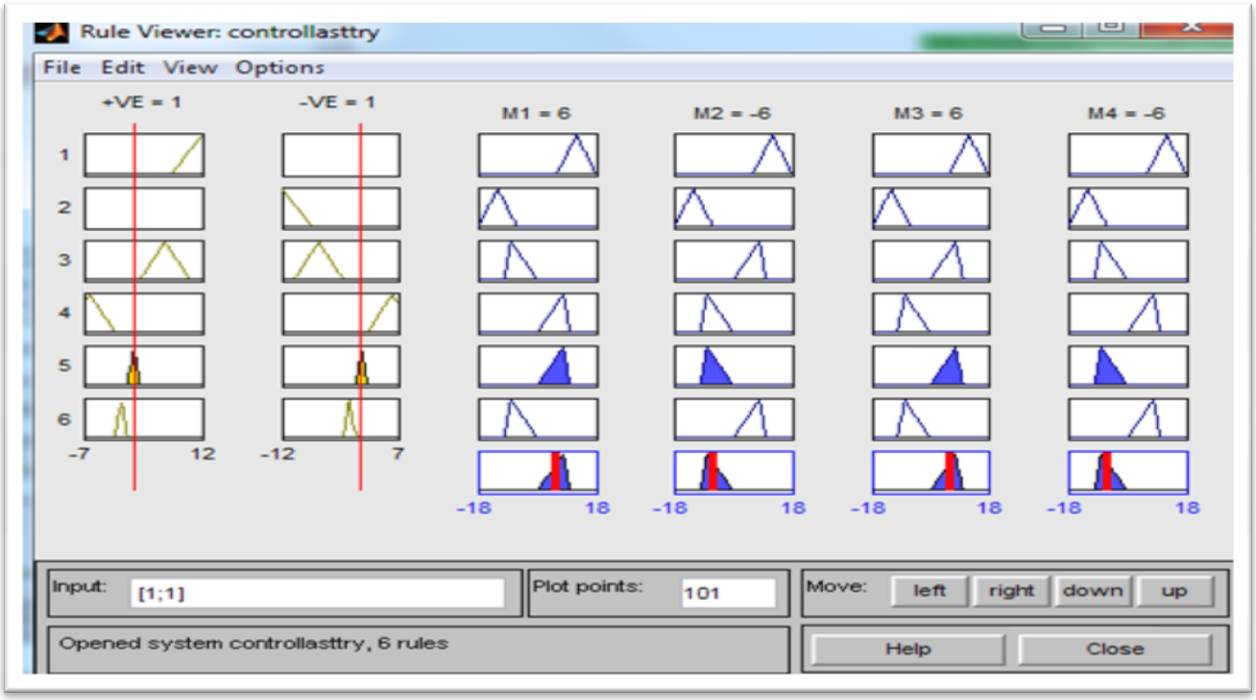
M4 = 12

Input: [12;0]

Plot points: 101

Opened system controllasttry, 6 rules

Figure 17 : rule viewer V1 = 12 ; V2 = 0



+VE = 1

-VE = 1

M1 = 6

M2 = -6

M3 = 6

M4 = -6

Input: [1;1]

Plot points: 101

Opened system controllasttry, 6 rules

Figure 18 : rule viewer V1 = 1 ; V2 = 1

REFERENCES

[1] Ilon, B.E., ‘Wheels for a course stable self-propelling vehicle movable in any desired direction on the ground or some other base”, US Patent and Trademarks office, Patent 3.876.255, 1975.

[2] Muir, P. F. & C. P. Neuman (1987). Kinematic Modeling for Feedback Control of an Omnidirection Wheeled Mobile Robot. IEEE Intenational Conference on Robotics and Automation.

[3] Muir, P. F. & C. P. Neuman (1987). Kinematic Modeling of Wheeled Mobile Robots. Journal of Robotic Systems, No. 4(2), pp. 281-340.

[4] Diegel, O.; Badve, A.; Bright, G.; Potgieter, J. &Tlatle, S. (2002). Improved Mecanum Wheel Design for Omni-directional Robots, Proc. 2002 Australian Conference on Robotics and Automation, Auckland, 27-29 Nov. 2002, pp. 117-121.

[5] Jia Guan-shuai; GuoJi-feng; , "Mechatronic model and simulation of four-wheelMecanum vehicle driven by BLDC," Consumer Electronics, Communications and Networks (CECNet), 2011 International Conference on , vol., no., pp.2317-2320, 16-18 April 2011

[6] Zhang Yunan; Wang Shuangshuang; Zhang Jian; Su Quan; Gao Jianmin; "Research on Motion Characteristic of Omnidirectional Robot Based on Mecanum Wheel," Digital Manufacturing and Automation (ICDMA), 2010 International Conference on , vol.2, no., pp.237-241, 18-20 Dec. 2010

[7] Ching-Chih Tsai; Feng-Chun Tai; Ying-Ru Lee; , "Motion controller design and embedded realization for Mecanum wheeled omnidirectional robots," Intelligent Control and Automation (WCICA), 2011 9th World Congress on, vol., no., pp.546-551, 21-25 June 2011.

[8] Ho-Hoon Lee, Seung-Gap Choi, A Model-Based Anti-Swing Control of Overhead Cranes with High Hoisting Speeds, International Conference on Robotics & Automation, 2001, 2547-2552.

[9] YodyiumTipsuwan and Mo-Yuen Chow "FuzzyLogic microcontroller implementation for DC motor speed control", IEEE Transactions on Power Electronics, V0l.11, No.3, June 1999, pp 1271-1276.

[10] Abdullah I. Al-Odienat and Ayman A. Al-Lawama, " The Advantages of PID Fuzzy Controllers Over The Conventional Types" American Journal of Applied Sciences DOI: 10.3844/ajassp.2008.653.658 Volume 5, Issue 6, pp 653-658

[11] M. de Villiers and Prof. G. Bright,"DevelopmentOf A Control Model For A Four Wheel Mecanum Vehicle" 25th International Conference of CAD/CAM, Robotics & Factories of the Future Conference, July 2010, Pretoria, South Africa

[12] FlorentinaAdăscăliţei, IoanDoroftei, "Practical Applications for Mobile Robots based on Mecanum Wheels-a Systematic Survey "Proceedings of International Conference On Innovations, Recent Trends And Challenges In Mechatronics, Mechanical Engineering And New High-Tech Products Development–MECAHITECH'11, vol. 3, year: 2011

[13] Hélder P. Oliveira, Armando J. Sousa, A. Paulo Moreira and Paulo J. Costa, "Modeling and Assessing of Omni-directional Robots with Three and Four Wheels", In CONTEMPORARY ROBOTICS - Challenges and Solutions, A. D. Rodic (Ed.), pp. 207-230, INTECH, ISBN 978-953-307-038-4, 2009.

[14] Ahmad Nor KasruddinNasir ,Mohd. Ashraf Ahmad ,Riduwan Ghazali, Nasrul Salim Pakheri , "Performance Comparison Between Fuzzy Logic Controller (FLC) and PID Controller for a Highly Nonlinear Two-wheels Balancing Robot " 2011 First International Conference on Informatics and Computational Intelligence

[15] NurulIzzatiBintiPandakJabo,"Speed Control Of Dc Motor Using PIDController Implementation With Visual Basic" Bachelor Thesis, Faculty of Electrical & Electronics Engineering Universiti Malaysia Pahang NOVEMBER, 2008.

[16] Pintu Chandra Shill, BishnuSarker and Kazuyuki Murase,"Evolutionary Tuning Of Fuzzy Rule Base SystemsFor Nonlinear SystemModelling And Control".InternationalJournal of Computer Science & Information Technology (IJCSIT) Vol 4, No 5, October 2012