International Journal of Emerging Engineering Research and Technology
Volume 3, Issue 3, March 2015, PP 76-83
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Comparison between the Effects of Different Types of Membership Functions on Fuzzy Logic Controller Performance

Omar Adil M. Ali[1], Aous Y. Ali[1], Balasem Salem Sumait[1]

[1]*Communication & Computer Engineering Department, Cihan University, Erbil, Iraq*

ABSTRACT

Membership functions (MFs) are the building blocks of fuzzy set theory, i.e., fuzziness in a fuzzy set is determined by its MF. Accordingly, the shapes of MFs are important for a particular problem since they effect on a fuzzy inference system. They may have different shapes like triangular, trapezoidal, Gaussian, etc. The only condition a MF must really satisfy is that it must vary between 0 and 1.

In this paper, a straightforward approach for designing a fuzzy logic based controller is presented to evaluate the effect of membership function in fuzzy logic controller, and presents the performance comparison of fuzzy logic controller with three different types of membership function. An attempt has been made to develop a fuzzy based control system for Antenna Azimuth Position control. This was done using Matlab/Simulink module

Keywords: PID Controller, Fuzzy Control, Hybrid Control, Antenna Azimuth position.

INTRODUCTION

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

The idea of fuzzy logic was invented by Professor L. A. Zadeh of the University of California at Berkeley in 1965 [1] .This invention was not well recognized until Dr. E. H. Mamdani [2] who is a professor at London University, applied the fuzzy logic in a practical application to control an automatic steam engine in, which is almost ten years after the fuzzy theory was invented. Then, in 1976, Blue Circle Cement and SIRA in Denmark developed an industrial application to control cement kilns. That system began to operation in 1982. More and more fuzzy implementations have been reported since the 1980s, including those applications in industrial manufacturing, automatic control, automobile production, banks, hospitals, libraries and academic education [3]. The main aim is to design a control system that will ensure good transient and steady state response of the system.

METHODOLOGY

Membership Function

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse. Or, the membership function is a graphical representation of the magnitude of participation of each input. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. Once the functions are inferred, scaled, and combined, they are defuzzified into a crisp output which drives the system.

For any set X, a membership function on X is any function from X to the real unit interval [0, 1]. The membership function which represents a fuzzy set is usually denoted by μA. For an element x of X, the value $\mu A(x)$ is called the membership degree of x in the fuzzy set. The membership degree $\mu A(x)$ quantifies the grade of membership of the element x to the fuzzy set. The value 0 means that x is not a

Address for correspondence:

eng_blasm@yahoo.com

member of the fuzzy set; the value 1means that

x is fully a member of the fuzzy set. The values between 0 and 1 characterize fuzzy members, which belong to the fuzzy set only partially.

A fuzzy set is completely characterized by its membership function (MF). Since most fuzzy sets in use have a universe of discourse X consisting of the real line R, it would be impractical to list all the pair defining a membership function. A more convenient and concise way to define an MF is to express it as a mathematical formula.

The definition of the membership functions is a very delicate point in the design of the FC, because the only restriction that a membership function has to satisfy is that its values must be in the [0,1] range. A fuzzy set can therefore, unlike a crisp one, be represented by an infinite number of membership functions.

Types of Membership Functions

The simplest membership functions are formed using straight lines. Due to their simple formulas and computational efficiency, both triangular MFs and trapezoidal MFs have been used extensively, especially in real-time implementations. However, since the MFs are composed of straight line segments, they are not smooth at the corner points specified by the parameters. [4, 5].

The most common types of MF are:

1. Triangular MFs
2. Trapezoidal MFs
3. Gaussian MFs
4. Generalized bell MFs
5. π- Shaped Membership Function
6. S- Shaped Membership Function

The list of MFs introduced in this section is by no means exclusive; other specialized MFs can be created for specific applications if necessary. In particular, any type of continuous probability distribution functions can be used as an MF here, provided that a set of parameters is given to specify the appropriate meanings of the MF. [12]

Fuzzy Logic Controller forAntenna Azimuth Position Control System

After explaining the most popular types of membership functions that are widely used in the design of the fuzzy controller in the previous section, we will show the effect of using various types of membership functions on the performance of the fuzzy logic controller and corresponding change in the system output when we change the type of the membership function on the same system. Due to the large number of known types of membership functions , we will use only three types of most used types in design which are the triangular, Trapezoidal (which are linear membership functions) and the Gaussian membership function (Non- linear).Our system in concern will be controlling the azimuth position of an antenna. We will design a FLC using the three types of membership functions and compare the response of the system in terms of speed and steady- state error for each type of membership function.

The design and simulation are done using MATLAB V7.6 / Simulink software.

Antenna Azimuth Position Control System

The antenna azimuth control system currently available on the market is described as a servo controlled antenna through the use of gears and feedback potentiometers. The current design lacks any sort of compensator controller that would provide stability control.

Norman S. Nise investigates the design of a control system for an antenna [6]. The basic idea is that someone, from a control tower, can adjust a simple potentiometer by hand and ultimately move a large antenna.

The antenna control system physical layout is shown in Figure. 1 and the block diagram of the system is shown in Figure .2, this block diagram will be used in the design and simulation for the control system [7].

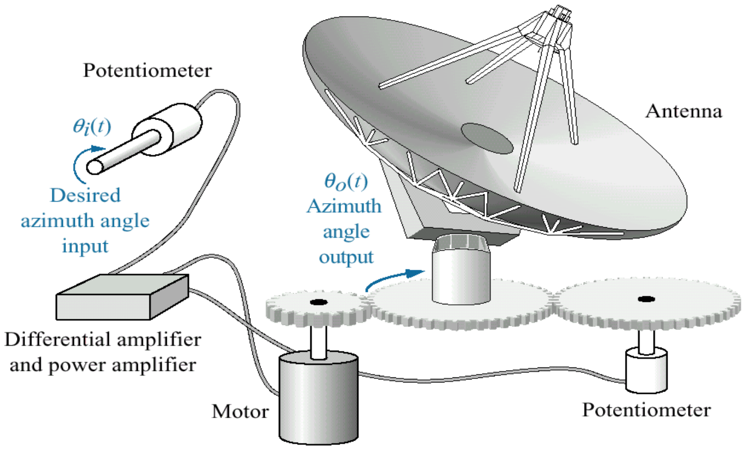


Figure1. *Physical Layout of the Antenna Azimuth Control Systemposition control system*

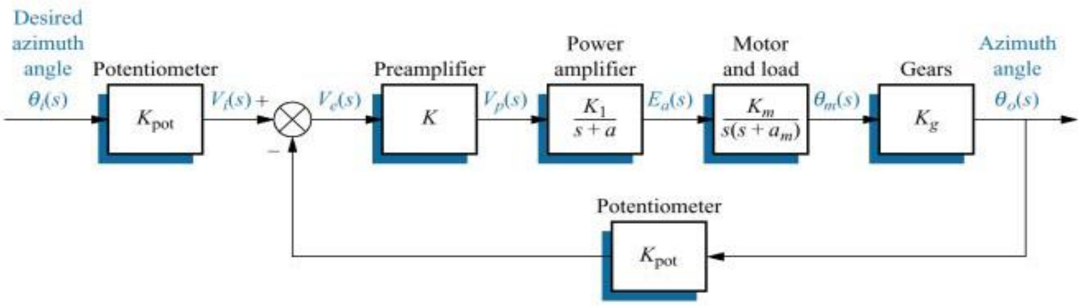


Figure2. *Block Diagram of the Antenna Azimuth Closed- Loop Control System*

The azimuth position antenna control system can be controlled by adjusting the firing angle of motor that is driving the antenna, thus the fuzzy controller is designed to control the system by adjusting the firing angle of the motor due to the change in the output angle [8, 9]. First it is to be said that the PI-like fuzzy controller is chosen for this job (the PI adds a pole at the origin, which increase the stability of the system at the steady-state). The controller contains two inputs and single output, the controller receives the difference between the reference angle and the actual system (motor) angle and this forms the first input which is called "error". Because the PI-like fuzzy controller is used, the second input must be the "integral" of the error, but sometimes it's difficult to formulate rules depending on an integral of error, because it may have very wide universe of discourse, thus the output of a controller can be integrated and not it's input [10]. In this case the inputs to the controller should be "error" and "change-of-error" (derivative of the error) and still realizing the PI-like controller In this case, to obtain the value of control output variable$u(t)$, the change of control output $\Delta u(t)$ is added to$u(t-1)$. The block diagram of a PI-like fuzzy controller is shown in Figure 3. For the fuzzy controller structure design, we used two inputs which are (Error & Change of Error) and one output which is named (Control Action). Both, the inputs and the output were designed to have 7 membership functions, which are designated as (NL , NM , NS , ZE , PS , PM , PL), then the rules were derived for the controller. The rules for the controller are given in table 1.

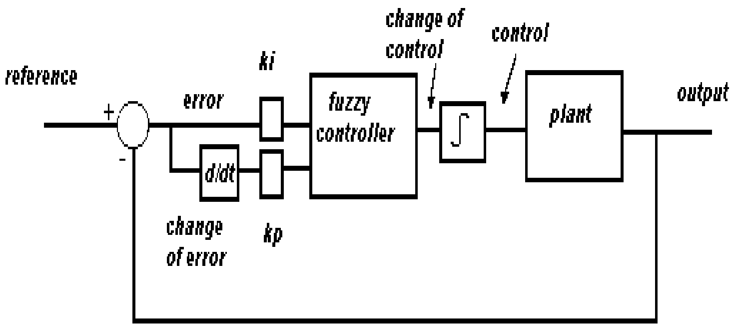


Figure3 *Block Diagram of PI- Like Fuzzy Control System(Using Integral of the Output)*

Table1. *The Rule Base Table of the Fuzzy Controller*

Δe \ e	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	ZE	PS	PM	PL	PL	PL	PL

Membership Functions of the System

As mentioned before, we will change the type of the membership function used in the design of the FLC. Then we will compare the effect of this change on the control action and the response of the system as a result.

We choose the universe of discourse for both input and output variables as:

-Error (-200 to 200) degree

-Change of Error (-100 to 100) degree

-Control Action (-1 to 1) Volt

The simulation results using MATLAB/ Simulink and the discussion of the response of the system using the three types of the membership function will be given later.

Triangular Membership Function

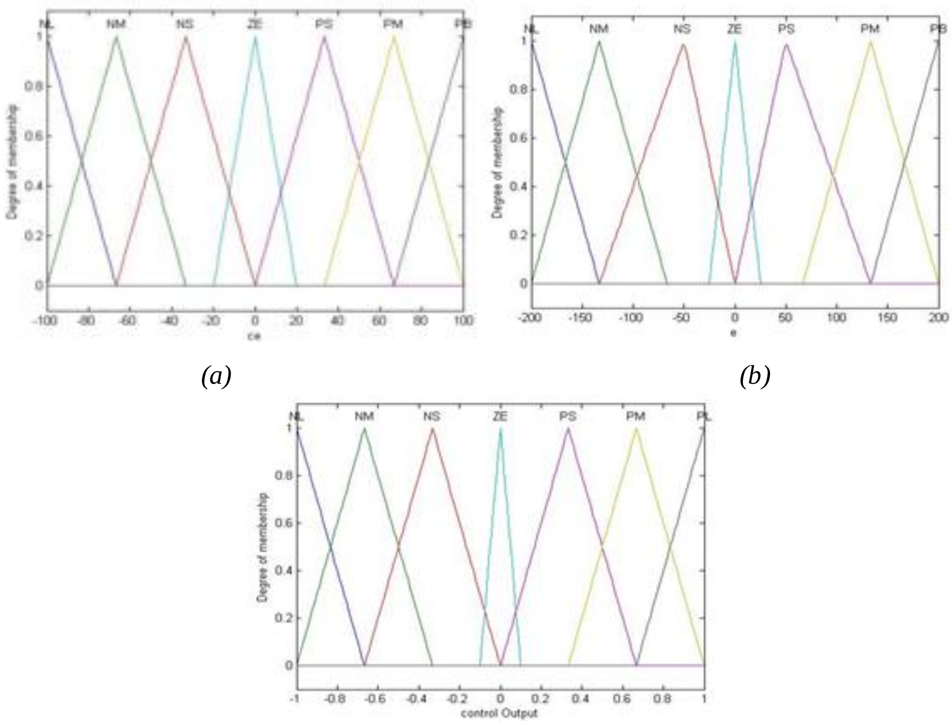
The input and output membership functions of the proposed FLC using Trapezoidal MF are given in Figure 4. (a, b & c).

Trapezoidal Membership Function

The input and output membership functions of the proposed FLC using Trapezoidal MF are given in Figure 5. (a, b , & c).

Gaussian Membership Function

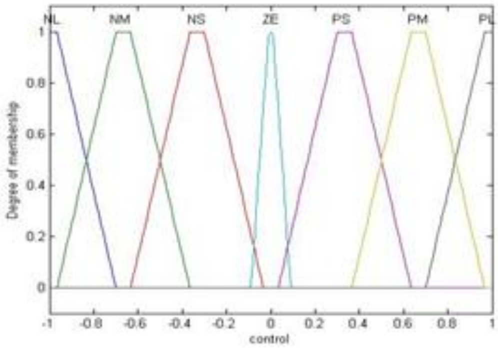
The input and output membership functions of the proposed FLC using Gaussian MF are given in Figure 6. (a, b & c).

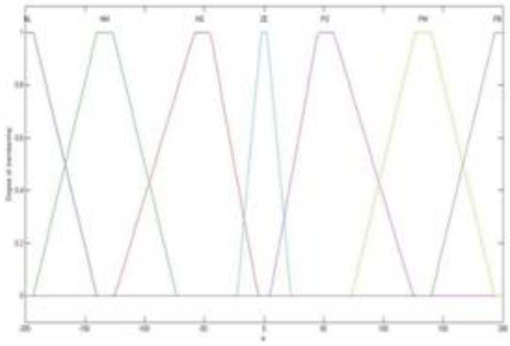


(a) (b)

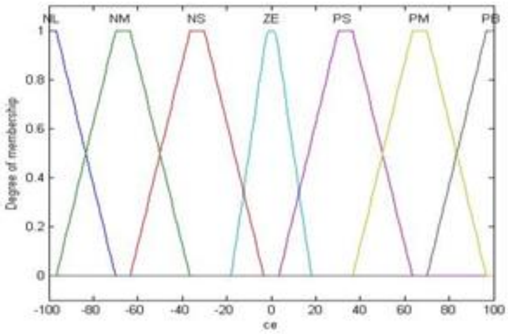
(c)

Figure4. *Input and output MF using Triangular MF (a) Error, (b) Error change, (c) Control action*



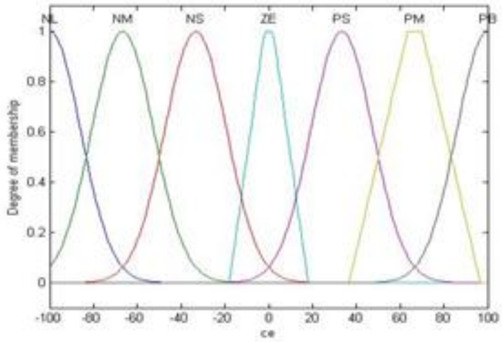


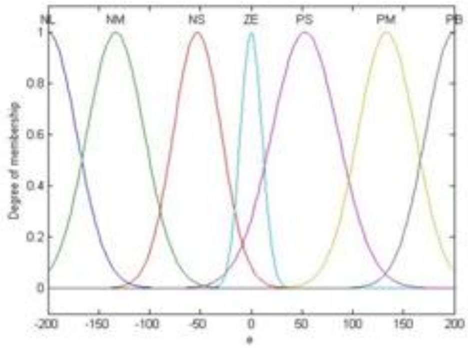
(a) *(b)*



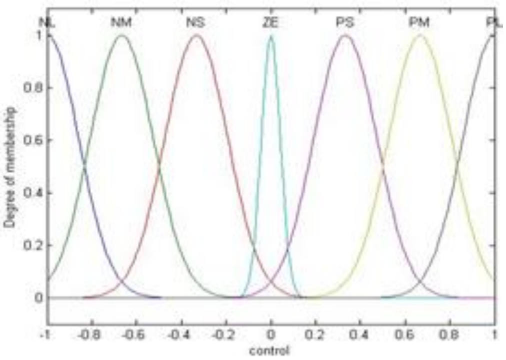
(c)

Figure5. *Input and output MF using TrapezoidalMF (a) Error, (b) Error change, (c) Control action*





(a) *(b)*



(c)

Figure6. *Input and output MF using Gaussian MF (a) Error, (b) Error change, (c) Control action*

Simulation Results

The simulation of Antenna Azimuth position control system is done using Matlab/Simulink toolbox. Mamdani type fuzzy logic controller is used for the implementation of this work. The proposed

Matlab/Simulink model is shown in figure 7. The simulation has been made considering two values for the desired azimuth position of the antenna; these values are [π/6 (0.5238) radian & π/3(1.047) radian].The performance comparison and the effect on the system response for the used three types of membership functions will be discussed later in the next section.

Position (π/6 (0.5238) radian)

The system response of the antenna azimuth position for a desired position (0.5238) rad, using (Triangular, Trapezoidal, & Gaussian MF`s) are shown in figure 8 (a, b, & c) respectively.

Position (π/3 (1.047) radian)

The system response of the antenna azimuth position for a desired position (1.047) rad, using (Triangular, Trapezoidal, & Gaussian MF`s) are shown in figure 9(a, b, &c) respectively.

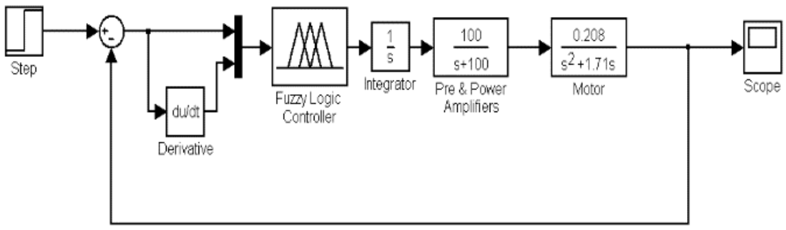
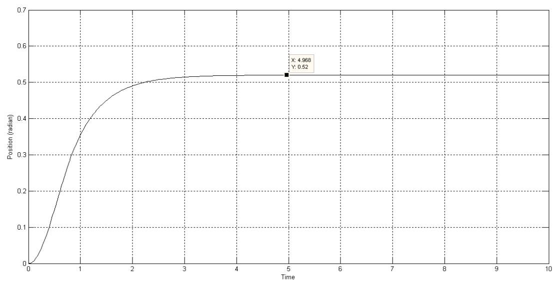
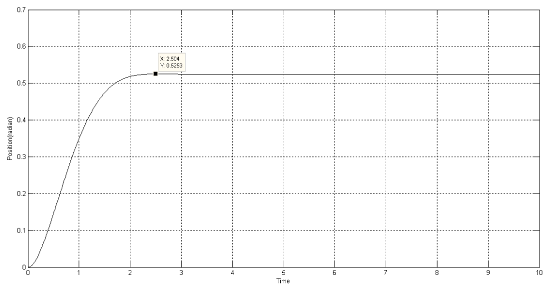


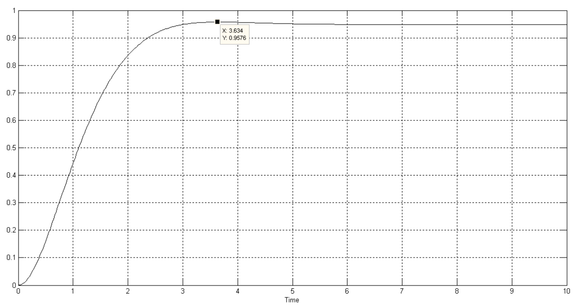
Figure7._Proposed System Model in MatLab/Simulink_



(a)

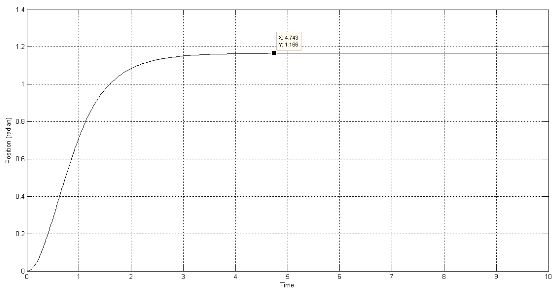


(b)

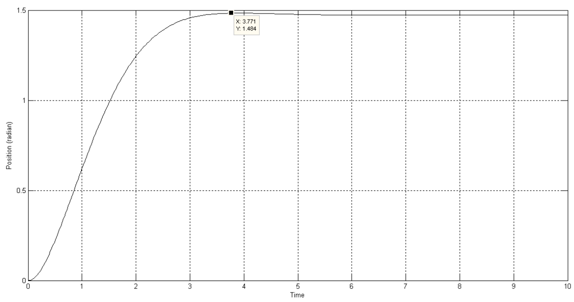


(c)

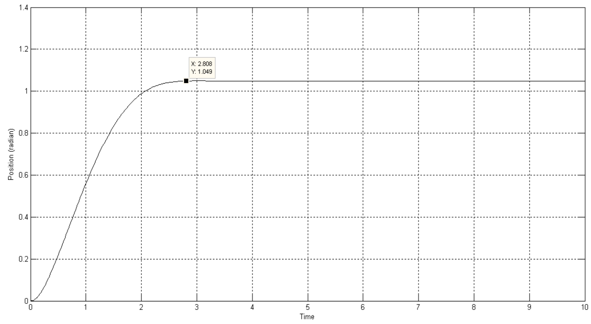
Figure8. *Antenna Position Using (a- Triangular MF, b- Trapezoidal MF c- Gaussian MF) for desired position ((0.5238) radian)*



(a)



(b)



(c)

Figure8. *Antenna Position Using (a- Triangular MF, b- Trapezoidal MF c- Gaussian MF) for desired position ((1. 047) radian)*

According to the results obtained in the previous section , the system response using three types of membership functions (triangular , trapezoidal & Gaussian) are compared in tables 2 & 3 in terms of system speed and steady- state error.

Table2. *System Response for position (π/6)*

Type of MF	Mp %	Tp / Sec.	Ess/ rad	Ts / Sec.
Triangular	0.13	2.8	0.0006	4
Trapezoidal	0	0	0.1184	4.74
Gaussian	46	3.771	0.4244	6.307

Table3. *System Response for position (π/3)*

Type of MF	Mp %	T_p / Sec.	E_{ss}/ rad	T_s / Sec.
Triangular	0.28	2.53	0.0002	3.874
Trapezoidal	0	0	0.0038	4.97
Gaussian	82	3.634	0.4142	6.4

CONCLUSION

This work has been successfully demonstrated effect of various membership functions in the fuzzy control of antenna azimuth position, different types of membership functions were explained. We took consideration for the most three popular types which are the triangular MF, trapezoidal MF&Gaussian MF. The fuzzy logic controller is implemented using these three MF`s, and the same MF is used for both the input and output variables. The response was analysed and compared and it shows that the triangular and trapezoidal MF are similar in response in terms of rise time and overshoot , but the triangular MF shows better performance concerning the steady-state behaviour specially with increasing the desired position angle. While the Gaussian MF was poor in response in all cases and this prove the theory that Gaussian MF are better in use concerning systems deals in data on probabilities and statistics.

REFERENCES

[1] ZadehL.A., "Fuzzy Sets", Information and Control Vol. 8, P (338-353),1965
[2] Mamdani, E. H., Application of fuzzy algorithms for the control of a simple dynamic plant. In Proc IEEE P (121-159), 1974.
[3] Hájek P., " Mathematics of Fuzzy Logic", Kluwer Academic Publishers, Dordrecht, The Netherlands , 1998
[4] Geurge J. KlirfBu Yuan," Fuzzy Sets And Fuzzy Logic", Prentice Hall,1995
[5] Li-Xin Wang," A Course in Fuzzy Systems and Control", Prentice-Hall International, Inc.,International Edition,1997.

[6] NiseN.,"Control Systems Engineering", John Wiley & Sons, Inc, 3rd Edition, 2000.

[7] Xuan L., Estrada J., DiGiacomandrea J.," Antenna Azimuth Position Control System Analysis and Controller Implementation", Project, 2009.

[8] J. GayathriMonicka," Performance Evaluation of Membership Functions on Fuzzy Logic Controlled AC Voltage Controller for Speed Control of Induction Motor Drive", International Journal of Computer Applications (0975 – 8887), Volume 13– No.5, January 2011.

[9] Pratumsuwan P., Thongchai S., Tansriwong S.," A Hybrid of Fuzzy and Proportional-Integral-Derivative Controller for Electro-Hydraulic Position Servo System",Energy Research Journal 1 (2): P 62-67, 2010.

[10] Shikha ,Lini& Rahul Gupta," Performance Comparison of Fuzzy Logic Controller with Different Types of Membership Function using Matlab Tools", IRNet Transactions on Electrical and Electronics Engineering,2010

[11] S. A. Loan & A. M. Murshid, "A novel VLSI architectureof multi membership function basedMAX-MIN calculator circuit," in Proc. of IEEEICAES Pilani, pp. 74-78, 2013.

[12] S. V. Shinde&U. V. Kulkarni "Modified Fuzzy Hyperline-Segment Neural Network For Classification With Mixed Attribues" 5th International conference on Computing, communication and Networking Technologies, IEEE pp. 1-7.

AUTHORS' BIOGRAPHY

Omar Adil M. Ali, received the B.Sc. degree in Electrical Engineering from Iraq, Baghdad, in Baghdad University in 1996, and the M.Sc. degree in Nuclear Engineering in Baghdad University in 2001. His research interests include Nuclear, Electrical, Electronic & Control Engineering, also in the field Fuzzy logic and Artificial Intelligence. Currently he is an assistant lecturer in Cihan University-Department of Communication and Control Engineering-Erbil-Iraq.

Aous Y. Ali, received the B.Sc. degree in Communication Engineering from Iraq, Mosul, in al Mosul University in 2009, and the M.Sc. degree in Electronic and Communication Engineering in SHIATS University in 2012. His research interests include Data communication and Telecommunication. Wireless communication systems, Mobile communication, control engineering, signal processing and Fuzzy logic.

Balasem Salem Sumit, received the Ph.D. in Electrical and communication /Department of Electrical and Communication /University TenagaNasional, Malaysia (2013), and the M.Sc. degree in Electrical and Electronic Engineering / Department of Electrical and Communication University of Technology, Iraq (2005), B.Sc. (2000) Electrical Engineering / University of Technology, Iraq. He is IEEE Member, member in IEEE in the following Societies, Communication Society (Gold Member), Computer Network Society, Broadband Communication Society, and Signal Processing Society. He has also worked as a Research Assistant with Dr. TiongSiehKiong at University TenagaNasional/Collage of Engineering since 2010 until 2013