Fuzzy Logic Controller in COG and MAMDANI Method

Tamilselvi.V (Assistant Professor)
PG Department of Mathematics
Vellalar College for Women, Erode.
Tamilnadu ,India.
tmlselvi18@gmail.com

T. Ahalya (II M.Sc., Mathematics)
PG Department of Mathematics
Vellalar College for Women, Erode
Tamilnadu ,India.
22pms104@vcw.ac.in

ABSTRACT

This project describes the process of fuzzy logic controller in waterbath temperature control system using MATLAB and MATLAB Fuzzy logic toolbox. The main aim is to achieve the output temperature of the waterbath system with good performance, stable, smooth and the least overshoot as nearly as the desired set point temperature at specified time period. This system utilized seven linguistic variables and 7*7 matrix rules for the fuzzy logic control system. Gaussian membership function will be applied in this system. The Max-min (MAMDANI) method and center of gravity singleton method for defuzzification will be used in the inference engines. The results of the simulink model with optimized efficient and good performance are presented. The desired output temperature is received from the waterbath system when this temperature is equal with the temperature which is initially defined in the step inputs of the simulating model by user.

INTRODUCTION

Waterbath temperature control system is significant utilized in many applications of process industries. For example: The production of drink products such as chocolate drinks, strawberry milk drink, etc,...are most widely used this temperature control. Fuzzy logic controller is designed with 49 rules and Gaussian Membership function. Center of gravity singleton method (COGs) is utilized to get the best accuracy of defuzzified value. If the temperature is higher than the bestowed range, the last outcome is poorly infected. So ,it is needed to arrive set point temperature rapidly, within marked time period and to reduce overshoot and error. Its first implementation to control the physical process which was proposed by MAMDANI. Then, fuzzy logic controller is received more interest due to its successful applications to significant industrial system.

Since FLC can adjust itself to altering situation it can outperform conventional PI Controllers for unstable dynamics and non-linear system. It contract to model based controllers, FLC is known as knowledge based controllers that does not require mathematics model of the process at any stage of the controller, design and implementation. Since, Waterbath hold heat of water very well, it is employed in industrial clinical laboratories, waste water plants, water bath are utilized in the application of sample, thawing, bacterial examinations, warming reagents, coin form determination and microbiological laboratory for incubations. Since the benefit of fuzzy logic controller is not needed for mathematical modeling, it is different with other controller, in particularly establish on the knowledge of the system conduct and experiment obtained by doing the control engines.

The advantages of FLC are as follows:
- High performance
- Low power consumption
- Low complexity, Low cost
- Ability to translate imprecise knowledge of human experts
- Easy to implement technology
- Software and Hardware design implementation support
- Results are easy to transfer from product to product
- Abilityto controlunstablesystemand Robustcontroller behaviour

Fuzzy controllers are more robust, because they can cover a much wider range of operating conditions and can operate with noise and disturbances of different nature. Developing a fuzzy controller is cheaper than other controllers to do the same thing. Fuzzy controllers are customizable and it is easier to understand and modify their rules, which not only use a human operators strategy but also are expressed in nature. It is easy to learn how Fuzzy controller operator and how to design and apply them to a concrete applications.

COG and MAMDANI METHOD

The Dynamics of the Waterbath temperature control system is,

$$\frac{dT}{dt} = \frac{F}{V}(T_i - T) + \frac{Q}{Vc_{p(\rho)}}$$

$$\frac{d_y(t)}{dt} = \frac{F(t)}{C} + \frac{Y_0 - Y(t)}{RC}$$

where

t = The time
T=The sampling time period
Y(t)=The output temperature
F(t)=The heat flowing inward the system
Y_0= The room temperature(constant for simplicity)
C=The system thermal capacity
R=The thermal resistance between the system borders and surroundings.

Taking the laplace transform of equation

$$sY(s) = \frac{F(s)}{C} + \frac{y_0(s)}{RC} - \frac{Y(s)}{RC}$$

$$a = \frac{1}{RC}, b = \frac{1}{C} \text{ and } U(s) = F(s) + \frac{ay_0(s)}{b}$$

$$sY(s) + \frac{Y(s)}{RC} = \frac{F(s)}{C} + \frac{y_0(s)}{RC}$$

$$Y(s)\left(s + \frac{1}{RC}\right) = \frac{F(s)}{C} + \frac{y_0(s)}{RC}$$

$$Y(s)(s + a) = bF(s) + ay_0(s)$$

$$Y(s)(s + a) = b\left[F(s) + \frac{ay_0(s)}{b}\right]$$

$$Y(s)(s + a) = b[U(s)]$$

$$\frac{Y(s)}{U(s)} = \left(\frac{b}{s+a}\right) = G(s)$$

Taking transform,

$$G(z) = \frac{Y(z)}{U(z)} = \frac{(bz)}{(z-a)(z-1)}$$

Symbolizing by a , b as some constant values depending values depending on R and C, the remaining parameter can be expressed by

2

$$a = e^{-\alpha(T)}$$

and

$$b = \frac{\beta}{\alpha}(1 - e^{-\alpha T})$$

.

The parameters are $\alpha = 1.00151 \times 10^4$ and $\beta = 8.67973 \times 10^{-3}$ was obtained from real water plant.

$$G(z) = \frac{Y(z)}{U(z)} = \frac{0.26z}{(z-0.9969)(z-1)}$$

$$G(z) = \frac{Y(z)}{U(z)} = \frac{0.26z}{z^2 - 1.9969z + 1.9969}$$

Assumed that the sampling period is limited by $T \geq 30$ sec

. **TESTING THE DEFUZZIFIED VALUES:**

Checking with the hand calculation using COG$_s$ method

1. Let error temperature = -0.8
   change of error temperature = -0.6
   error e(k) LN at (0.7) MN at (0.3)
   Derivative of error de(k) MN
   According to the values must be plotted on the output membership function.

   a) If e(k) is LN and de(k) is MN then the output is LN(-0.8496)
   b) If e(k) is MN and de(k) is MN then the output is MN(-0.8496)

   By using minimum method ,

   $$\mu1 = min\{0.7,1\} = 0.7$$

   $$\mu2 = min\{0.3,1\} = 0.3$$

2. The membership member function for the conclusion reached by the rules,

   $$\mu1(x) = min\{0.7, LN\}$$
   $$\mu2(x) = min\{0.3, LN\}$$
   Since $\mu1(x) = min\{0.7, LN\}$

   Calculate the μ crisp value with center of gravity singleton method,

   $$\mu = \frac{\sum_i \mu(s_i)s_i}{\sum_i \mu(s_i)}$$
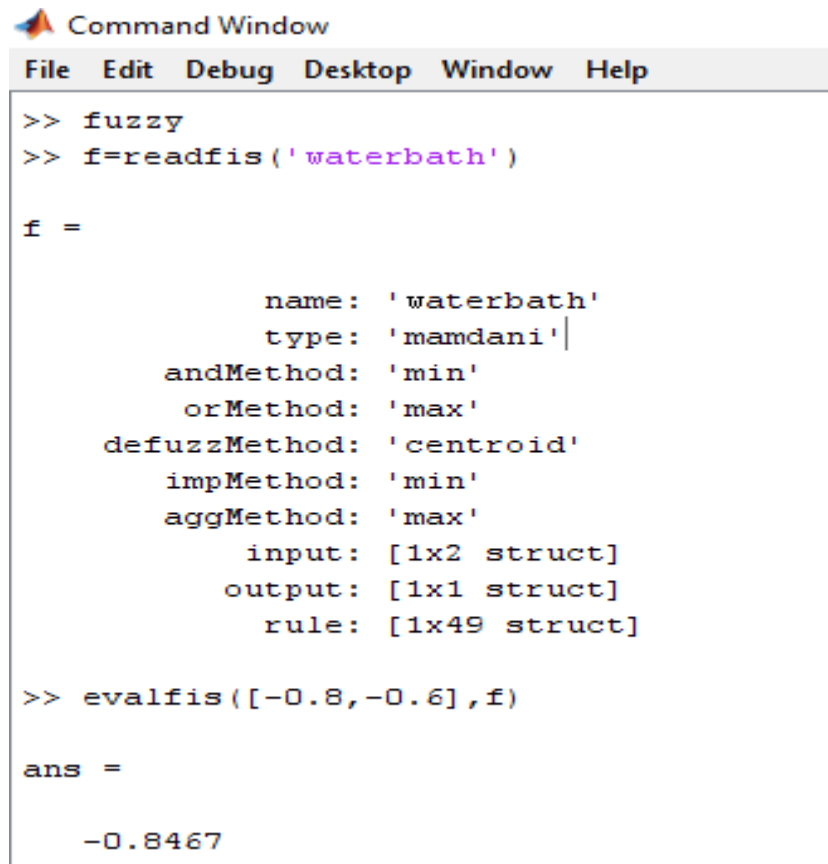
   $$\mu = \frac{0.7 \times \mu_{LN}}{0.7}$$

   $$\mu = \frac{0.7 \times -0.8496}{0.7}$$

   $$\mu = -0.8496$$

3

From the above calculation, it is founded that the large negative value of the output signals. The calculated value is -0.8496.

Checking with MATLAB


```
Command Window

File  Edit  Debug  Desktop  Window  Help

>> fuzzy
>> f=readfis('waterbath')

f =

              name: 'waterbath'
              type: 'mamdani'
         andMethod: 'min'
          orMethod: 'max'
       defuzzMethod: 'centroid'
         impMethod: 'min'
         aggMethod: 'max'
             input: [1x2 struct]
            output: [1x1 struct]
              rule: [1x49 struct]

>> evalfis([-0.8,-0.6],f)

ans =

    -0.8467
```

The final value of hand calculation is compared to MATLAB, both are equal. So, the defuzzified value is precise and the rule base of FLC that utilize in this system is confirmed.

DESIGN PROCEDURE:

1.   **Fuzzy Logic Controller[FLC]**

The two inputs and single output are designed in the FLC to control the water temperature of the water bath system. The inputs of the FLC are error (e), derivative of error (de) and u is the output signal of the fuzzy logic controller. The block diagram of FLC with water bath temperature control system in figure
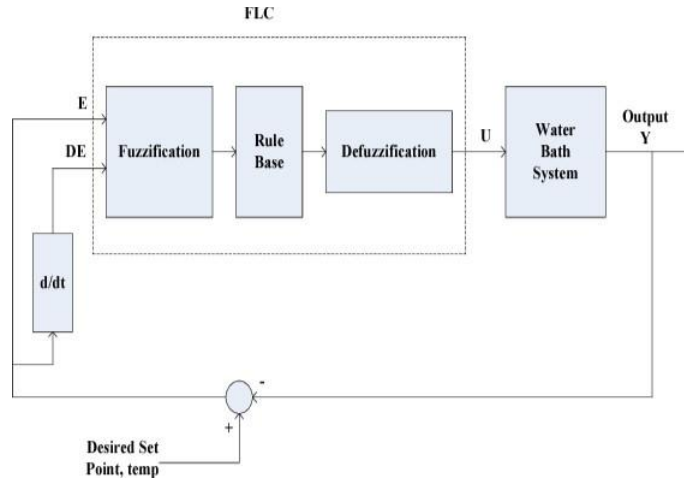
Figure 1: Block diagram for FLC

The fuzzy logic controller contains three parts. These are fuzzification is converted the crisp values to fuzzy values. Rule base is a collection of rules to apply in a special system. Defuzzification is transformed the fuzzy values to non fuzzy values [crisp values]. The output of the FLC is the control signal which is the input of the water bath temperature control system. The water bath system is produced the actual temperature. The error temperature value is the difference between the desired set point temperature and the actual temperature come back as the feedback from the water bath system. The derivative of error temperature is received by taking the derivation of error temperature with respect of time. This system is utilized the five GUI tools to implement the FLC

Fuzzy logic toolbox has five GUI tools to create , revise and investigate the fuzzy inference system. They are FIS editor, Membership function editor, Rule viewer, Surface viewer and Rule editor the FIS editor window of FLC is displayed in figure.
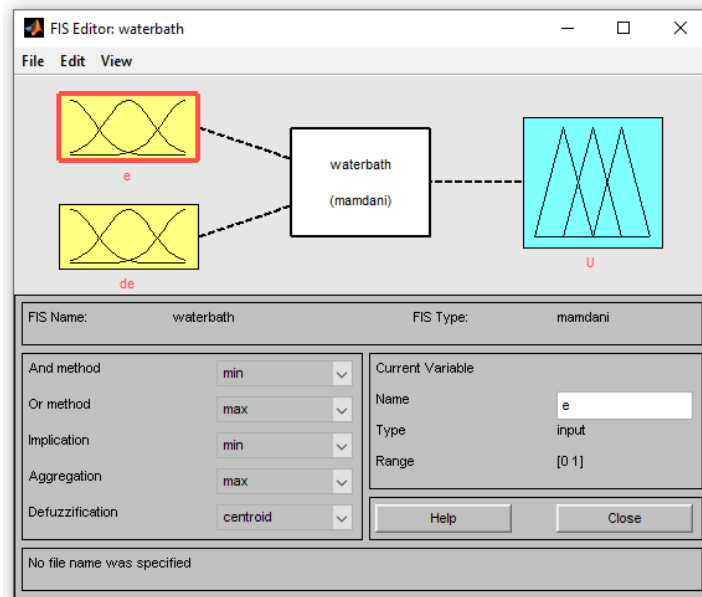

.

Figure 2: FIS editor of FLC

5

2 .Membership Functions:

The two inputs and single output membership functions of FLC are defined on the common range [-1,1].The Gaussian membership function are utilized with equal base and 50 percent over lab between the vincity membership functions. Therefore, the seven fuzzy set of FLC inputs and outputs are Large Negative(LN), Medium Negative(MN), Small Negative(SN), Zero(ZE), Small Positive(SP), Medium Positive(MP) and Large Positive(LP). TheGaussian Membership function of inputs and output is presented in
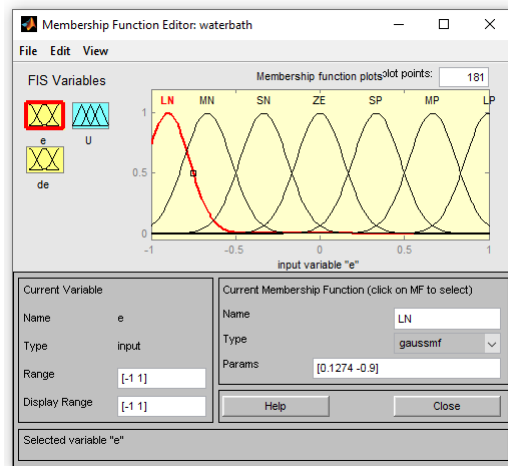

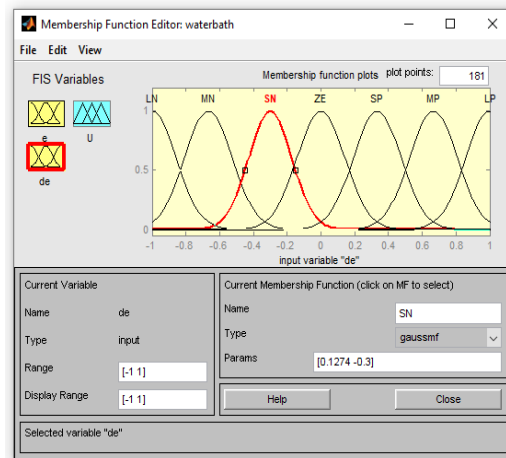**Figure 3: Gaussian Membership function for error temperature**
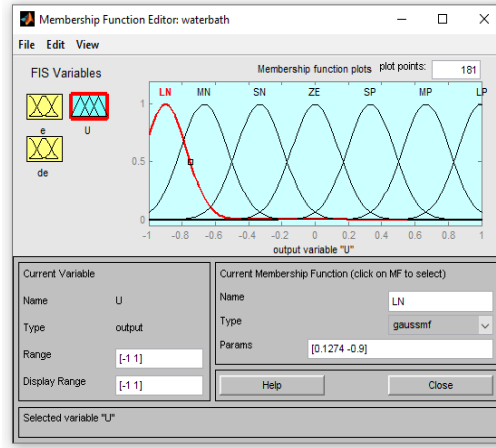

Figure 4: Gaussian Membership function for change of error

Figure 5: Gaussian Membership function for control signal

where ,

LN : Large Negative
MN : Medium Negative
SN : Small Negative
ZE : Zero
SP : Small Positive
MP : Medium Positive
LP : Large Positive

Rule Base

DE/E	LN	MN	SN	ZE	SP	MP	LP
LP	ZE	SP	MP	LP	LP	LP	LP
MP	SN	ZE	SP	MP	LP	LP	LP
SP	MN	SN	ZE	SP	MP	LP	LP
ZE	LN	MN	SN	ZE	SP	MP	LP
SN	LN	LN	MN	SN	ZE	SP	MP
MN	LN	LN	LN	MN	SN	ZE	SP
LN	LN	LN	LN	LN	MN	SN	ZE

The seven liguistic variables and 49 rules are applied to design the FLC. The rules are restrain if error temperature is LN and derivative of error temperature is MP, then control signal is SN as shown in table
The following 49 rules are:

1. If(e is LN) and (de is LP) then (u is ZE)
2. If(e is LN) and (de is MP) then (u is SN)
3. If(e is LN) and (de is SP) then (u is MN)
4. If(e is LN) and (de is ZE) then (u is LN)
5. If(e is LN) and (de is SN) then (u is LN)
6. If(e is LN) and (de is MN) then (u is LN)
7. If(e is LN) and (de is LN) then (u is LN)

8. If(e is MN) and (de is LP) then (u is SP)
9. If(e is MN) and (de is MP) then (u is ZE)
10. If(e is MN) and (de is SP) then (u is SN)
11. If(e is MN) and (de is ZE) then (u is MN)
12. If(e is MN) and (de is SN) then (u is LN)
13. If(e is MN) and (de is MN) then (u is LN)
14. If(e is MN) and (de is LN) then (u is LN)
15. If(e is SN) and (de is LP) then (u is MP)
16. If(e is SN) and (de is MP) then (u is SP)
17. If(e is SN) and (de is SP) then (u is ZE)
18. If(e is SN) and (de is ZE) then (u is SN)
19. If(e is SN) and (de is SN) then (u is MN)
20. If(e is SN) and (de is MN) then (u is LN)
21. If(e is SN) and (de is LN) then (u is LN)
22. If(e is ZE) and (de is LP) then (u is LP)
23. If(e is ZE) and (de is MP) then (u is MP)
24. If(e is ZE) and (de is SP) then (u is SP)
25. If(e is ZE) and (de is ZE) then (u is ZE)
26. If(e is ZE) and (de is SN) then (u is SN)
27. If(e is ZE) and (de is MN) then (u is MN)
28. If(e is ZE) and (de is LN) then (u is LN)
29. If(e is SP) and (de is LP) then (u is LP)
30. If(e is SP) and (de is MP) then (u is LP)
31. If(e is SP) and (de is SP) then (u is MP)
32. If(e is SP) and (de is ZE) then (u is SP)
33. If(e is SP) and (de is SN) then (u is ZE)
34. If(e is SP) and (de is MN) then (u is SN)
35. If(e is SP) and (de is LN) then (u is MN)
36. If(e is MP) and (de is LP) then (u is LP)
37. If(e is MP) and (de is MP) then (u is LP)
38. If(e is MP) and (de is SP) then (u is LP)
39. If(e is MP) and (de is ZE) then (u is MP)
40. If(e is MP) and (de is SN) then (u is SP)
41. If(e is MP) and (de is MN) then (u is ZE)
42. If(e is MP) and (de is LN) then (u is SN)
43. If(e is LP) and (de is LP) then (u is LP)
44. If(e is LP) and (de is MP) then (u is LP)
45. If(e is LP) and (de is SP) then (u is LP)
46. If(e is LP) and (de is ZE) then (u is LP)
47. If(e is LP) and (de is SN) then (u is MP)
48. If(e is LP) and (de is MN) then (u is SP)
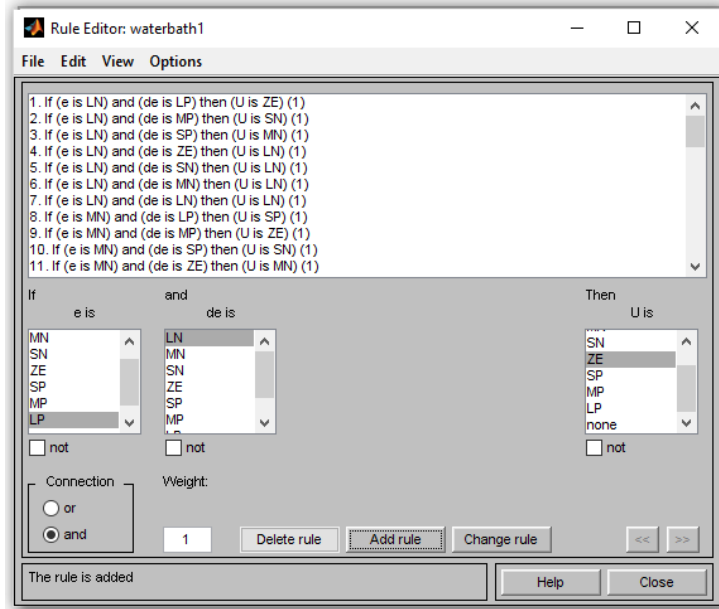49. If(e is LP) and (de is LN) then (u is ZE)
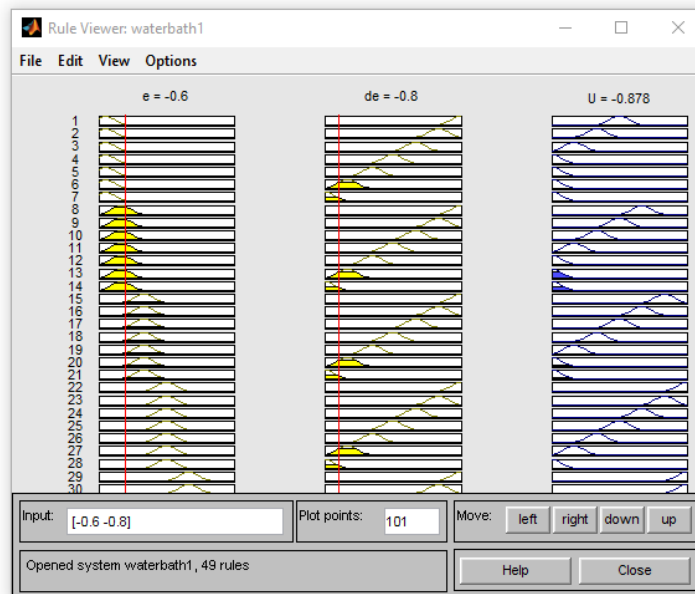
Figure 6: Rule editor of FLC
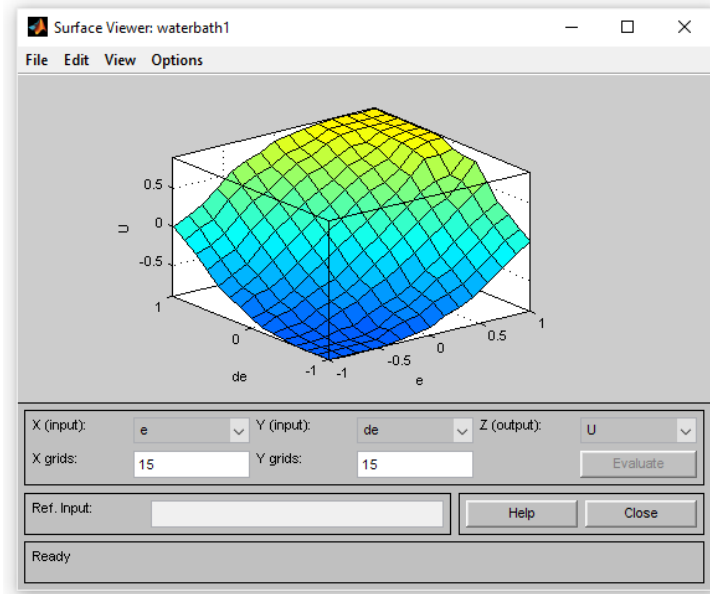

Figure 7: Rule viewer of FLC

Figure 8: Surface viewer of FLC

Building the rule declarations in if-then formate is permitted by the rule editor establish on representations of input and output changeable described with FIS Editor. The Fuzzy system can be saved, closed, opened and edited by the menu items in the five GUI tools. The function block parameter for FLC is displayed. The fuzzy inference system that serves in the fuzzy logic toolbox has to be saved with name .fis file. Then, this .fis file must to be inserted in fuzzy logic controller block to simulate tha tank model. So, this fuzzy block parameter is essentially needed to send and save current fuzzy inference system into the workspace by writing the name .fis in this block.

Desired at point Temperature (°C)	Specified time period (in minutes)
35	$0 \leq t \leq 30$
45	$30 < t \leq 60$
55	$60 < t \leq 90$
65	$90 < t \leq 120$
75	$120 < t \leq 150$
85	$150 < t \leq 180$
75	$180 < t \leq 210$
65	$210 < t \leq 240$
55	$240 < t \leq 270$

.

Therefore , the desired Temperature is defined in input. The Initial temperature value is set 35 for $0 < t \leq 30$ min in input. Then $30 < t \leq 60$ min , 55 for $60 < t \leq 90$ min , 65 for $90 < t \leq 120$ min , 75 for $120 < t \leq 150$min ,85 for $150 < t \leq 180$ min , 75 for $180 < t \leq 210$ min , 65 for $210 < t \leq 240$ min , 55 for $240 < t \leq 270$ min are set in the next step , it can be seen that FLC is operated quickly and delivered the result depend on the requirement of user. So, the result is good and best efficiency by using COG_s method and gaussian membership function for this system.

CONCLUSION

This project describes the performance evaluatiom of fuzzy logic controller in water bath system to control the temperature. This system is executed through the MATLAB simulink and MATLAB Fuzzy logic Toolbox. Also 49 rules and Gaussian Membership function is applied to get the best result for this system. It can be seen that the FLC is operated quickly and delivered the result depend on the requirement of user. So, the result is good and best efficiency by using center of gravity method and Gaussian membership

REFERENCE

1. https://nitsr.ac.in "Fuzzy set theory ".

2. https://codecrucks.com "Fuzzy sets (Type 1 and 2) ".

3. https://www.marian.ac.in "Module IV ".

4. https://www.tutorialspoint.com "Artificial Intelligence - Fuzzy logic control systems ".

5. https://www.mathworks.com "Fuzzy Inference Process – MATLAB works and MAMDANI method ".

6. https://www.wikipedia.org "Fuzzy rule ".

7. Norhaslinda Hasin., Mohd Zamauri Ab Rashid., "Development of Fuzzy Logic Water Bath Temperature Controller using MATLAB ", 2012 IEEE International Conference on Control System, Computing and Engineering, Nov.2012, Penang.

8. https://en.m.wikipedia.org "Singleton ".

9. https://www.britannica.com "Laplace Transform ".

10. Marimuthu N.S, NCE, Anna University, Tamil Nadu GCE, College of Engineering, University of Kerala, "Design of Intelligent Self-Tuning Temperature Controller for Water Bath Process " International Journal of Imaging Science and Engineering (IJISE).

11. https://en.m.wikipedia.org "Defuzzification ".

12. https://en.m.wikipedia.org "Fuzzy Control System ".

13. Abraham Kandel., "Fuzzy expert system ", CRC press, 1991.

14. Om Prakash Verma., "Intelligent Temperature Controller for Water-Bath System", International Journal of Computer, Information Science ans Engineering Vol:6 No:9,2012.

15. Novel by George klir., "Fuzzy sets and Fuzzy logic ", Prentice hall ptr, 1995.

16. https://www.julabo.com, "Applications of water baths ".

17. www.slideshare.net.com, "Water bath laboratory applications ".

18. https://user.engineering.uiowa.edu "Fuzzy Logic ".