

Anfis with Cauchy membership function for robotic arm

NaserAlanabi¹, Dr. Jyoti Shrivastava²

¹ Research Scholar, ² Senior Assistant Professor

^{1,2} Department of Electrical and Electronic Engineering, College of Engineering and Technology, SHIATS, Allahabad, India.

Email : ¹nassa1968@gmail.com, ²jyotishri72@rediffmail.com

Abstract-An adaptive fuzzy gain scheduling scheme for robotic arm has been proposed. This paper focus on adaptive fuzzy based tracking and gain controller algorithm for obtaining the joints position relative to the desired trajectory, which drives static and different time variations on the environmental changes. We able to estimate them at any point of time, when $t > 0$ or alternatively, starting from the fuzzy initial states, Fuzzy initial states along with system dynamic equations provide us particular fuzzy differential equations (FDEs), referred as fuzzy Cauchy problem, we construct the fuzzy Cauchy problems during the initial time, we introduce two different ways, first we apply the non-fuzzy differential equations with initial conditions of data based. And the second, we apply with anfis with Cauchy membership function for robotic arm to apply with two angles. The proposed adaptive fuzzy based tracking and gain controller algorithm requires much less training patterns than a neural net based adaptive scheme does and hence avoiding excessive training time. Results of simulation show that the proposed adaptive fuzzy controller offers better performance than fixed gain controllers at different operating conditions.

Index terms-Fuzzy logic, Cauchy Membership Function, ANFIS, Robotic arm.

1 INTRODUCTION

In the brainy control of a robotic arm, movementschedulingplays a vital role and also akey task. The greatest interesting task is the difficult of picking stability through the dynamic equations of nonlinear to undefinesituation. To perform these tasks, the solicitations of artificial intelligence like fuzzy logic and neural networks in designing and control are considerably developing particularly in latest years. For this, manyresearchers introduced numerous methodologies used genetic algorithms or fuzzy logic [9, 10, 12, and 13]. In order to permit for fuzziness and uncertainties of path statistics, path state of affairs can be demonstrated using fuzzy linguistic variables.Robotic arm is also established using new simple and overalloutlinetechniques for Robotic control[7]. The basis of malfunctioning of the Robotic arm is the obstacles.To overcome this issue, numerousdeterminations have been doneby providing effective arm movement routes for escapinghindrances. When assign this as probability, thisdriveslaterallywith the real time procedure and their control for improved performance. The design and methods for probabilistic self-localization for Robotic arm was established by Olson C.F. et al. [6]. To provide path optimization of multiple manipulators, Garget. al. effectivelyapplied torque reduction for path optimization of multiple manipulators[8].To advance accurate mathematic model, Zhang MingLu and Jiao Xinjing applied the classical control theory which produced the substantial results [5].To estimate the unfamiliar robotic dynamics, Fuzzy logic system is presented by using adaptive algorithm. Fuzzy system to robot course-plotting is introduced by Edward T.

Lee [5]. Thesteady adaptive fuzzy-based chasing control for roboticarmbyconstraint uncertainties and exteriordisruption was developed by H. F. Ho et al. [11].Ahamed W has applied sustainable attention to the intellectual control techniquedepends on the design of structureperformance such as the ant colony algorithm, fuzzy control method[14]. Neverthelessthese methods has an essential to improve their performance. Particularly, the pure performance model is discussed through the fuzzy logic and the unique mathematical design is unnoticed and the offline phase fuzzy control demonstrating scheme is simplydebated. In order to make the picking arm apperceive accurately complex environmental condition, to regulate their speed and reach smoothly the target position.

The electrical portions of robot manipulators are used to run the regulators, actuators, which also has the subsequent sub portions: DC/stepper/servo motors or hydraulic/pneumatic cylinders, power amplifier, power supply,and transmission part [1, 2&4]. To regulate the timing between the sub portions of robotic arm to spread the toproute,Control part is used.The greatest task in control algorithms is a linear compartment controller project for nonlinear systems. Linear PID controllers are used in robot manipulators. In this, when we go for designing part, this robotic manipulator is very hard since this system is barely nonlinear and indeterminate.To mitigate aforementioned issues, the nonlinear robust controller is used to control the system of nonlinear. In which, the Computed torque controller is a powerful nonlinear controller. The concept behind this is feedback linearization and calculation of the compulsory arm torques by the control law of nonlinear feedback. This controller performs very healthy, when altogetherthe sphysicaland

the dynamic constraints are identified. It has the disadvantage i.e dissimilarity in dynamic constraints.

In this paper, we have used the fuzzy tracking controller to get the wanted joints tracking route. By this, we can maintain the performance of the robotic arm by the parameters like taking coordination skill and driving velocity and angle velocity on the circumstances of altering situation. To overcome the aforementioned issues like nonlinear and uncertainties, we have used the nonlinear robust controller which is used to regulate the robotic arm. Here the nonlinear controller is Computed torque controller. And we have used fuzzy logic theory to mitigate the uncertainties difficult. In this investigation, we have applied PD fuzzy controller to adjust the coefficients of CTC.

2 RELATED WORK

2.1. Robotic Systems

The robotic structures are branched through their degree-of freedom. A very simple robotic system which has two DOF while a complex robotic system which has more DOF. The robotic arm movement is stimulated by the constraints of friction, settling time and joint motion. The parameter of friction need to be careful with respect to robotic arm movement. The most significant feature in the circumstance of any real time designs is settling time. The transient response is mentioned by the settling time. High-speed robots have the smallest settling time. By this, this provides less physical vibrations in the motion of robotic arm. The joint motion is based on the angular motion of the joint. The power requirement is regulated by the Joint movement. The theoretical angular movement is defined by the actual angular arm motion which is delivered by the controller minus the movement lost due to friction.

2.2 Dynamic Formulation of 2-DOF Robot Manipulator

To define the performance of robotic manipulator such as nonlinear or linear dynamic behavior, Dynamic modeling of robot manipulators is used. The link of parameters among accelerations to force/torque or current/voltage, joint movement and velocity is defined by the dynamic design of Robot manipulator and the specific dynamic effects of inertia, coriolios, centrifugal, and the other parameters to the performance of system is also termed by the dynamic design of Robot manipulator. The subsequent equation is the equivalence of an *n-DOF* robot manipulator equation [2, 3]:

$$M(q) \ddot{q} + N(q, \dot{q}) = \tau \tag{1}$$

Where τ is the actuation torque, $M(q)$ is the symmetric and positive described inertia matrix, $(N(q, \dot{q}))$ is the

vector of nonlinearity term. This dynamic equation can also be inscribed in a succeeding form [20-25]:

$$\tau = M(q)\ddot{q} + B(q) [\dot{q} \ \dot{q}] + C(q) [\dot{q}]^2 + G(q) \tag{2}$$

Where $C(q)$ is the matrix of centrifugal torques in manipulator position, $B(q)$ is the matrix of coriolios torques in manipulator position, and $G(q)$ is the vector of gravity force in manipulator position. This is represented as a decoupled design by the humble second order linear differential dynamics. Thus, the angular acceleration is originate as future [4]

$$\ddot{q} = M^{-1}(q) [\tau - N(q, \dot{q})] \tag{3}$$

By the control fact of opinion, this method is very pretty.

2.3 Representation of Picking Robot Arm Trajectory Tracking

The recent posture of taking robotic arm is shown as Fig.1. This is denoted as (x, y, θ) , the expectation posture denoted as (x_r, y_r, θ_r) , additionally the input regulatory point of picking and controlling robotic arm is represented as $P(v, w)$, route error of picking and controlling robotic arm is described as next in terms of coordinates,

$$\begin{bmatrix} x_e \\ y_e \\ \theta_e \end{bmatrix} = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_r - x \\ y_r - y \\ \theta_r - \theta \end{bmatrix} \tag{4}$$

The differential posture error equations is represented by the succeeding

$$\begin{cases} \dot{x}_e = w y_e - v + v_r \cos \theta_e \\ \dot{y}_e = -w x_e + v_r \sin \theta_e \\ \dot{\theta}_e = w_r - w \end{cases} \tag{5}$$

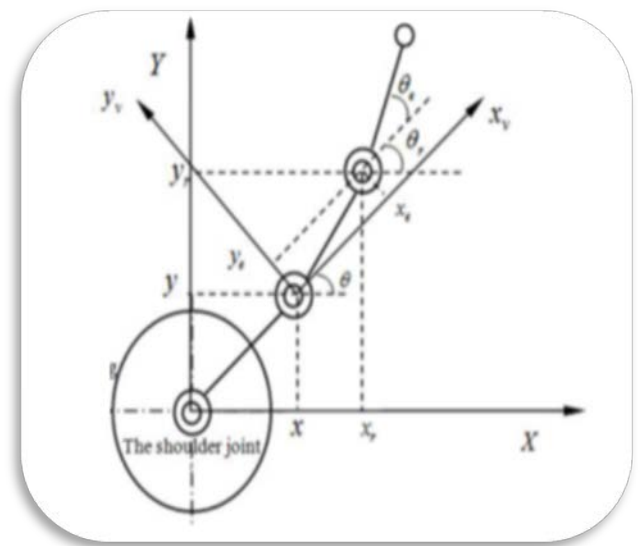


Figure.1 Diagram of Pose Error for Picking-arm in the Coordinate

To discover the prerequisite of the limited joint angular velocity w and joint input velocity v , the scheme $(x^e, y^e, \Theta_e)^T$ should be restricted on the condition of control input and encounter by the state of $\lim_{t \rightarrow \infty} \|(x_e, y_e, \theta_e)^T\| = 0$ any error for the determination of looking for control degree. Initially based on the preferred path curvature, adjust the fuzzy control variable of the joint velocity, then apposed y_e and Θ_e control input to get the fuzzy chasing control variable of joint angular velocity.

2.4 The Picking Arm Fuzzy Control Strategy

The dynamic features of the picking and controlling robotic arm route planning is extremely nonlinear motion with the speed of 0.5 to 15 km/h, which features difficult link of time domain and the distributed system constraints. So, in order to overcome the stability control problem, it is vital to create the whole mathematical design to label the origin of control motivating necessities. By using fuzzy logic, it can improve the user practice performance to mimic the human dynamic expectation and reaction behavior without using not much mathematical expression and create the steady fuzzy choice and perform the determined discrimination. The fuzzy controller based on the principle of taking robotic arm is shown in Figure.2. The main assembly comprises the exact fuzzification, fuzzy judgment, fuzzy approach and fuzzy control instructions.

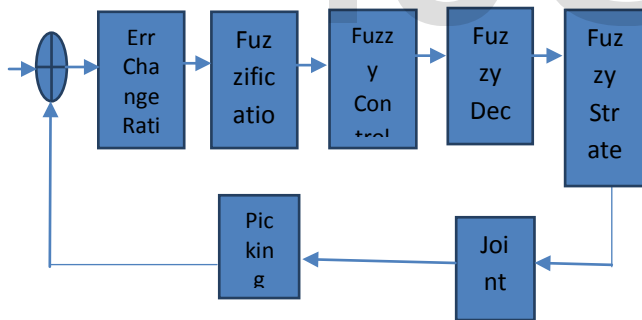


Figure.2 The Fuzzy Control Principle of Picking-arm

The Joint velocity error and joint Velocity Error in Angular are the input language variables. To diminish the overshoot and decline the influence, these input language variables can promise the system on start-up and acceleration trembling of taking robotic arm.

2.5 Non-Fuzzy Relation between Posture and the Desired Trajectory

This section explains the control characteristic of non-fuzzy association among the posture and the wanted route with the real picking power transmission and the attained preferred through the literature review. The arm joints initiate quality center angle and driven time

relationship diagram are shown in Figure.3 and Figure.4, so applying the fuzzy chasing algorithm is the trajectory tracking control goal and create it charming and firm run in order to detain its waving.

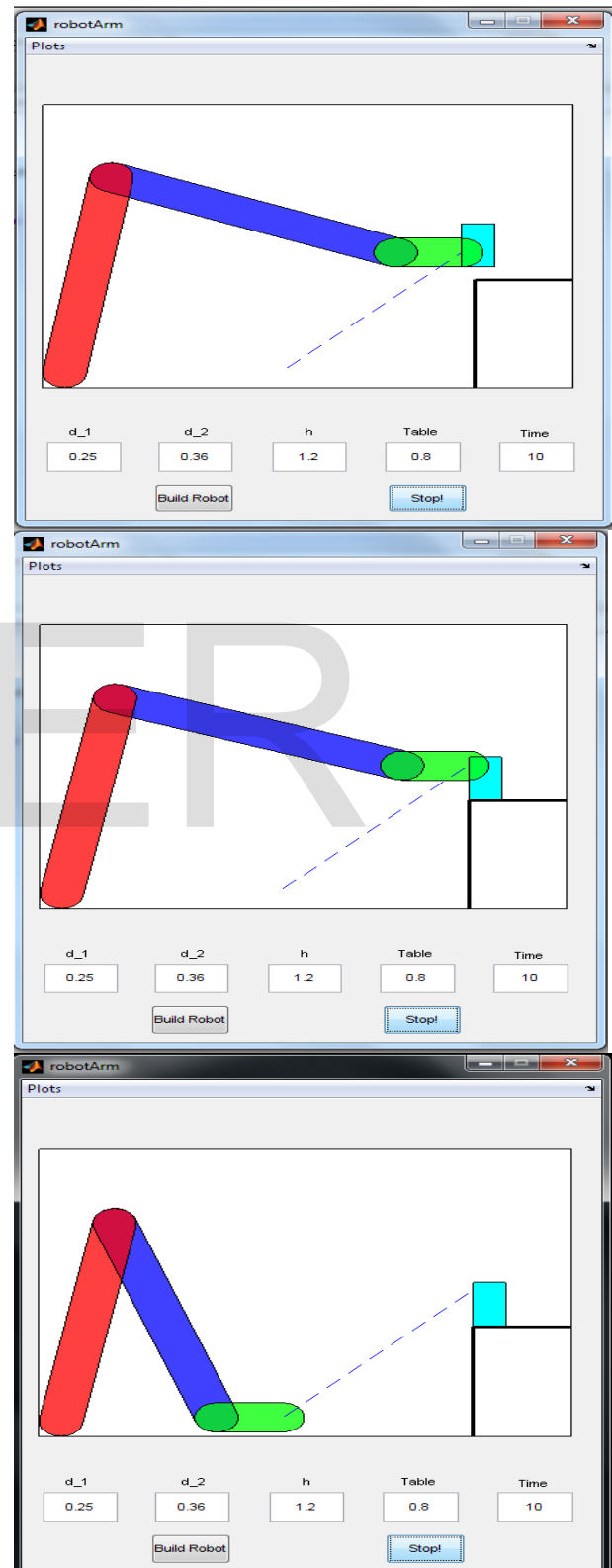


Figure a,b,c states that Driven State Position of the Robotic Arm Movement

2.6 Picking Arm Fuzzy Controller

The two input variables of the angle error TG and Velocity Error in Angular TGC and an output variable u and the 56 rules are present in the fuzzy controller of picking and controlling robotic arm .

(1). The angle error TG : consider the fixed error Tg and feedback error Tf are linguistic variables TG , the membership function form is shown in Figure.5, the center point of TG triangular form fluctuations consistently within $[-0.03:0.01:0.03]$.

$$TG = Tg - Tf \tag{6}$$

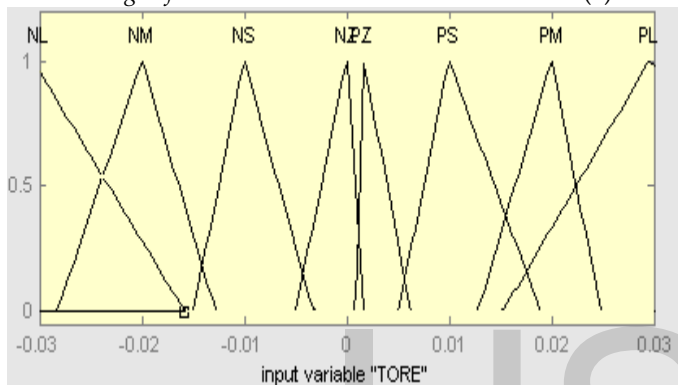


Figure.5 TG Membership Function

(2). The Velocity Error in Angular TGC : observed as angular velocity variance error in separate time, the joint angle speed error membership shown as Figure.6, the representation of the linguistic variables is given below, $TGC = TG * t - TG(t-1) * T / \Delta t$.

$$\tag{7}$$

Where, differential time is $t - kT$ ($k=0,1,2,\dots,n$), T is the period of sampling, 7 triangular membership occupations are described as Figure.6, the membership midpoint variable altered in $[-0.5:0.2:0.5]$.

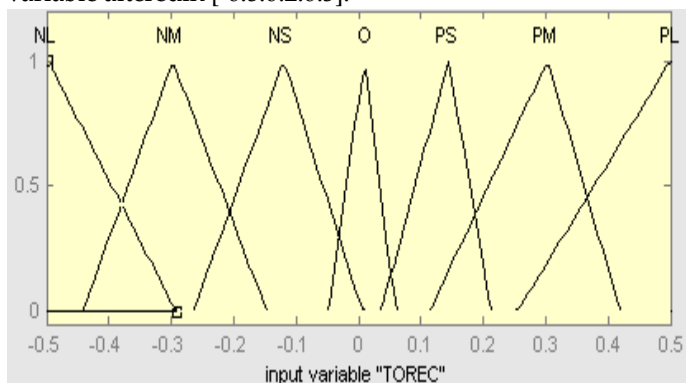


Figure.6 Membership Function of TGC

(3) Output Variables in Joint U : Joint triangle figure's midpoint lies respectively $-0.2, -0.12, -0.05, 0, 0.05, 0.13, 0.2$, the physical features of research and sensor are decided by the variable form. The joint servo motor in 2ms

will be used to do the command. If the output variable is unstable, the improvement of the anti-fluttering requires the steadying action. So, the fuzzy based rule strategy is core design of picking arm.

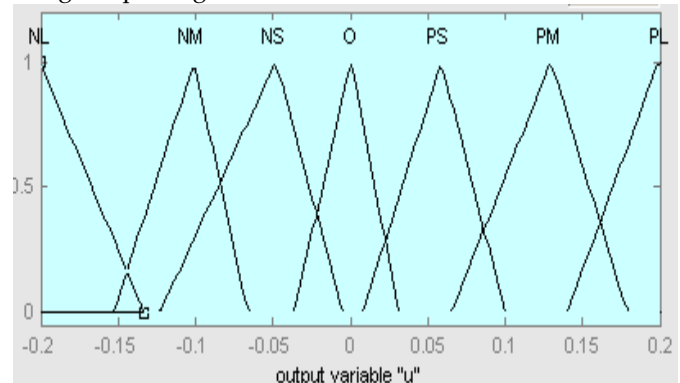


Figure.7 Joint Output Control Linguistic Variable U

3 PROPOSED WORK

This section explains the algorithm of fuzzy control for picking and controlling robotic arm and the algorithm of fuzzy tracking and the fuzzy gain scheduling controller using Computed torque controller.

3.1 Adaptive Fuzzy Control Algorithm of Picking & Controlling Robot Arm

The fuzzy control algorithm shadowed the "If TG and TGC then U ". The algorithm of Fuzzy control for picking and controlling robotic arm using TG, TGC, U and 56 inference language rules is proposed as R following

- (1) If $TG = NL$ and $TGC = NL$ then $U = PL$
- (2) or If $TG = NL$ and $TGC = NM$ then $U = PL$
- (3)
- (55) or If $TG = PM$ and $TGC = PL$ then $U = NL$
- (56) or If $TG = PL$ and $TGC = PL$ then $U = NL$

The human strategy is reproduced by the overhead 34 fuzzy control rules. The variables of Linguistic are described in the sets of fuzzy. Based on the knowledge of fast removal rules, the fuzzy algorithm is attained. The control rules of fuzzy for picking robot arm shown as Table.2

Table.2 Fuzzy Control Rules Status of Joint

TORE	TOREC							
	NL	NM	NS	NZ	PZ	PS	PM	PL
NL	PL	PL	PL	PL	PM	PS	PS	PZ
NM	PL	PL	PM	PM	PM	PS	PZ	PS
NS	PL	PL	PM	PS	PS	NS	PZ	PS
NZ	PL	PL	PM	PZ	PZ	NS	M	NL
PZ	PL	PM	PS	NS	NS	NS	NM	NL
PS	PL	PM	PS	NS	NM	NM	NL	M
PM	PS	PZ	NS	NM	NL	NM	NL	M
PL	PZ	NS	NS	NM	NL	NL	NL	NM

When the rules of fuzzy R is increased, TG and TGC can be achieved consequently and the fuzzy controller output attained $U1 = TG1 \times TG C1$, the superficial vision for 34 fuzzy rules can be exposed as succeeding.

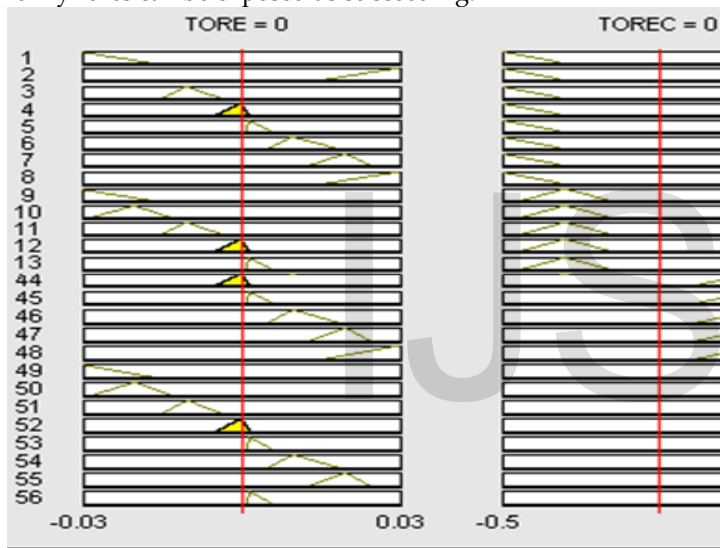


Figure.8 the Surface Views of 56 Fuzzy Rules

3.2 Adaptive Fuzzy tracking Algorithm Design

To achieve our proposed tracking algorithm picking and controlling robotic arm in different torque and force with the help of adaptive fuzzy rules and base rules, we adopt the two order curve tracking method. This is observed the adjacent distance point from the picking box as the desired starting point. The preferred track in sector-by-sector and two times curve solution is estimated. And our design track picking trajectory and two order curve appropriately. Even though this is moderately common to the tracking track with the flexibility, tracking accuracy, and virtue of good stability. For tracking rectification, it is appropriate. The Eq. 8. Which explains algorithm principle. We have to reflect that we optimal the target picking position point $P(v, w)$ then the deviation vector point (x, y, z) for the picking

target point which computed in the coordinate system and apply two order curve to attach the point of the target and the origin in place of the expectations succeeding route. To define the angular acceleration w and angular velocity of arm joint v , this tracking algorithm is used in the trajectory design.

$$Y = Ax^2, A = Y_e / X^2_e \quad (8)$$

$$\begin{cases} v = \sqrt{x^2 (1 + 4 A^2 x^2)} \\ w = 2A x^3 / v \end{cases} \quad (9)$$

estimate the solution can be increased as following

$$\begin{cases} v_n \cong K_n \\ w_n = 2 A_n K_n \end{cases} \quad (10)$$

By computing v_n and w_n , we may choose the parameter of control cycle and speed control a and then, in order to reduce the deviation, the picking and controlling robotic arm joint angular velocity v_n and acceleration w_n attuned suitably t and to attain route tracking right deviation, take the shortest distance goal path from the taking apple slowly.

3.3 Design Computed Torque Controller

The great nonlinear method proposed to control the robot manipulator is the torque controller. The concept behind this is feedback linearization and calculation of the compulsory arm torques by the control law of nonlinear feedback. This controller performs very healthy, when altogether the physical and the dynamic constraints are identified. When we go with practical session, the most of physical model parameters are unknown or time variant. Consequently, to remunerate the equation of dynamic robotic manipulator, CTC need to be mixed with the methods of other. The computed torque controller for tracking reaction is proposed by Vivas and Mosquerain indeterminate atmosphere. When we compare this with the predictive approach, predictive plan gives healthier result than the overhead investigation. If an alternative linear state-space equation in terms of $\dot{x} = Ax + BU$ described as following

$$x' = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u \quad (12)$$

where $N = B(q) [q' \ q'] + C(q) (q')^2 + G(q)$ and this is recognized as the Brunousky canonical form. By equation (10) and (11) the Bruno sky canonical procedure can be inscribed in the form of the state $x = [e^T e^T]^T$ as [1]:

$$d/dt[e e'] = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{pmatrix} e \\ e' \end{pmatrix} + \begin{pmatrix} 0 \\ 1 \end{pmatrix} N \quad (13)$$

This is a control law of nonlinear feedback which assures the route of the tracking of robotic manipulator. When we choose the proportional-plus-derivative feedback for $N(t)$, it outcomes in terms of the PD-CTC ;

$$\tau = M(q) (q''_d + K_v e' + K_p e) + N(q, q') \quad (14)$$

The conjunction of the tracking error to zero is assured by the linear system theory. Where K_p and K_v are the gains of controller. The result schemes is shown in Figure 9. It has two feedback loops, namely, inner loop and outer loop. In this, an inner loop is a remunerate loop and an outer loop is the loop of tracking error.

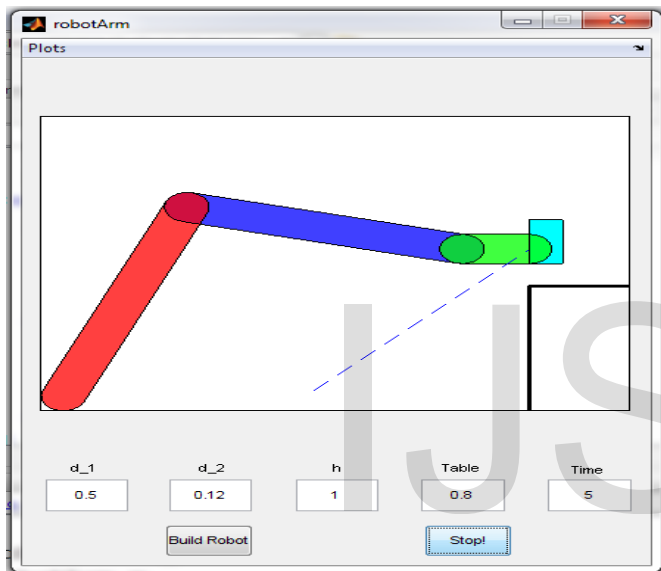


Fig. 9. Design Computed Torque Controller

3.4 Fuzzy Logic Methodology

The fuzzy logic controller has played vital role to model the nonlinear controller for nonlinear and uncertain designs based on basis of fuzzy logic methodology [21-25]. The fuzzy control which has broad application area and simple controller comprises Input fuzzification, Fuzzy rule base, Inference engine and Output defuzzification. The block diagram of fuzzy controller is shown in Figure 10. The block diagram of controller to regulate the 2 DOF robot manipulator is shown in Figure 11.

To transmit the rule base in the set of fuzzy, the fuzzy inference engine proposals a mechanism. It is separated into two most significant methods i.e. Mamdani and Sugeno methods. Mamdani who considered one of the first fuzzy controllers to regulate the system engine. This design is allocated into four ladders: fuzzification, rule evaluation, aggregation of the rule outputs and defuzzification. Michio Sugeno who practice a singleton as a membership purpose of the rule resultant portion. The

succeeding description shows the fuzzy rule base of Mamdani and Sugeno methods.

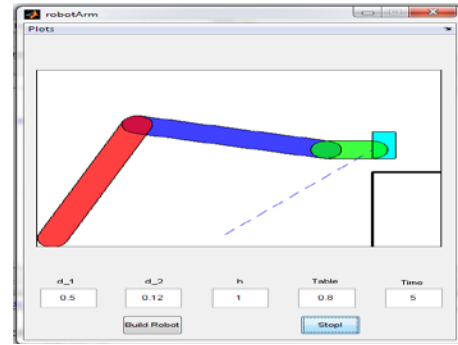


Fig. 10. Fuzzy Controller

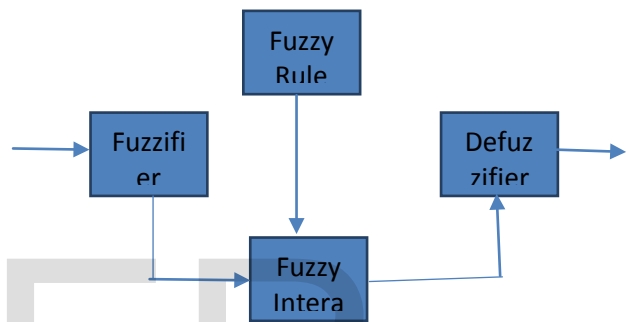


Fig. 11. Block Diagram of Fuzzy Controller

$$\text{If } x \text{ is } A \text{ and } y \text{ is } B \text{ then } z \text{ is } C \text{ 'mamdani'} \quad (15)$$

The Figure 11 shows the membership functions and philological variable. The rule calculation concentrates on fuzzy rule in the forerunner of the rules of fuzzy. To compute the output of fuzzy set, the aggregation is used.

Where r is the number of fuzzy rules triggered by x_k and y_k , and μ_{U_i} is the fuzzy amplification of i -th rule. The final and last step in the fuzzy inference system is the Defuzzification. To convert fuzzy set to crisp set, it is applied. So the input of defuzzification is the output of aggregate and the output of defuzzification is a crisp number. The common defuzzification methods are Centre of gravity method and Centre of area method. The following equation is used in COG technique to compute the defuzzification,

Where COG (x_k, y_k) and (x_k, y_k) demonstrates the defuzzification output of crisp value, $U_i \in U$ is the output of the fuzzy set in terms of discrete element, $(\mu_{U_i}(x_k, y_k, U_i))$ is the fuzzy set membership function, and r is the number of fuzzy rules.

3.5 Discussions over proposed approach

The proposed method performs very well and gives improved control than nonlinear PID control, when we have all essential information about the constraints of

robotic manipulator and the nonlinear dynamic formulation of system. This is very tough in reality while the dynamics of the robotic arm can alter throughout the process which can disturb the outcome of the control. Here we can reduce the outcome of CTC because of the dynamic design. And fuzzy system is applied to online alteration of the CTC parameters to avoid this state. By this, we can attain the wanted settling time and very minor steady state tracking errors. Constructed on fuzzy logic procedure

$$f(x) = U_{fuzzy} = \sum_{i=1}^M \theta_i \tau(x) \quad (20)$$

where θ_i is the adjustable parameter and $\tau(x)$ is defined by

$$\tau(x) = \sum_i \frac{\mu(x_i)x_i}{\mu(x_i)} \quad (21)$$

Where $\mu(x_i)$ is the membership function.

This procedure has two core portions; first one is the computed torque controller and the second one is fuzzy tuning controller. Centered on this procedure;

$$\tau = M(q) (\ddot{q} + K_v \dot{e} + K_p e) + N(q, \dot{q}) \quad (22)$$

If the Lyapunov function in this technique described as follows;

$$V = (1/2) M(q) \dot{q}^T \dot{q} + e^T K_p e + 1/2 \sum_i \frac{\mu(x_i)x_i}{\mu(x_i)} \quad (23)$$

And the distinguish to attain

Consequently the skew symmetry of the initial term is given by;

$$\dot{V} = -\dot{q}^T K \dot{q} - \sum_{j=1}^M \frac{1}{\gamma_j} \Phi_j \quad (24)$$

The projected technique is shown in Figure 6.

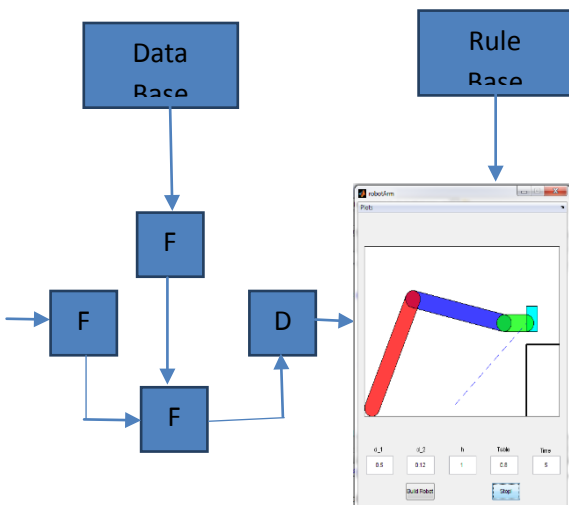
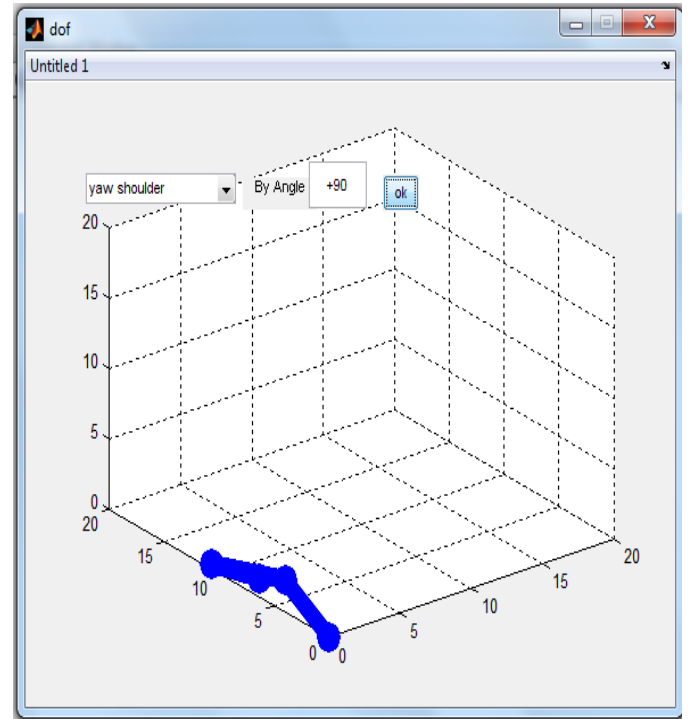


Fig. Adaptive Fuzzy Gain scheduling Controller

4 SIMULATION RESULTS



```

albow end transofmrn matrix is
0.8995   -0.0580   -0.4330    9.8971
0.0580   -0.9665    0.2500   -2.2500
-0.4330  -0.2500   -0.8660   -5.5981
0         0         0         1.0000
    
```

```

shoulder end transofmrn matrix is
0.8995   -0.0580   -0.4330    4.5000
0.0580   -0.9665    0.2500   -2.5981
-0.4330  -0.2500   -0.8660   -3.0000
0         0         0         1.0000
    
```

```

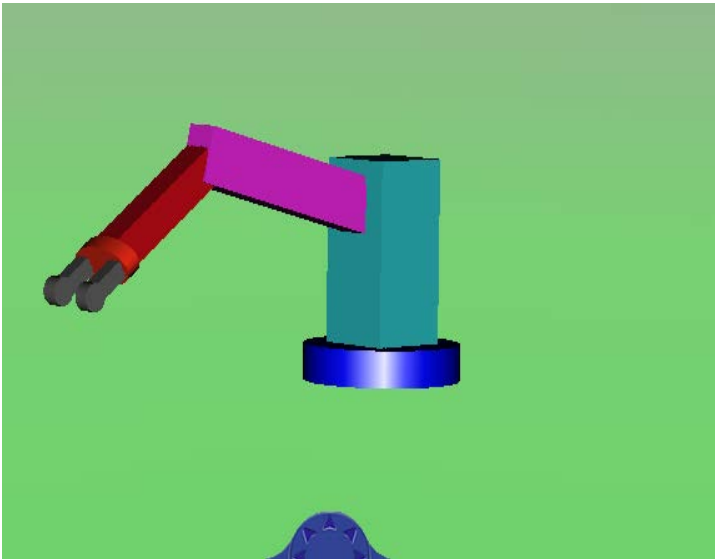
end effector transofmrn matrix is
-0.5364    0.7434   -0.3995    8.6359
-0.5891    0.0092    0.8080    1.7818
0.6043    0.6688    0.4330   -2.2851
0         0         0         1.0000
    
```

```

albow end transofmrn matrix is
0.8080    0.3995   -0.4330   10.2452
0.5335   -0.8080    0.2500    3.5490
-0.2500  -0.4330   -0.8660   -4.0981
0         0         0         1.0000
    
```

```

shoulder end transofmrn matrix is
0.8080    0.3995   -0.4330    5.3971
0.5335   -0.8080    0.2500    0.3481
-0.2500  -0.4330   -0.8660   -2.5981
0         0         0         1.0000
    
```



5 CONCLUSION

We apply with anfis with Cauchy membership function for robotic arm to apply with two angles. The proposed adaptive fuzzy based tracking and gain controller algorithm requires much less training patterns than a neural net based adaptive scheme does and hence avoiding excessive training time. Results of simulation show that the proposed adaptive fuzzy controller offers better performance than fixed gain controllers at different operating conditions.

5.1 Acknowledgments

REFERENCES

- [1] M. Bazregar, FarzinPiltan, A. Nabaee and M.M. Ebrahimi, "Parallel Soft Computing Control Optimization Algorithm for Uncertainty Dynamic Systems", International Journal of Advanced Science and Technology, 51, 2013
- [2] MojtabaYaghoot, FarzinPiltan, MeysamEsmaili, Mohammad Ali Tayebi, MahsaPiltan, "Design Intelligent Robust Model-base Sliding Guidance Controller for Spherical Motor", IJMECS, vol.6, no.3, pp.61-72, 2014. DOI: 10.5815/ijmecs.2014.03.08
- [3] M. Mucienteset.el. , "Design of a fuzzy controller in mobile robotics using genetic algorithms", Elsevier Applied Soft Computing, Vol. 7, and No. 2, 540-546 (2007).
- [4] Ho H. F. at. et. al., "Robust fuzzy tracking control for robotic manipulators", Simulation Modelling Practice and Theory, Vol. 15, Issue 7, 801-816 (2007).
- [5] Nguyen. V. B. and Morris A. S., "Genetic Algorithm Tuned Fuzzy Logic Controller for a Robot Arm with Two-link Flexibility and Twojoint Elasticity", Springer J Intell Robot Syst, Vol. 49, 3-18(2007).

[6] FarzinPiltan, Mohammad R. Rashidian, Mohammad Shamsodini and SadeqAllahdadi, Effect of Rule Base on the Fuzzy-Based Tuning Fuzzy Sliding Mode Controller: Applied to 2nd Order Nonlinear System", International Journal of Advanced Science and Technology, 46:39-70, 2012

[7] W. Ahamed and C. Kambhampati, "Stable quantum filters with scattering phenomena", International Journal of Automation and Computing, vol. 5, no. 2, (2008), pp. 132-137.

[8] FarzinPiltan, Mohammad H. Yarmahmoudi, Mohammad Shamsodini, EbrahimMazlomian, Ali Hosainpour, "PUMA-560 Robot Manipulator Position Computed Torque Control Methods Using MATLAB/SIMULINK and Their Integration into Graduate Nonlinear Control and MATLAB Courses", International Journal of Robotics and Automation, 3(3): 167-191, 2012.

[9] FarzinPiltan, Mehdi Eram, Mohammad Taghavi, Omid Reza Sadrnia, Mahdi Jafari, "Nonlinear Fuzzy Model-base Technique to Compensate Highly Nonlinear Continuum Robot Manipulator", IJISA, vol.5, no.12, pp.135-148, 2013. DOI: 10.5815/ijisa.2013.12.12

[10] [19] S. Heidari, FarzinPiltan, M. Shamsodini, K. Heidari and S. Zahmatkesh, "Design New Nonlinear Controller with Parallel Fuzzy Inference System Compensator to Control of Continuum Robot Manipulator", International Journal of Control and Automation, 6(4), 2013.

[11] Mahdi Mirshekaran, FarzinPiltan, ZahraEsmaili, TannazKhajeaian, MeysamKazeminasab, "Design Sliding Mode Modified Fuzzy Linear Controller with Application to Flexible Robot Manipulator", IJMECS, vol.5, no.10, pp.53-63, 2013. DOI: 10.5815/ijmecs.2013.10.07.

[12] Ali Barzegar, FarzinPiltan, Mahmood Vosoogh, Abdol Majid Mirshekaran, AlirezaSiahbazi, "Design Serial Intelligent Modified Feedback Linearization like Controller with Application to Spherical Motor", IJITCS, vol.6, no.5, pp. 72-83, 2014. DOI: 10.5815/ijitcs.2014.05.10.

[13] AzitaYazdanpanah, FarzinPiltan, Ali Roshanzamir, MarjanMirshekar, NargesGholamimozafari, "Design PID Baseline Fuzzy Tuning Proportional- Derivative Coefficient Nonlinear Controller with Application to Continuum Robot", IJISA, vol.6, no.5, pp.90-100, 2014. DOI: 10.5815/ijisa.2014.05.10.

[14] MeysamKazeminasab, FarzinPiltan, Zahra Esmaili, Mahdi Mirshekaran, AlirezaSalehi, "Design Parallel Fuzzy Partly Inverse Dynamic Method plus Gravity Control for Highly NonlinearContinuum Robot", IJISA, vol.6, no.1, pp.112-123, 2014. DOI: 10.5815/ijisa.2014.01.12.

[15] FarzinMatin, FarzinPiltan, Hamid Cheraghi, NasimSobhani, Maryam Rahmani, "Design Intelligent PID like Fuzzy Sliding Mode Controller for Spherical Motor", IJIEEB, vol.6, no.2, pp.53-63, 2014. DOI: 10.5815/ijieeb.2014.02.07.

IJSER