Design and Simulation Intelligent Controller for Robot Arm Response Enhancement Using Intelligent Techniques

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Abstract

In recent years, the robot is very widely used in practical applications; in particular, trajectory planning of a planar is studied. The weakness point of previous methods for determining acceptable trajectories, and its need long time to obtain a solution. In this a new intelligent approach is used to enhance the output response for the system , since almost research in recent year ; integrate the intelligent controllers to obtain modified controller , but a new problems are appear , such as complexity in system, integrated, and the system programming for different inputs needs high execution time, but in this approach, three controllers (Neuro-PID-Fuzzy) are used separately in this system , these controllers common in inputs, outputs and the PID controller is used here a a selector switch to track the system on line and select the good response in specific time therefore the good finally response is appear in the command output, this approach is simulated by MATLAB.

الخلاصة

في السنوات الاخيره استخدم الانسان الالي بشكل واسع في التطبيقات العملية ، تم دراسة التتبع بالانسان الالي خلال مروره في مسارات ووجد ان نقطة ضعف البحوث القديمه في هذا الموضوع هي في تحديد المسارات المقبولة والتي تحتاج الى زمن طويل للحصول على اشاره جيده . في هذا البحث استخدمت طريقه جديدة مبتكره للحصول على أفضل استجابة للنظام حيث إن معظم البحوث في السنوات الحالية تقوم بالدمج بين أكثر من مسيطر للحصول على استجابة جيده، ولكن ظهرت مشكله التعقيد في النظام وصعوبة الدمج بين المسيطرات الذكية وكذلك صعوبة البرمجة للإدخالات المختلفة بالاضافه إلى تقليل زمن تنفيذ البرنامج بشكل ملحوظ ، أما في هذا البحث فقد استخدمت ٣ مسيطرات (FUZZY- PID - NEURAL) منفصلة في نظام واحد حيث يعمل كل مسيطر على حده بدون الاعتماد على الأخر ولكن جميعها تشترك في إخراج واحد وإدخال واحد. واستخدم المسيطر الثلاثيPID كمفتاح اختيار للاستجابة الجيدة ألخارجه من المسيطر الضبابي والمسيطر العصبي حيث يقوم بمراقبه الاستجابة على طول الفترة الزمنية وفي كل لحظه يختار الاستجابة الجيدة بالتالي ستكون الاستجابة للنظام هي بالحقيقة متكونة من أفضل الإخراج للمسيطرين الذكيين وطبقت ألطريقه على حركه عشوائية لذراع الإنسان الآلي وأخذت إدخالات مختلفة وقورنت مع مسيطرات ذكيه مفرده على نفس النظام وتم برمجتها ببرنامج MATLAB

1- General Introduction:

Robots are effectively used in a wide range of applications; they must gain the ability to work in unpredictable and changing environments. Robots used in space exploration and construction will have to sense their environment and carryout their tasks regardless of the presence of objects in the work area. The ability to move an arm around an obstacle and to a goal is an intuitive skill for human beings [Kellyn, 1994].The ability of a machine to emulate human behavior has always been the goal of artificial intelligence. More than 90% of industrial controllers are still implemented based around PID algorithms, particularly at lowest levels. With its three-term functionality covering treatment to both transient and steady-state responses, proportional- integral-derivative (PID) control offers the simplest and yet most efficient solution to many real-world control problems [Ang *et al.*, 2005]. The PID controller is a one of the earliest industrial controllers. It has many advantages: Its cost is economic, simple easy to be tuned and robust. This controller has been proven to be remarkably effective in regulating a wide range of processes[Gaing, 2004]. Neural networks and fuzzy logic systems are two of the most important results of research in the area of artificial intelligence. They have been effectively applied to everything from voice and image recognition to toasters and automobile transmissions. Neural networks are best known for their learning capabilities. Fuzzy logic is a method of using human skills and thinking processes in a machine. While neural networks and fuzzy logic have added a new dimension to many engineering fields of study, their weaknesses have not been overlooked. In many applications, the training of a neural network requires millions of iterative calculations. Sometimes the network can not adequately learn the desired function. Fuzzy logic systems, on the other hand, acquire their knowledge from an expert who encodes his knowledge in a series of IF/THEN rules. Fuzzy logic systems are easy to understand because they mimic human thinking. The problem arises when systems have many inputs and outputs. Obtaining a rule base for large systems is difficult, if not impossible [Kellyn, 1994, Cirstea *et al.,* 2002].

2: Fuzzy Logic Controller:

Fuzzy logic has its roots in the work of renegade mathematicians who saw the value of a multivalent logic system. The credit for fuzzy logic's application to the areas of control and in engineering belongs solely to Lotfi Zadeh. In 1965, he formalized fuzzy set theory and in 1973 brought fuzzy set theory into the context of control systems. According to Lotfi Zadeh, fuzzy logic brings to control systems a "higher machine intelligence quotient" [Cox E. 1993]. Figure (1) shows the block diagram of a typical fuzzy logic controller (FLC) and the system plant as described in [Cirstea *et al.,* 2002].

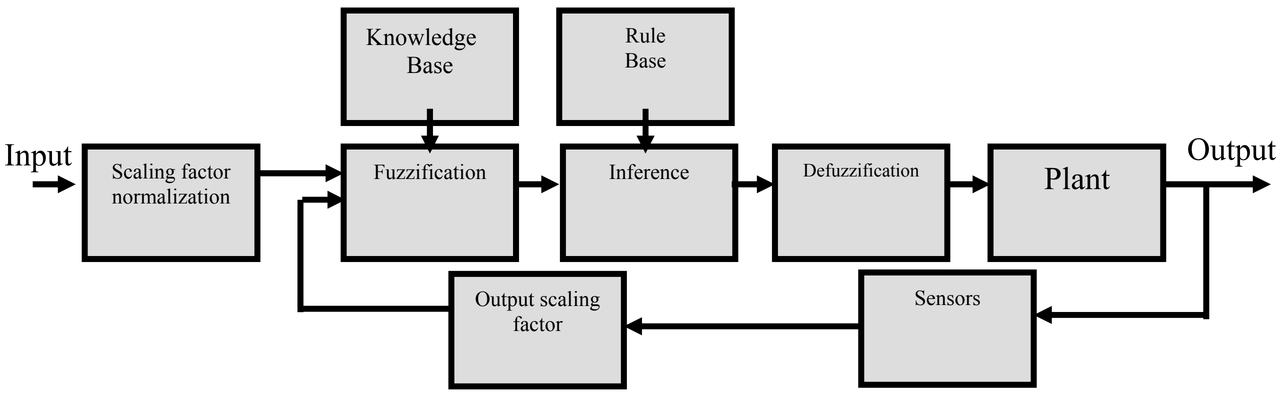


Figure (1) :Fuzzy logic controller structure

Fuzzy logic is a technique that attempts to systematically and mathematically emulate human reasoning and decision-making. Fuzzy logic allows engineers to exploit their empirical knowledge and heuristics represented in the “if/then” rules and transfer it to a function block. Fuzzy logic thus provides engineers with a clear and intuitive way to implement control systems, decision-making and diagnostic systems in various branches of industry [DAVE C.JEFF S.2007]

There are five principal elements to a fuzzy logic controller:

The fuzzy logic controller consist of:

- **Fuzzification (fuzzifier)**: Change crisp value to linguistic variable .
- **Knowledge base**: Provides all the necessary definitions for the Fuzzification.
- **Rule base**: It is usually obtained from expert knowledge.

- **Inference engine**: Any rule which its firing
- **Defuzzification**: Change linguistic variable to crisp value.

3- Neural Network

The attitudes of researchers toward neural networks have experienced an evolution since their inception in the early 1940s. According to Leon Cooper, these attitudes "progressed from skepticism through romanticism to what we have at present: general realistic acceptance of neural networks as the preferred -most efficient, most economic - solution to certain classes of problems"[Kellyn, 1994] [Richard *et al.,* 1991].Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. You can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements. Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific target output. Such a situation is shown below. There, the network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically many such input/target pairs are needed to train a network. [Matlab,2007]

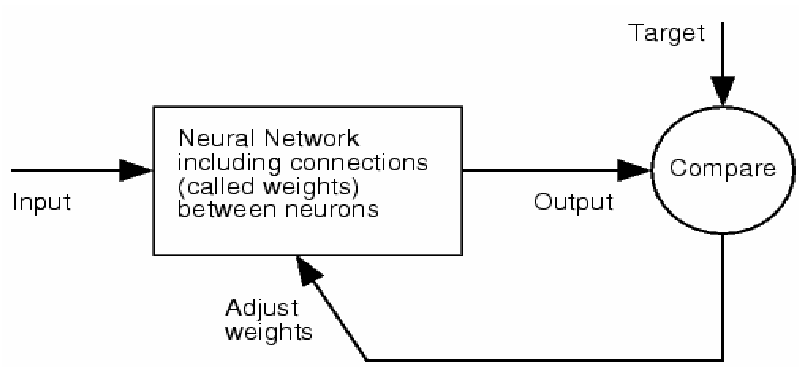


Figure (2): Basic configuration of ANN

Neural networks have been trained to perform complex functions in various fields, including pattern recognition, identification, classification, speech, vision, and control systems.

4-**PID Controller**

The PID algorithm remains the most popular approach for industrial process control despite continual advances in control theory. This is not only due to the simple structure, which is conceptually easy to understand and implemented in practice. the general equations for the PID controller is:

$$G(s) = K_P + K_I \times \frac{1}{S} + SK_D \qquad eq.(1)$$

$$G(S) = K_P(1 + \frac{1}{T_1 S} + T_D S) \qquad eq.(2)$$

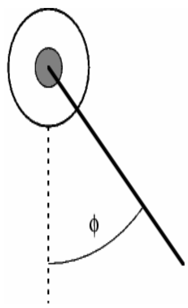
The control variable is thus a sum of three terms : P-term (proportional error) , I- term (integral error), and D-term (derivative error) . the controller parameters are the proportional gain Kp, Ti, and derivative time Td .To obtain the PID parameters the Ziegler Nichols closed loop method can be used. This method is straightforward. First, set the controller to P mode only. Next, set the gain of the controller (kc) to a small value. Make a small setpoint (or load) change and observe the response of the controlled variable. If kc is low the response should be sluggish. Increase kc by a factor of two and make another small change in the setpoint or the load. Keep increasing kc (by a factor of two) until the response becomes oscillatory. Finally, adjust kc until aresponse is obtained that produces continuous oscillations. This is known as the ultimate gain (ku). Note the period of the oscillations (Pu) [**Pirabakaran and Becerra, 2001**]. The control law settings are then obtained from the following table (1),

Table (1): Control law for the PID parameters [**Pirabakaran K.and Becerra V.M.2001**]

	k_C	T_i	T_D
P	ku/2		
PI	Ku/2.2	Pu/1.2	
PID	Ku/1.7	Pu/2	Pu/8

5-Modeling of Robot Arm

For robots to become effectively used in a wide range of application, they must gain the ability to work in unpredictable and changing environments. Robots used in space exploration and construction will have to sense their environment and carry out their tasks regardless of the presence of objects in the work area. This paper addresses the problem of planning the trajectory of A Single-link robotic arm and the objective is to control on the movement of this link , as shown in figure (3). The PID controller in previous research is a convenient structure that has been employed for control the robot arm movement purposes [Ferreira and Machado, 2003].



Figure(3).: A diagram of A Single-link robotic arm [Ferreira F. and Machado T., 2003] .

The equation of motion for the arm is [Cirstea *et al.,* 2002.]

$$\frac{d^2\phi}{dt^2} = -10\sin\phi - 2\frac{d\phi}{dt} + u \qquad \text{------(3)}$$

Where (ϕ) is the angle of the arm, and (u) is the torque supplied by the DC motor.

The output of reference model

$$\frac{d^2 y_r}{dt^2} = -9\sin y_r - 6\frac{dy_r}{dt} + 9r \qquad \text{------(4)}$$

where y_r is the output of the reference model, and r is the input reference signal.
Using state space to analysis the system
From equation (3)

$$\theta'' = -10\sin\theta - 2\theta' + u$$

$$x1 = \theta \qquad x2 = \theta'$$

$$x1' = \theta' = x2 \qquad x2' = \theta'' = -10\sin x1 - 2x2 + u$$

in state space form

$$\begin{bmatrix} x'1 \\ x'2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -10 & -2 \end{bmatrix} \begin{bmatrix} \sin x1 \\ x2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

From equation (2)

$$y_r'' = -9\sin y_r - 6y_r' + 9r$$

$$z1 = y_r \qquad z2 = y_r'$$

$$z1' = y_r' = z2 \qquad z2' = y_r'' = -9\sin z1 - 6x2 + 9r$$

in state space form

$$\begin{bmatrix} z1' \\ z2' \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -9 & -6 \end{bmatrix} \begin{bmatrix} \sin z1 \\ z2 \end{bmatrix} + \begin{bmatrix} 0 \\ 9 \end{bmatrix} r$$

Where :

θ = *angle of the arm*

y_r = output of the reference model

X' = stat variables for the angle of arm

Z' = stat variables

u = *input torque*

r = refrence input

The arm should operate in two dimensions in an environment containing a randomly desired placed. The starting position and desired position of the arm are arbitrary, as well. The arm will be modeled as a single-link planar manipulator. The controller will determine a series of joint angles, Q(t), that move the end effectors from a given starting position (*x*s, *y*s) to a desired final position (*x*g, *y*g)

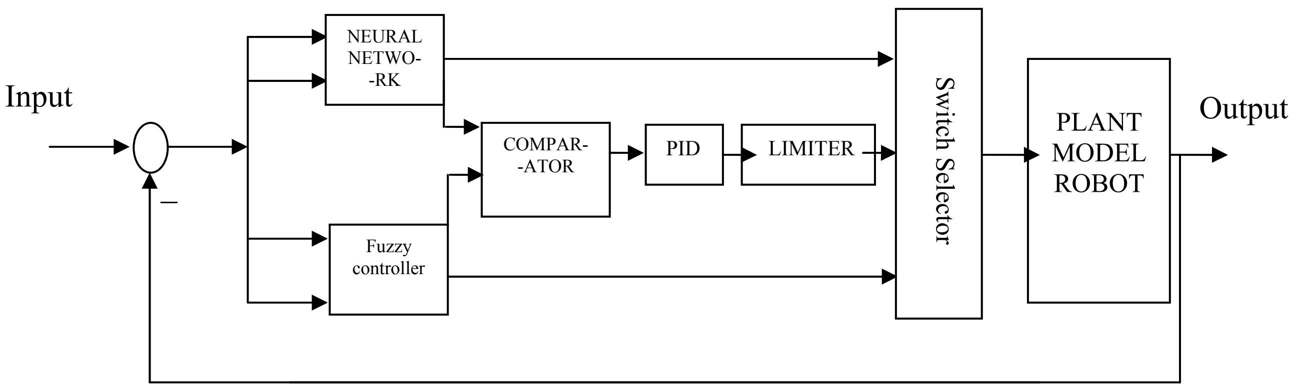


Figure (4): Block diagram of the proposed intelligent controller with closed loop model

6- Simulation Result

Planning the trajectory of a robotic arm has been itself a topic of many research projects. Planning the trajectory of a redundant robotic arm adds a new dimension to the problem, more degrees of freedom, more nonlinear equations. Place an obstacle in the work area and the problem becomes a challenge of optimizing differential equations, iterative numerical solutions, and "guess and shoot" methods [Cirstea *et al.,* 2002.].The main problems in previous researches, is that the computer resources necessary to solve a system of equations or optimize a performance index. Researchers acknowledge that "minutes" are necessary to plan one trajectory on some of the world's fastest computers. Simply determining the equations to be solved is a formidable task. What is needed is an approach that is easy to apply and will work in real-time. Also when using the mixed intelligent controllers some problem will appear such as increase the system complexity ,increase the execution time for the program , increase the complexity in system structure. Therefore to solve these problems a novel approach is used here by separated neuro-fuzzy techniques, which controlled by PID controller ,the PID controller work as a selector switch as shown in figure(4) , to select the desired response from the intelligent controllers , finally the good output response will appear with high efficiency . Also in this approach a solution is not found by analytical or numerical techniques. While an analytical technique is difficult, moving an arm in the presence of an desired position. Separated Neuro-fuzzy systems excel in using sample data to determine an input-output relationship. Separated neuro-fuzzy technology is the fusing of both neural networks and fuzzy logic. Neural networks bring to this solution the ability to learn while fuzzy logic is based on mimicking an expert's thinking. Figure (4) show the system model using the Matlab Simulink

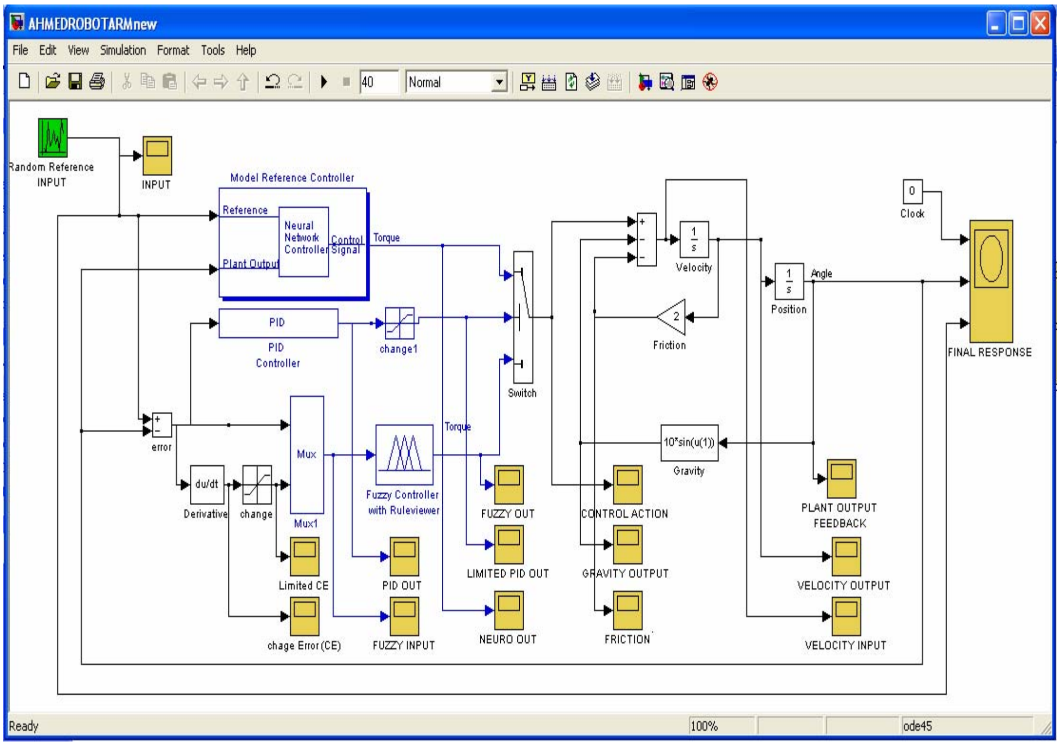
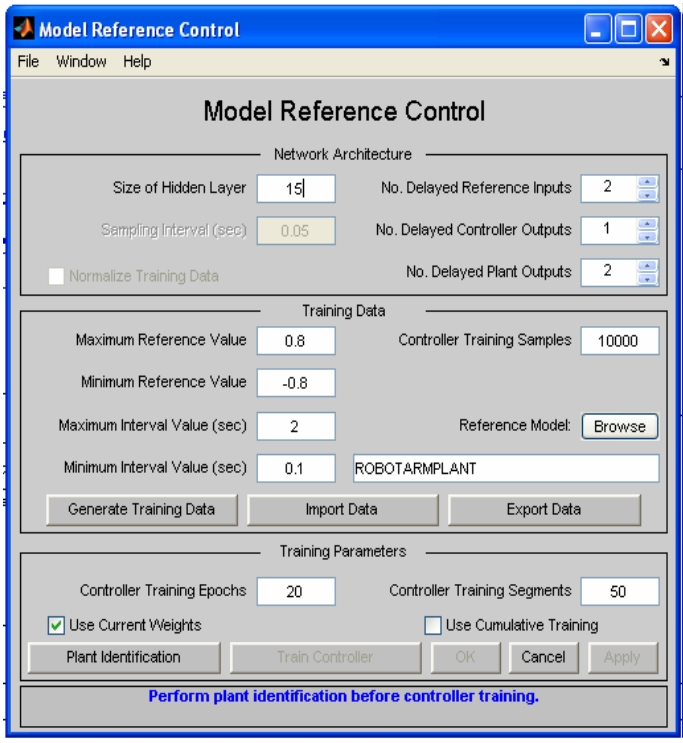


Figure (5): Matlab Simulink model for robotic arm with separated Neuro- PID-Fuzzy

Form this model , 3 controllers are used (Neural, Fuzzy, PID) and finally the selector switch is used to select the good response ,since this switch is controlled by PID controller , the internal structure and the Scope drawing for the system are shown bellow :

-Neural controller (model Reference control) and Fuzzy Rule Viewer



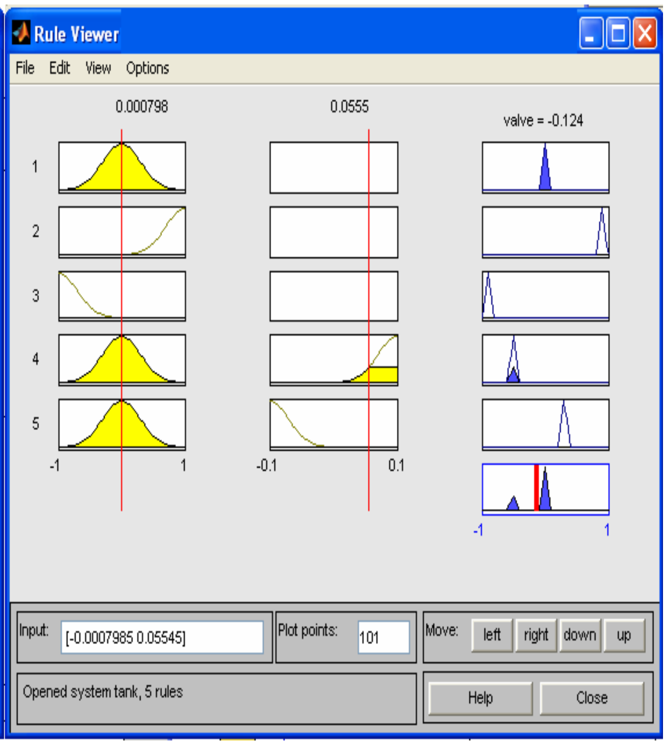


Figure (6): Model Reference Control

Figure (7): Fuzzy Rule Viewer

The Scope drawing for the system with random reference input, are shown bellow, since the signal is tracked from the input to output by 15 Scopes :

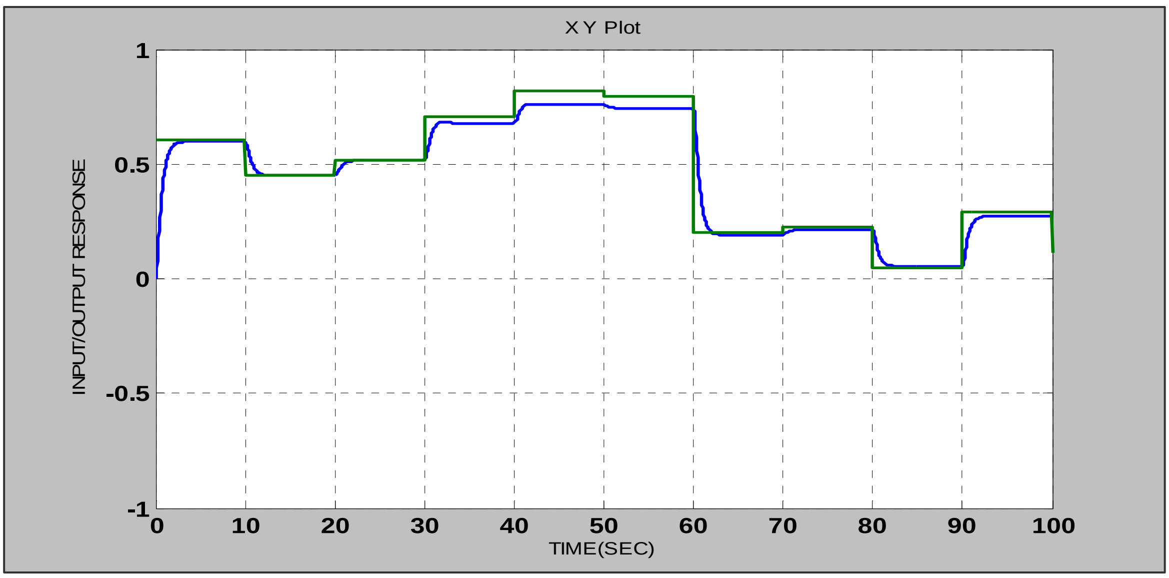


Figure (8): Scope No.15 : Final Output /Input Responses

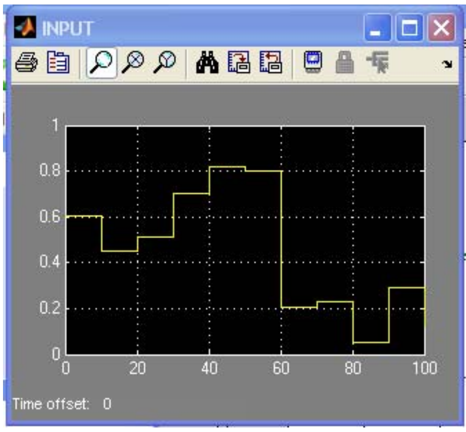


Figure (9): Input Signal

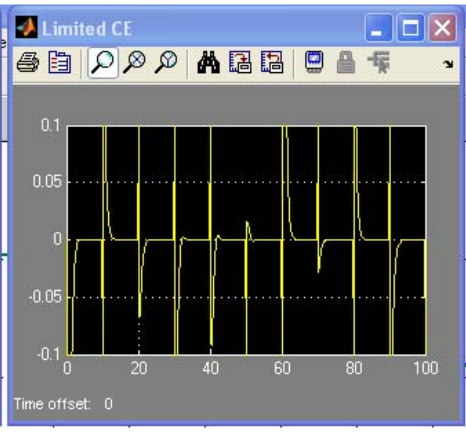


Figure (10): Limited Change Error Signal

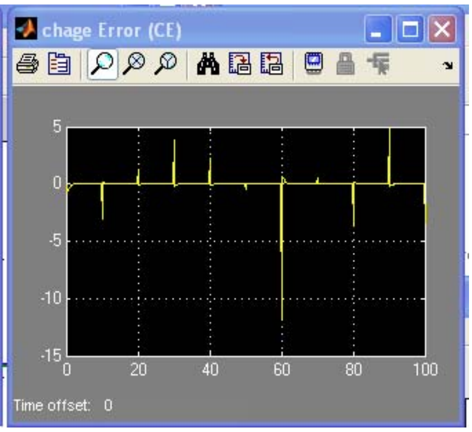


Figure (11): Change Error Signal

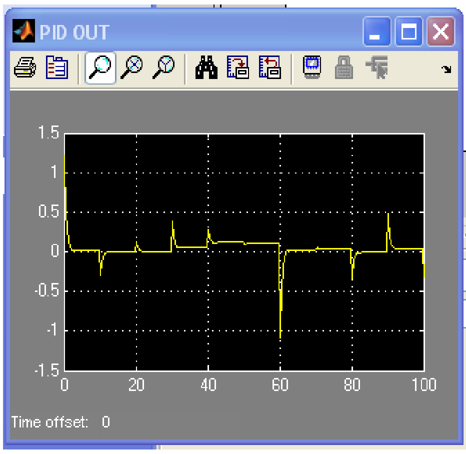


Figure (12): PID output Signal

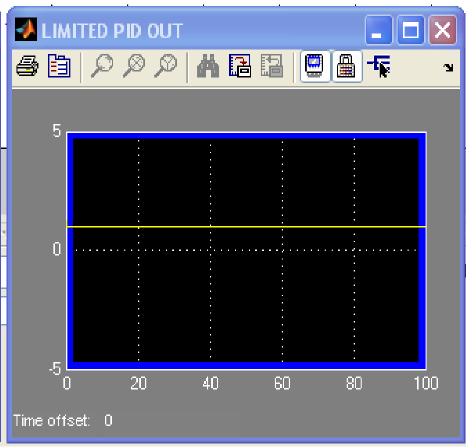


Figure (13): Limited PID output Signal

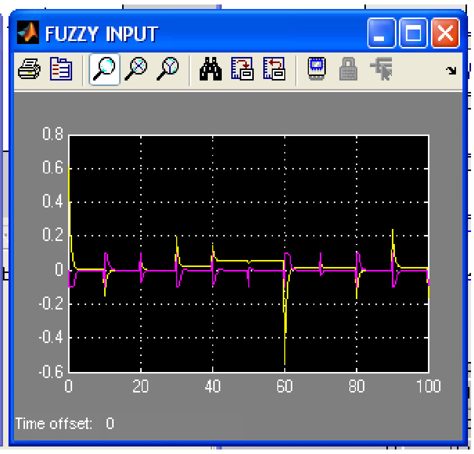


Figure (14): Fuzzy Inputt Signal

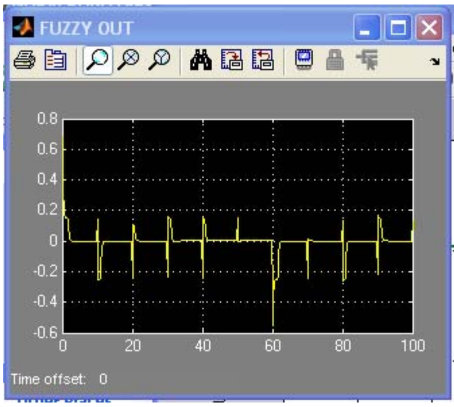


Figure (15): Fuzzy output

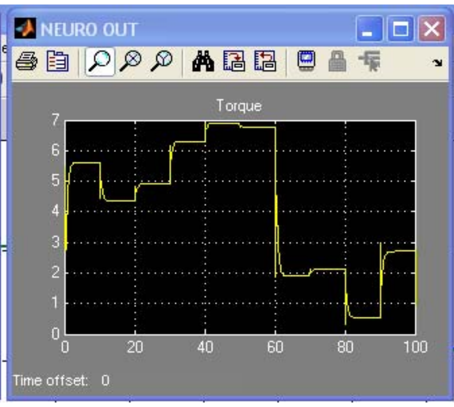


Figure (16): Neuro output

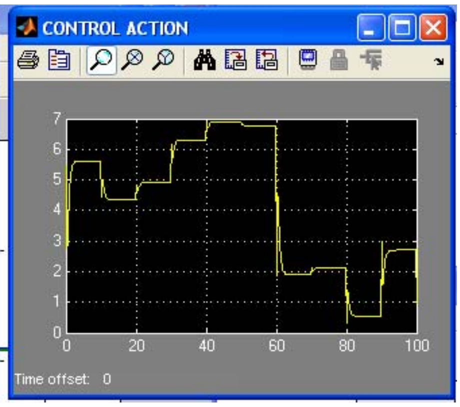


Figure (17): control Action

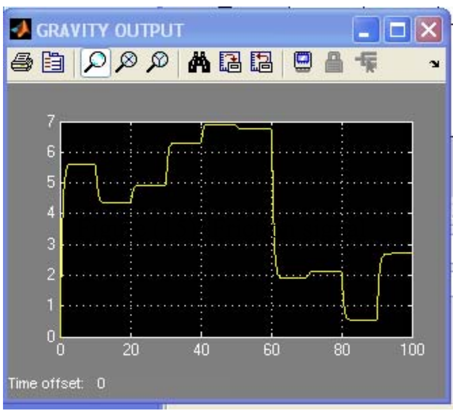


Figure (18): Gravity signal

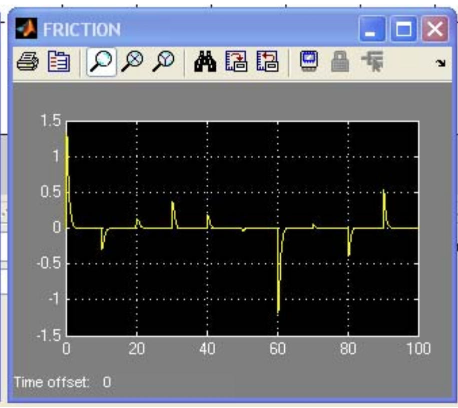


Figure (19): Friction signal

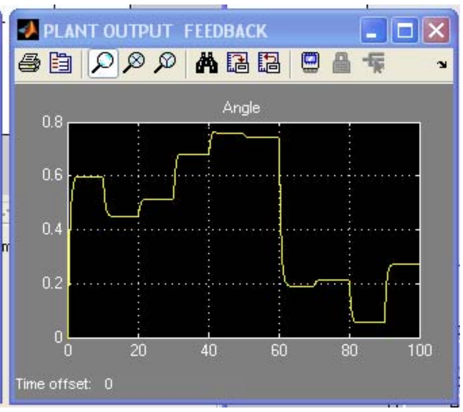


Figure (20): Robot Arm signal

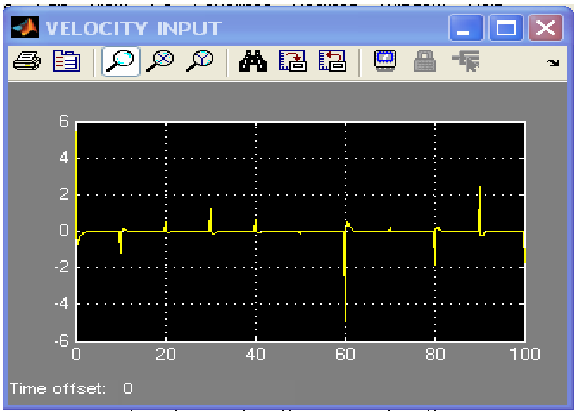


Figure (21): Velocity Input

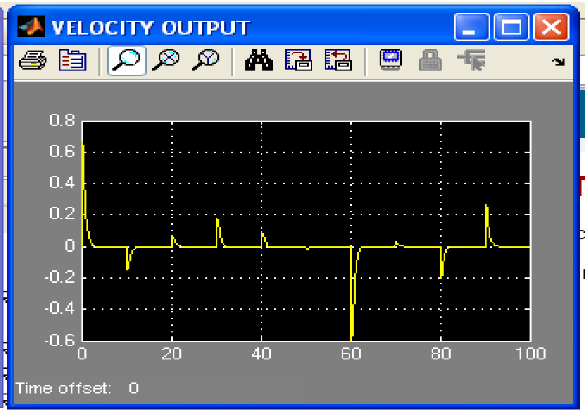


Figure (22): Velocity output

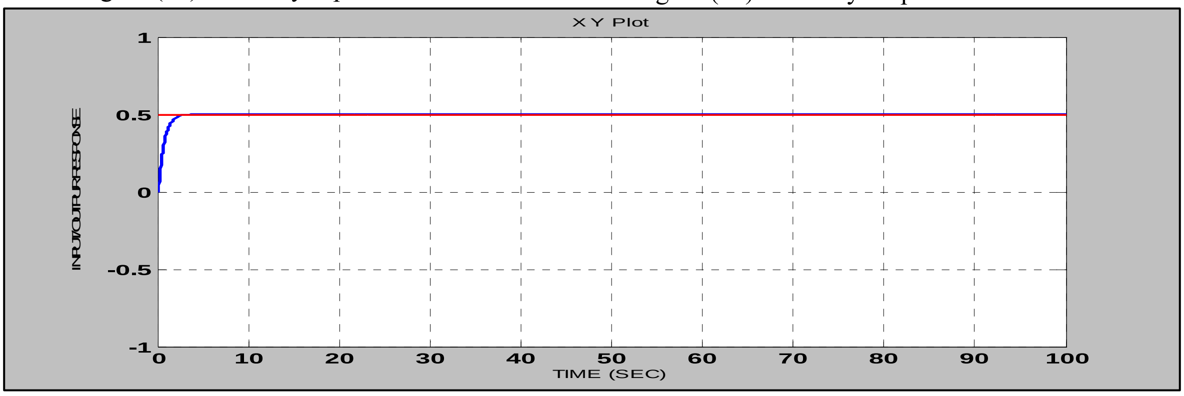


Figure (23): Half Step

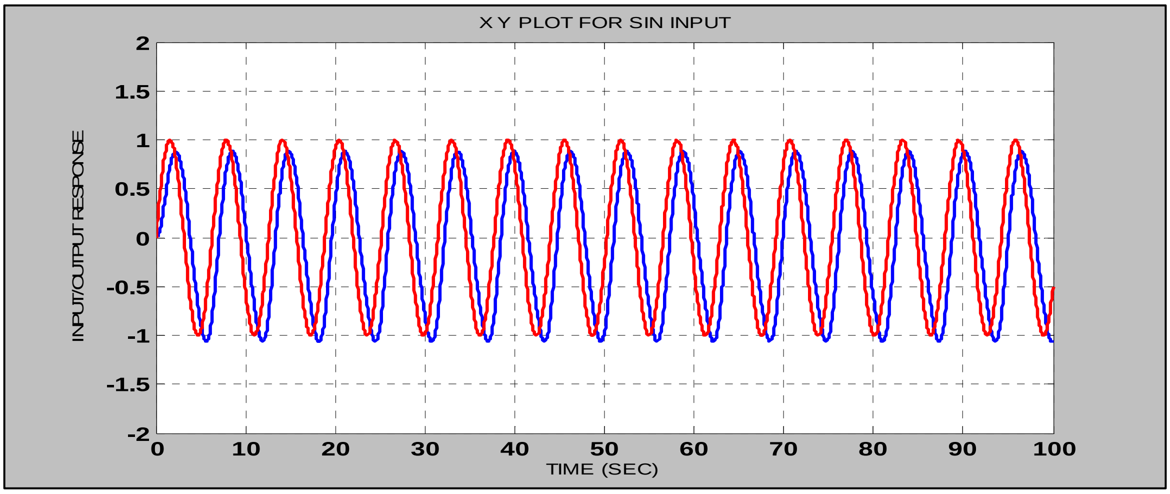


Figure (24): Sine Input /Output Response

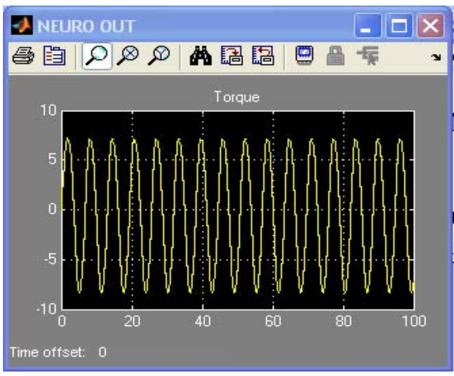


Figure (25): Neuro Out for sin input

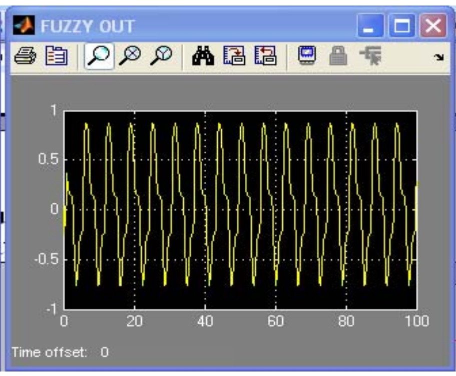


Figure (26): Fuzzy Out for sin input

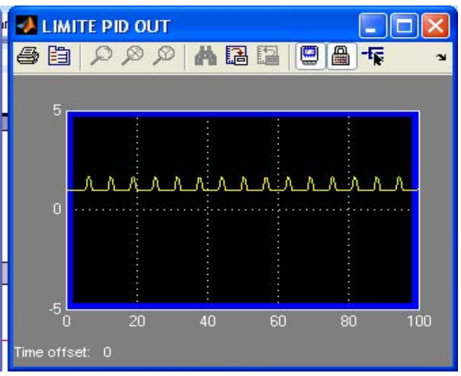


Figure (27): Limited PID Out

7-Conclusion

The intelligent control technique is very useful technology in robot system, since the ability to learn how to control a process from sample data. In this paper, separated Neuro-PID-Fuzzy controller is proposed to emulate a human’s example control of robotic arm, from the experimental result, several conclusions can be concluding.

-The proposed intelligent controller is a powerful controller to control on robotic arm model, since the good output responses are obtained.
- More robust stability and good performance characteristic is obtained
- Can be integrate genetic algorithms as a future work to obtain more enhancement in the output response and to develop this method
-The rule table for the different inputs can be extracted from the output response than modify it to enhance the output, therefore this method not depends on any human expert to provide initial control rules for the fuzzy controller
- Small execution time and un complex controller can be obtained by this method.

8-References

Cirstea M.N, Dinu A., Khor J.G., and Mcormick M. (2002). " Neural and Fuzzy Logic Control of Drives and Power Systems" , Vol. No. 22, pp. 13-15.

Cox E. (1993). "Fuzzy Fundamentals" *IEEE Spectrum*,vol.No.5, (October), pp. 58-61.

DAVE C.JEFF S.(2007). "Nonlinear Control And Decision Making Using Fuzzy Logic In logix”, Rockwell Automation, Inc. USA. Publication 9324-WP006A-EN-P – August.

Ferreira F. and Machado T., (2003). “Fractional-order hybrid control of robotic manipulators”, in *Proc. of the 11th International Conference on Advanced Robotics*, Coimbra, pp.393-398, June.

Gaing Z., (2004). “A particle swarm optimization approach for optimum design of PID controller in AVR system” *IEEE Trans. Ener. Conver.,* vol. 19, no. 2, pp.384-391, June.

Kellyn W. E. (1994). "Neuro-Fuzzy Control of a Robotic Arm " MSc. Thesis, electrical engineering , Texas Unv. August.

Matlab help tool books (ver 7.4.0.287(R2007a)), January, 2007

Pirabakaran K. and V.M. Becerra (2001). 'Automatic Tuning of PID controllers using Model reference adaptive control technique', 27th Annual Conference of IEEE industrial Electronics Society ,IECON01

Richard J. Mammone and Yehoshua Y. Zeevi (1991). "Hybrid Neural Network Architectures: Equilibrium Systems That Pay Attention", in *Neural Networks: Theory and Applications* . Boston: Academic Press, Inc. pp. 81-96.