COMPARATIVE STUDY OF ADVANCED CONTROLLERS: APPLICATION FOR AN ARM MANIPULATOR

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Abstract

Research on the dynamic modeling and control of the arms manipulators has received increased attention since the last years due to their advantages.
In this present work we present a new approach for a robot manipulator with two degrees of freedom based on the Adaptive Neuro-Fuzzy Inference System (ANFIS) controller to ensure the position robot control strategy, the proposed control scheme is based on the dynamic model derived using Bond Graph Methodology.
Our robot manipulator ANFIS system control's simulated in Matlab Simulink environment; the results obtained present the efficiency and the robustness of the proposed control with good performances compared with PID and the FIS controller method.

Keywords: *Robot Manipulator, Bond Graph, ANFIS, Fis Controller.*

1. Introduction

The arm manipulator is a mechanical system multi-articulated, in which each articulation is driven individually by an electric actuator is the most robot used in industry, Many efforts have been made in developing control scheme to achieve the precise tracking control of robot manipulators [1]-[2]-[3].
The traditional PID controller with simple structure and stable performance is widely used. But it is difficult to meet the high precision and fast response, moreover the parameters tuning of classical PID controller is so complex [11] .Therefore fuzzy algorithm is introduced. Fuzzy control is a particular type of intelligent control, has a great potential since it is able to compensate for the uncertain nonlinear dynamics using the programming capability of human control behavior. The main features of fuzzy control is that a control knowledge base is available within the controller and control actions are generated by applying existing conditions or data to the knowledge base, making us of inference mechanism [4]-[2]. Also, the knowledge base and inference mechanism can handle no crisp, incomplete information; the knowledge itself will improve and evolve through learning and past experience [2]. Fuzzy logic control does not require a conventional model of the process, whereas most conventional techniques require either an analytical model or an experimental model. Fuzzy logic control is particularly suitable for complex and ill-defined process in which analytical modeling is difficult due to the fact that the process is not completely known and experimental model identification is not feasible because the required inputs and output of the process may not be measurable [4]. The Adaptive Neuro-Fuzzy Inference System combines the concepts of fuzzy logic and neural networks to form a hybrid intelligent system that enhances the ability to automatically learn [5].

2. Bond Graph Modelling

The bond graph is a graphical representation of the power flow, represented by bonds Fig. 1, in a physical system. The power P is the product of the generalized conjugated variables e (effort) and f (flow),

$$P(t) = e(t).f(t)$$

The physical meaning of the effort and flow variables depends upon the physical domain the bond represents. A unidirectional semi headed arrow shows this energy interchange (the arrow on the bond denotes the direction of positive energy flow).

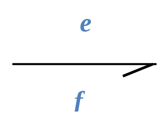

Fig. 1: Energy bond

From the bond graph model developed for a robot manipulator with two degrees of freedom [8], we can formulate a set of manipulator robot differential equations in the following matrix form:

$$\begin{bmatrix}\tau_1\\ \tau_2\end{bmatrix} = \begin{bmatrix} M_{11}(q) & M_{12}(q)\\ M_{21}(q) & M_{22}(q)\end{bmatrix}\begin{bmatrix}\ddot{q}_1\\ \ddot{q}_2\end{bmatrix} + \begin{bmatrix} C_{11}(q,\dot{q}) & C_{12}(q,\dot{q})\\ C_{21}(q,\dot{q}) & C_{22}(q,\dot{q})\end{bmatrix}\begin{bmatrix}\dot{q}_1\\ \dot{q}_2\end{bmatrix} + \begin{bmatrix}G_1(q)\\ G_2(q)\end{bmatrix}$$

Where:
The elements of the inertia matrix M (q) in the terms of the parameters of the robot manipulator are given by:

$$M_{11}(q) = I_1 + I_2 + m_1 l_{c1}^2 + m_2 l_{c2}^2 + m_2 l_1^2 + 2 m_2 l_1 l_{c2} c_2$$

$$M_{12}(q) = M_{21}(q) = I_2 + m_2 l_{c2}^2 + 2 m_2 l_1 l_{c2} c_2$$

$$M_{22}(q) = 2 I_2 + m_2 l_{c2}^2$$

The matrix elements $C_{ij}(q,\dot{q})(i, j = 1,2)$ centrifugal and Coriolis force are:

$$C_{11}(q,\dot{q}) = -m_2 l_1 l_{c2} \dot{q}_2 s_2$$

$$C_{12}(q,\dot{q}) = -m_2 l_1 l_{c2} s_2 (\dot{q}_1 + \dot{q}_2)$$

$C_{21}(q,\dot{q}) = m_2 l_1 l_{c2} \dot{q}_1 s_2$

$C_{22}(q,\dot{q}) = 0$

Finally the elements of the vector of gravitational torques G (q) are given by:

$G_1(q) = (m_1 + m_2) g l_{c1} c_1 + m_2 g l_{c2} c_{12}$

$G_2(q) = m_2 g l_{c2} c_{12}$

3. Control Law Used

3.1. Classical PID Controller

Generally, a classical PID controller of each articulation controlled independently is given with the main following formula [7]:

The classical PID control law of first articulation is given by:

$$\tau_1(t) = K_{p1}\varepsilon_1(t) + K_{d1}\frac{d\varepsilon_1(t)}{dt} + \frac{1}{K_{i1}}\int \varepsilon_1(t)dt$$

When the classical PID control law of second articulation is given by:

$$\tau_2(t) = K_{p2}\varepsilon_2(t) + K_{d2}\frac{d\varepsilon_2(t)}{dt} + \frac{1}{K_{i2}}\int \varepsilon_2(t)dt$$

Where: $\varepsilon_i = q_i^* - q_i \ (i = 1,2)$ is the main position error

The Fig.2 shows the structure of arm manipulator robot classical PID Control.

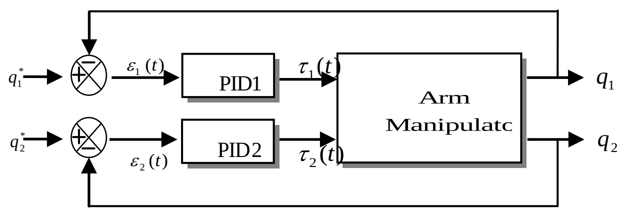

Fig-2: Arm manipulator robot classical PID Control

3.2. Fuzzy Logic Position Control Strategy

The principal design elements in a general fuzzy logic control system shown in Fig.3 are as follows: Fuzzification, Control rule base establishment and Deffuzification [4].

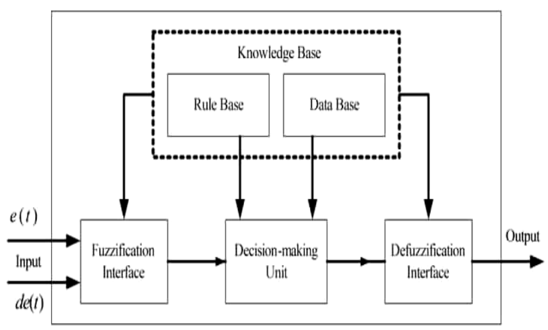

Fig-4: Arm manipulator robot Fuzzy logic control structure

The structure of Arm manipulator robot FLC-MIMO Control show in [9]

3.3. Adaptive Network Based Fuzzy Inference System Position Controller

The ANFIS is a multilayer feed forward network which employs neural network and fuzzy logic learning algorithms to design a plan from input to output. A typical architecture of an ANFIS is shown in Fig.1, in which a circle indicates a fixed node, whereas a square indicates an adaptive node. For simplicity, it was assumed that the desired logic system has two inputs x, y and one output z. Since the proposed neuro-fuzzy model of the ANFIS similar to the first order Sugeno fuzzy model, laws are considered as follows:

Rule 1: if (x is A_1) and (y is B_1), then ($Z_1 = p_1 x + q_1 y + r_1$).

Rule 2: if (x is A_2) and (y is B_2), then ($Z_2 = p_2 x + q_2 y + r_2$).

Where A_i and B_i are the fuzzy sets in the antecedent, and p_i , q_i and r_i are the design parameters that are determined during the training process. As in Fig.5, the Anfis consists of five layers [6]

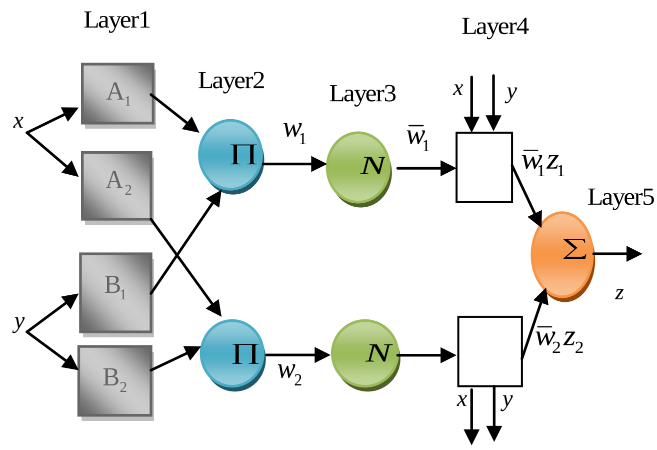

Fig.5: Structure of ANFIS

4. Simulation Results and discussions

This simulation was implemented in Matlab/Simulink.. The figures follows show position error in three cases of control, PID, fuzzy logic and by ANFIS.

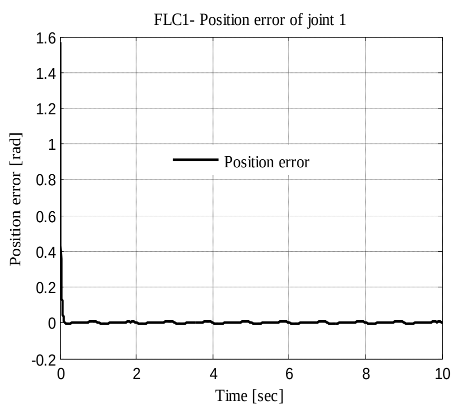

Fig.6. FLC 1 for the first link position error

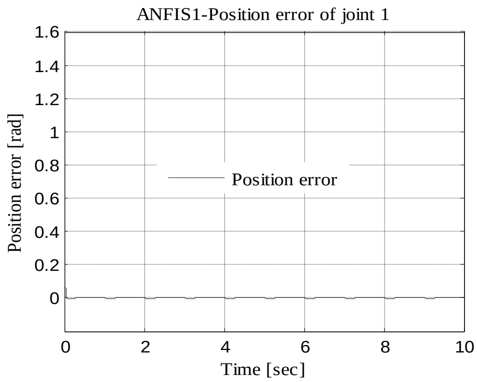

Fig.7.ANFIS 1 for the first link position error

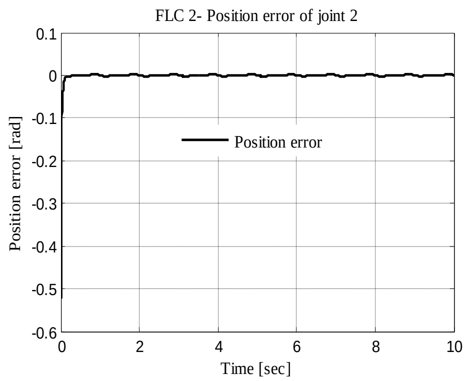

Fig.8. FLC2 for the second link position error

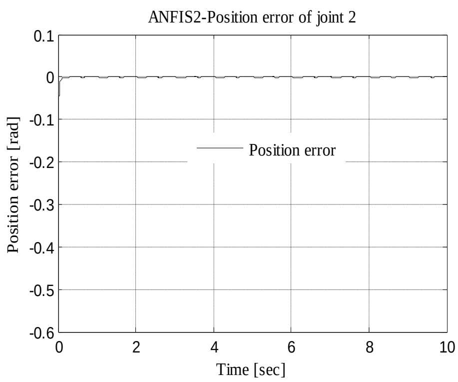

Fig.9. ANFIS 2 for the second link position error

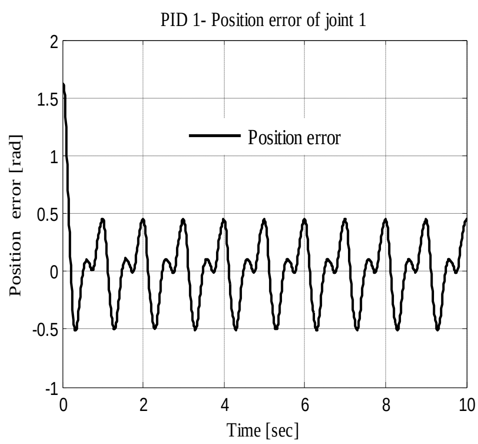

Fig.10 PID1 for the first link position error

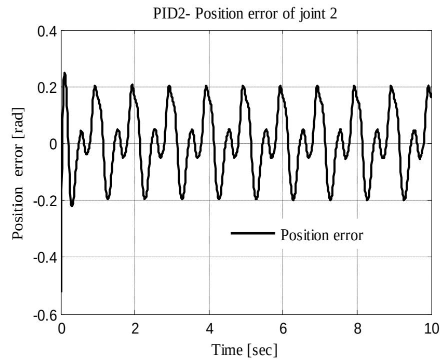

Fig.11. PID 2 for the second link position error

5. Conclusion

In this present work an arm manipulator robot using two degree of freedom was controlled using three types of controls strategies, SISO control based PID, FLC and ANFIS, this last give more and more efficiency for the robot model with more position stability and good dynamical performances so industrials would take into account the efficiency of the developing control model for the futures two freedom robot design considerations.

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