Proceedings of KIIS Spring Conference 2008 Vol. 18, No. 1.

휴머노이드 로봇팔의 물체 조작을 위한 지능형 거리 제어기

Intelligent Distance Controller for Humanoid Robot Arms Handling a Common Object

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Abstract

The main object of this paper is concentrated on distance control of two robot arms of a humanoid using Fuzzy Logic Controller (FLC) for handling a common object. Serial Link Robot arms are widely used in most significantly in Humanoids serving for older people and also in various industrial applications. A method is proposed here that separates the interconnections between two robot arms so that the resulting model of two arms is decomposed into fuzzy logic based controller. The distance between two end effectors is always kept equal to that of the diameter of an object to be handled, so that the object would not fall down. Mathematical model of this system was obtained to simulate the behavior of serial robotic arms in close loop control before using fuzzy logic controller. Lagrangian equation of motion has been used to obtain the appropriate mathematical model of Robotic arms. The results are shown to provide some improvement over those obtained by more conventional means.

Key words: *Fuzzy Logic, Humanoid Robot Arms, Lagrangian Dynamics, Distance Controller.*

I. INTRODUCTION

There has been considerable research on the use of cooperating robotic arms. There are many engineering tasks where using more than one robot arm is either necessary or more economical. A pair of arms can move objects that either are beyond the load carrying capacity of a single arm or have centers of gravity that prohibit a single arm from maintaining the desired object orientation while moving. Moving a large box or lifting a long tub of water so that it remains level all the time are typical examples. Multi coordinated robot arms could also be used to decrease the time required to complete an assembly task and to minimize external feature requirements[1].

The present configuration consists of two robot arms as shown in fig[1]. It is assumed that the two end effectors rigidly grip a common inertial load. Robot arms have highly nonlinear dynamics [2]. Several strategies have been proposed to manage the tracking control of robot arms. On the other hand, intelligent control methods are progressing nowadays. Nonlinear intelligent control methods used in applications of robot arm should face difficulty resulting from the dynamic modeling of robot. Some of these methods are fuzzy control, neural network control and neuro-fuzzy control.

In this paper, the main object of this study is concentrated on the distance controller of two robot arm end effectors for handling a common object. This establishes a fuzzy logic controller to control nonlinear behaviour of a system. Therefore, a distance controller design is adopted and will be applied for such system. In feedback loop of our control system, a fuzzy logic controller (FLC) is used to provide control signals for the manipulator system and used to generate the joint torques and to enhance the performance of the system in control process.

Acknowledgement: This work was supported by grant No. RTI04-01-02 from the Regional Technology Innovation Program of the Ministry of Commerce, Industry and Energy(MOCIE)

2. MODELLING ROBOT ARMS

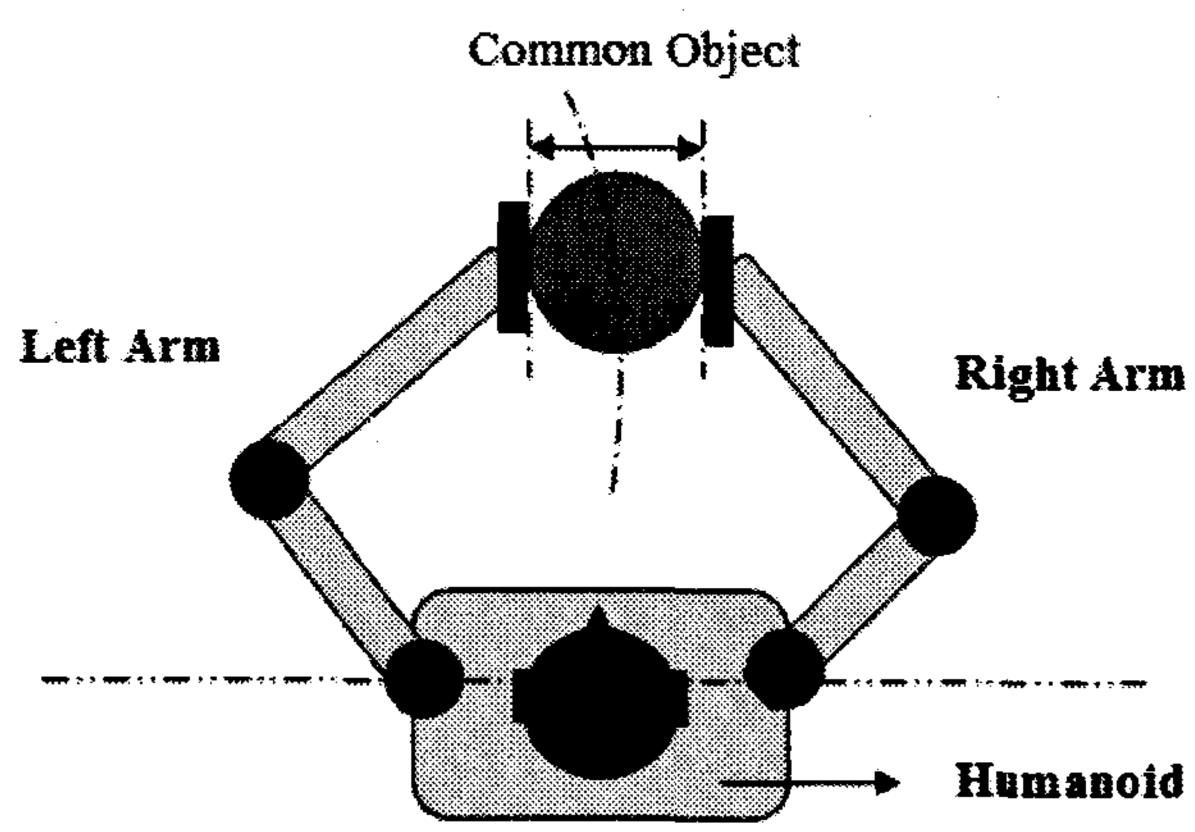

Fig 1: Two robot arm gripping a common object

Due to symmetry in model, dynamics of left arm is similar to dynamics of right arm. Hence the dynamics of right arm is considered as shown in figure 2.

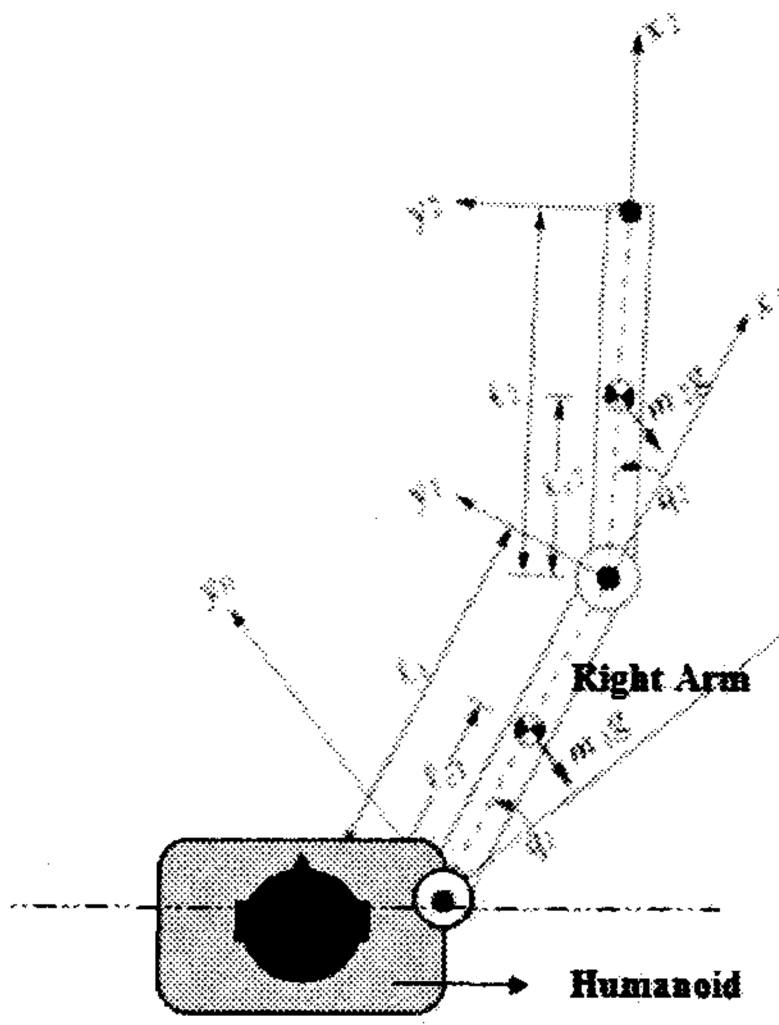

Fig 2: Two-link revolute joint right arm.

Finding the joint translation.
For the first joint,

$$x_{c1} = l_{c_1}\cos(q_1)$$
$$y_{c1} = l_{c_1}\sin(q_1)$$

For the second joint,

$$x_{c_2} = l_1\cos q_1 + l_{c_2}\cos(q_1+q_2)$$

$$y_{c_2} = l_1\sin q_1 + l_{c_2}\sin(q_1+q_2)$$

The translational part of the kinetic energy is

$$K_T = \frac{1}{2}m_1 v_{c_1}^T v_{c_1} + \frac{1}{2}m_2 v_{c_2}^T v_{c_2} = \frac{1}{2}\dot{q}^T\left\{m_1 J_{c_1}^T J_{c_1} + m_2 J_{c_2}^T J_{c_2}\right\}\dot{q}$$

Where
The potential energy of the manipulator is just the sum of those of the two links. Thus, the potential energy is:

$$P = P_1 + P_2 = (m_1 l_{c1} + m_2 l_1) g \sin q_1 + m_2 l_{c2} g \sin(q_1+q_2)$$

Finally, we can write down the dynamical equations of the system:

$$\sum_{j=1}^{n} d_{kj}(q)q_j + \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ijk}(q)q_i q_j + g_k(q) = \tau_k, \quad k = 1,\ldots,n \qquad (4)$$
$$d_{11}q_1 + d_{12}q_2 + c_{121}q_1q_2 + c_{211}q_2q_1 + c_{221}q_2^2 + g_1 = \tau_1$$
$$d_{21}q_1 + d_{22}q_2 + c_{112}q_2^2 + g_2 = \tau_2$$

Equation 4 represents the motion equations for Right arm.
Similarly for Left arm, the dynamic equation of motion would be

$$d_{11}\ddot{q}_3 + d_{12}\ddot{q}_4 + c_{121}\dot{q}_3\dot{q}_4 + c_{211}\dot{q}_4\dot{q}_3 + c_{221}\dot{q}_4^2 + g_3 = \tau_3$$
$$d_{21}\ddot{q}_3 + d_{22}\ddot{q}_4 + c_{112}\dot{q}_4^2 + g_4 = \tau_4$$

3. DESIGN OF INTELLIGENT DISTANCE CONTROLLER

Different methods can be used to control of robot arms to follow any particular trajectory or path planning. However, for a humanoid to handle common object with two arms, distance between two arm end effectors is always need to be constant. This task can be achieved by using intelligent algorithms. Several of these methods are Fuzzy Logic, Neural Network and Neuro-Fuzzy. In this paper, an attempt has been made to achieve this task using Fuzzy Logic based Intelligent Distance Control Techniques. As shown in Fig 3 in the block diagram, PID controllers are used for robotic arms to follow the reference signal to each joint. This helps the robotic arms to follow the trajectory. But while performing this task, the distance between two end effectors may not be constant. It is very essential to maintain the same distance between end effectors within the limited tolerance boundaries throughout the path of robotic arms for handling common object.

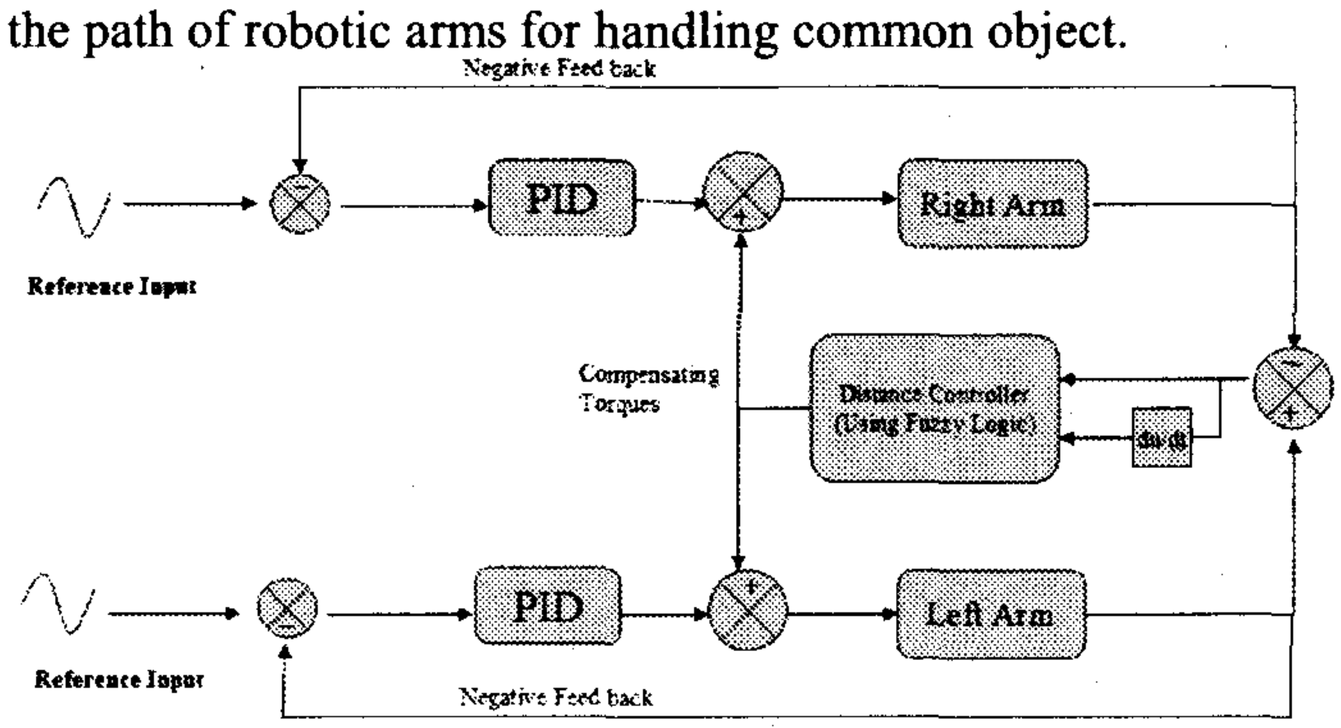

Fig 3: Block Diagram of Distance controller for Humanoid arms

Distance controller regulates the additional torque required by the joints to keep the distance between end effectors constant while maintaining their given trajectory. As there are four joint torques to be controlled $\tau_1, \tau_2, \tau_3, \tau_4$, therefore four outputs are used for fuzzy logic controller which supplies compensating torques to maintain constant distance between two end effectors.

3.1 Fuzzification

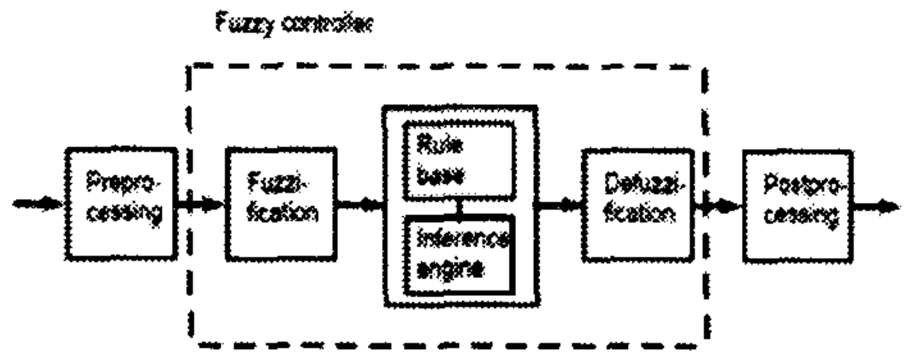

Fig 4: Block Diagram of Fuzzy logic

In this study, fuzzy logic controller has two inputs and four output: the position error which is the difference between diameter of the object and relative difference of the two end effectors actual positions), change of the error and the joint compensating torques $\tau_1, \tau_2, \tau_3, \tau_4$, for two robot joints. Input and output fuzzy members functions are assumed to be symmetry. Triangle member functions were used in membership functions. For simplicity, the position error is partitioned into three fuzzy sets: negative (N), zero (Z), positive (P).

Linguistic Variables
Input: Error ((Pa1-Pa2)-d), Rate of change of error
Output: Torque1, Torque2, Torque3, Torque4

3.2. Rule Base

The one of the important steps of fuzzy logic controller is rule table. The total number of rules is thirty six in this study. The fuzzy logic rule table for robot manipulators is shown in Table1. The torque output for fuzzy logic unit is partitioned into three fuzzy sets: Neg(N), zero (Z), Pos(P).

		Error					
		Negative		Zero		Positive	
Change of error	Negative	T1=Positive	T2=Zero	T1=Negative	T2=Negative	T1=Negative	T2=Negative
		T3=Zero	T4=Negative	T3=Zero	T4=Zero	T3=Positive	T4=Positive
	Zero	T1=Zero	T2=Positive	T1=Zero	T2=Zero	T1=Zero	T2=Negative
		T3=Zero	T4=Negative	T3=Zero	T4=Zero	T3=Positive	T4=Positive
	Positive	T1=Positive	T2=Positive	T1=Positive	T2=Zero	T1=Negative	T2=Zero
		T3=Zero	T4=Negative	T3=Positive	T4=Zero	T3=Positive	T4=Positive

Table 1: Rule Base

Simulink model is developed in Matlab as shown in fig(5). PID controller has been adopted for each joint of each robotic arm to folow the given reference input.

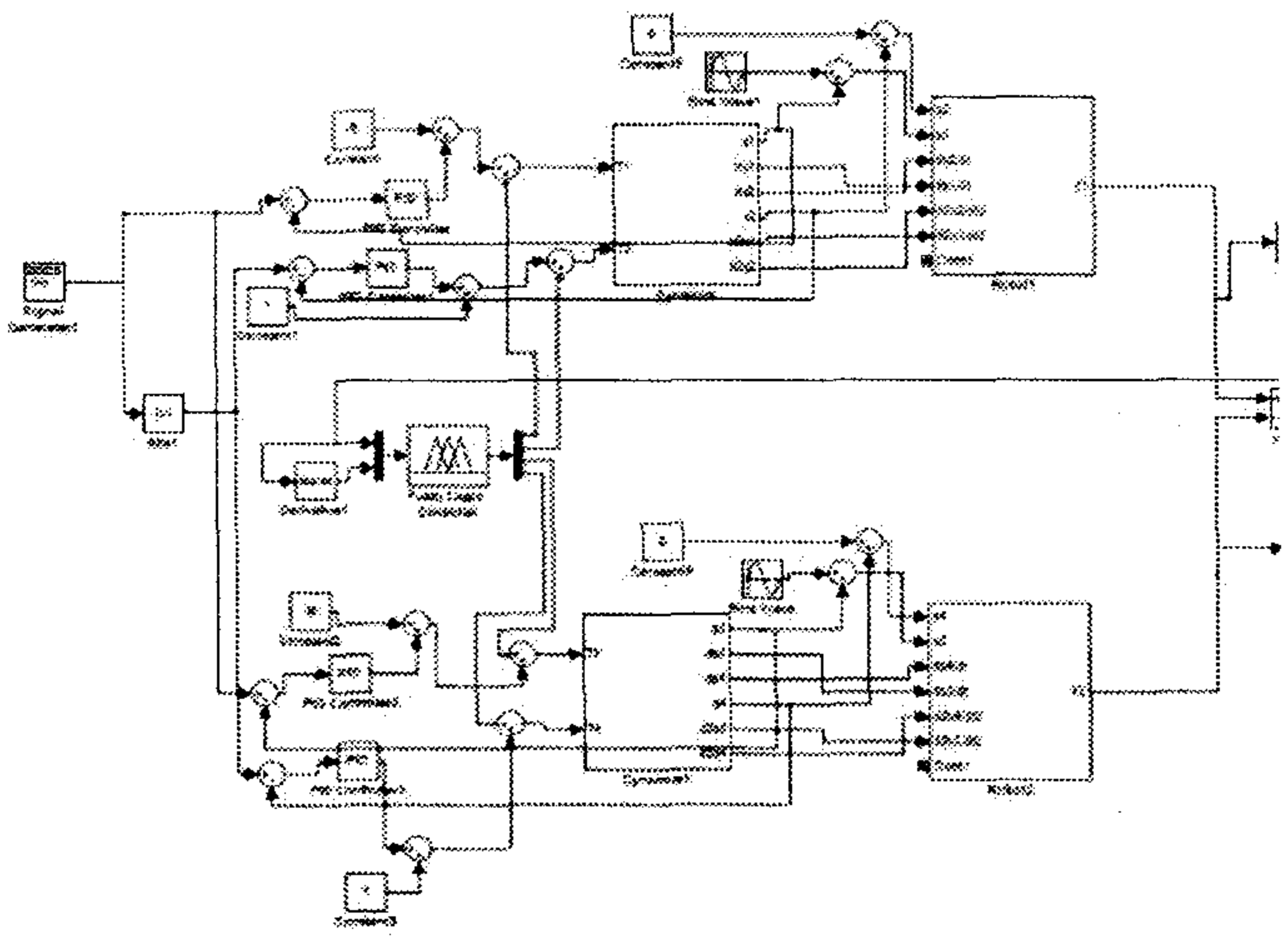

Fig 5: Simulink Model of Fuzzy control for two Robot arms with 2 DOF each

Dynamics of each robotic arm was developed and finally relative differnece between diameter of object and end effectors diatnce and rate of change of this relative difference are two inputs to the fuzzy logic distance controller. The outputs of distance controller are four compensating torques which will be fed back to joints of each arm. This compensating torques always ensure that the disatnce between endeffectors is kept constant.

4. SIMULATION AND RESULTS

Simulation results demonstrate that the distance controller

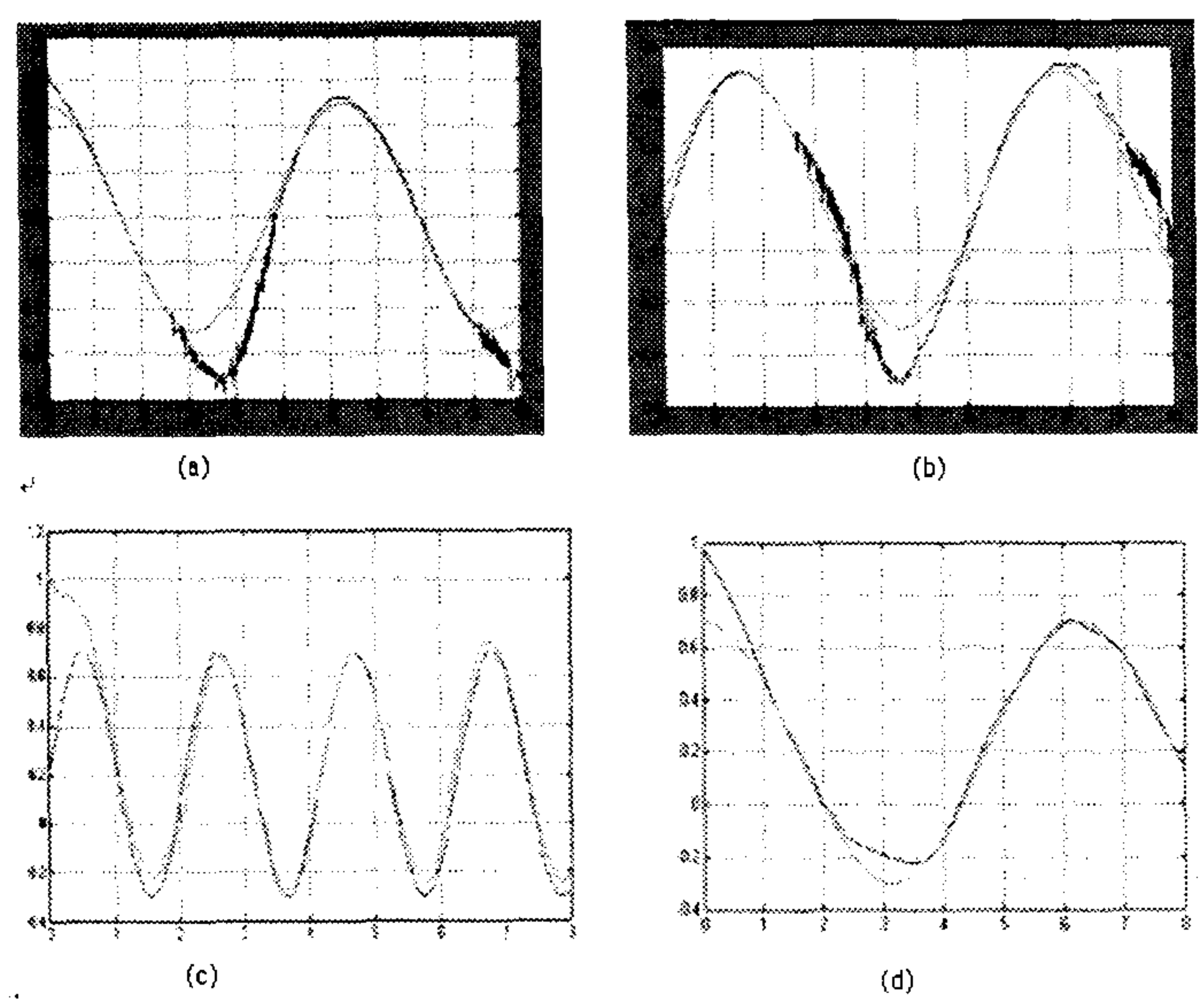

Fig 6: Results for simulation: desired and actual positions of four joint torques 1, 2 ,3 4 respectively

has given convincing results in maintaining the constant distance between two end effectors. Fig(6) a, b shows the trajectory of right arm end effectors And c,d of fig(6) shows the trajectory of left arm end effectors. Green curve represents the desired reference path and blue line represents the actual fuzzy output.

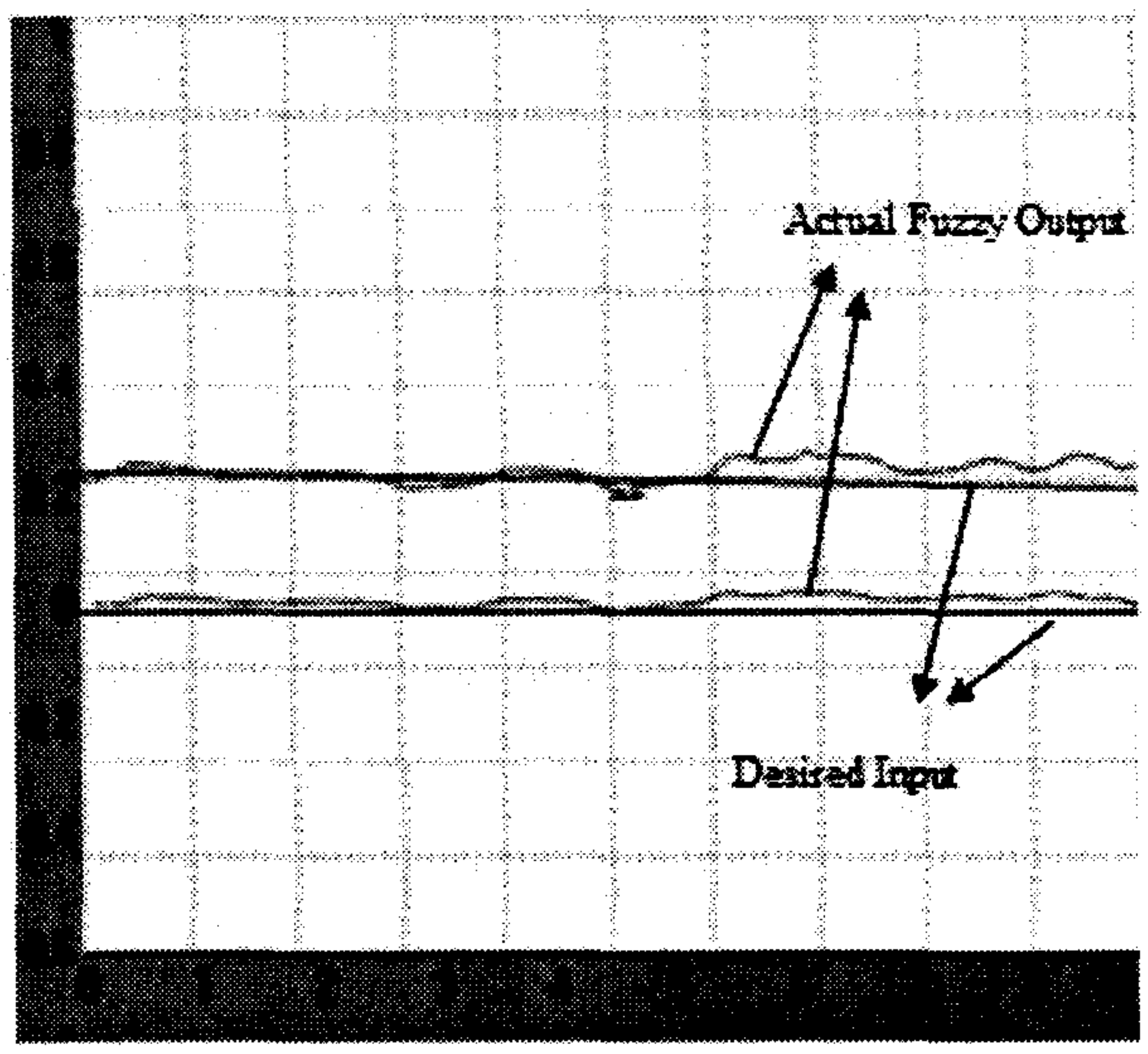

Fig 7: Blue lines represents the reference input, Green line represents the distance controller output

In the above fig(7), the desired constant distance between the end effectors is represented by blue lines. The diameter of the object with limited tolerance boundaries is assumed to be 0.2m. The green line represents the actual fuzzy distance controller output which shows the satisfying result that it has been almost maintaining the constant distance between two end effectors through out its path.

5. CONCLUSION

Distance controller based on fuzzy logic is developed for two arms of a Humanoid for handling common object. Using this intelligent control algorithm, the simulation results clearly demonstrate that the proposed controller is an effective approach to handle common object and trace the desired trajectory. The proposed fuzzy logic control has reached desired performance as shown in simulation results. The tracking performance of robot arms can be improved by fine tuning of values in membership functions for four outputs of the Fuzzy Logic Controller. In a subsequent study, task space inverse dynamics can be developed and discussed for robot arms.

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