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A Fuzzy Logic Approach for Tracking Control a Single-Link Manipulator

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--ABSTRACT--

The fuzzy logic method is used in many applications such as control strategy of robot manipulators. In fact, the application of the concepts of fuzzy set theory in structural control has recently attracted increasing interest. This paper is dealt with an introduction of the fuzzy sets, and its application for tracking control of a single-link robot.

Keywords: Fuzzy Logic method, Single-link robot, Tracking control.

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I. INTRODUCTION

Fuzzy Logic (FL) method is introduced by Lotfi Zadeh for the first time [1-3]. The Fuzzy logic is a multi valued logic approach that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Moreover, notions like rather tall or very fast can be formulated mathematically by fuzzy method, and then processed by computers, in order to apply a more human-like way of thinking in the programming of computers [4]. In fact, for ones who are not familiar with Fuzzy logic, sometimes it seems mysterious and scary, but when it became familiar, it is known as a fast procedure to be applied in scientific problems. Fuzzy Logic has emerged as a profitable tool for controlling and steering of systems and complex industrial processes, as well as for household and entertainment electronics, as well as for other expert systems and applications. Indeed, the Fuzzy Logic is being used in many engineering applications, because it is known as a simple solution for some specific problems. Moreover, one benefit of fuzzy controllers is that they are more adapted with non-linear systems, and effective enough to provide the desired non-linear control actions by carefully adjusting their parameters, especially for robotic systems. In fact, a lot of works have been carried on control of robotic systems such as mobile robots and manipulators [5-9]. Sordalen [10] presented a theoretical model of a fuzzy based reactive controller for a non-holonomic mobile robot. Yang et al. [11] proposed an augmentation to previous applications of FL to 2D robot motion planning. Peri and Simon [12] presented a FL controller to control the motion of differential drive mobile robots. Carelli et al. [13] carried out simulations on a nonholonomic mobile robot to test the performance of the proposed fuzzy controller.

In this paper, the nonlinear dynamic model of a single-link manipulator is presented, and then the dynamic equations of the system are linearized. By setting up a fuzzy controller, the rules related to fuzzification, inference and defuzzification is arranged, and the tracking control of the system is simulated. The simulation results show the applicability of the proposed control strategy.

I. DYNAMIC MODEL OF THE SYSTEM

In this section, the dynamic model of the system is presented. The system is a single link manipulator shown in Fig. 1.

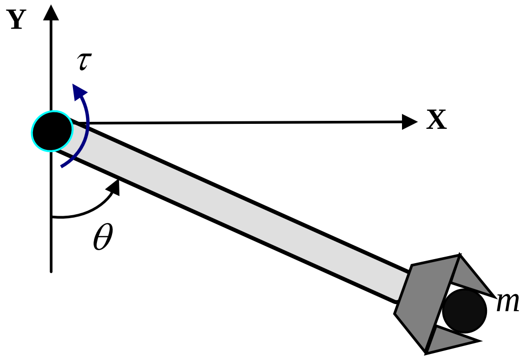

Figure 1. The single-link manipulator

Furthermore, the parameters of the system are assumed as:

Parameters	Nomenclatures
Angular displacement of link	θ
Angular velocity of link	$\dot{\theta}$
Length of link	l
Mass of end point of link	m
Torque exerted to joint	τ
Gravitational constant of earth	g

Table 1. Parameters of the single-link manipulator

To develop the nonlinear dynamic equation of the system, the Lagrange's principle is implemented. Thus the kinematic energy (T) and potential energy (U) of the system are given as:

$$T = \frac{1}{2} m l^2 \dot{\theta}^2 \qquad (1)$$

$$U = -mgl \cos\theta$$

And using the Lagrange's principle, the nonlinear dynamic equations of the system can be summarized as:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\theta}}\right) - \frac{\partial T}{\partial \theta} + \frac{\partial U}{\partial \theta} = \tau \qquad (2)$$

$$\Rightarrow ml^2 \ddot{\theta} + mgl \sin\theta = \tau$$

And, the linearized equations of the system are expressed as:

$$ml^2 \ddot{\theta} + mgl\, \theta = \tau \qquad (3)$$

And the state vector is assumed as $X = \begin{bmatrix} x_1 & x_2 \end{bmatrix} = \begin{bmatrix} \theta & \dot{\theta} \end{bmatrix}$, and the state-form of the dynamic equations of the system are:

$$\dot{X} = AX + B\tau \qquad (4)$$

$$A = \begin{bmatrix} 0 & 1 \\ -\frac{g}{l} & 0 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ \frac{1}{ml^2} \end{bmatrix}$$

II. DESIGN OF FUZZY CONTROLLER

Fuzzy control of the system includes fuzzification, inference, and defuzzification. The membership functions is defined, and Fuzzy operators are applied to the system. Then, the defuzzification of the controller is done.

III. SIMULATION RESULTS

In this section, a simulation results for the tracking control of a single-link manipulator is performed. The values of parameters are given as: $m = 2kg, l = 1m,$. Moreover, the initial condition of the system is assumed as $\theta = 0\,rad, \dot{\theta} = 0\,rad/s$, and it is desired that the manipulator reaches to the final position with $\theta = 1\,rad, \dot{\theta} = 0\,rad/s$. The schematic of Simulink file of the system in MATLAB is shown as Fig. 2:

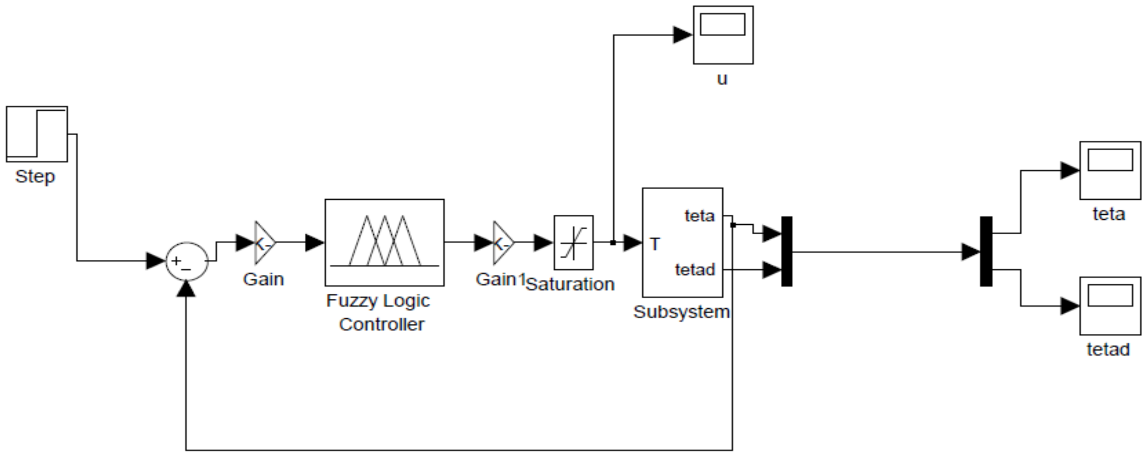

Figure 2. The schematic of Simulink of the system

The simulation results for the angular displacement and the input torque of the system is shown as:

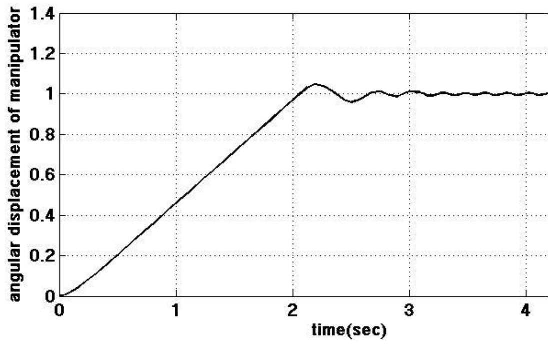

Fig. 3) angular displacement of manipulator

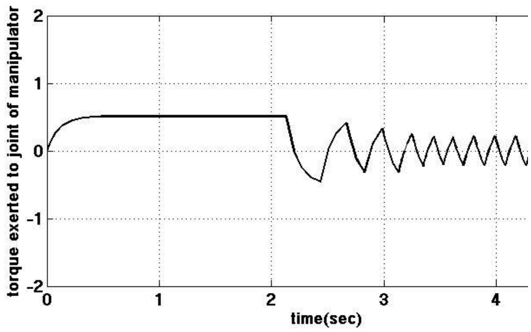

Fig. 4) torque exerted to joint of manipulator

The results show that the fuzzy controller can achieve the desired path.

IV. CONCLUSION

In this paper, the tracking control of a single-link manipulator is aimed using a fuzzy controller. The dynamic of the system is derived, and then some suitable rules are presumed to set up a fuzzy controller, and the simulation results show the applicability of the method.

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