Fuzzy Logic Control for Manipulator Robot actuated by Pneumatic Artificial Muscles.

A. Rezoug, S. Boudoua, and F. Hamerlain

Abstract -- **In this work, we proposed fuzzy logic control of the manipulator robot actuated by the pneumatics artificial muscles. By using bang-bang motion generation, the control objective is the position and velocity tracking the robot. Simulations results demonstrate the feasibility and advantages of our proposed approach.**

Index Terms-- **Fuzzy Logic control, Manipulator Robot, Pneumatic Actuator.**

I. Introduction

The control of the arms manipulators is very delicate because of the disruptions due to the environment and to the complex structure of the robot that leads to nonlinear dynamic equations and greatly coupled. Besides, the parameters of inertia depend on the load that is often unknown. The control using conventional methods is difficult to realize because of the high nonlinearity of the robot system.

Up to now, the fuzzy controller has been the most successful application field for fuzzy logic. Many applications show that the fuzzy controllers yield results superior to those obtained by the conventional control algorithms. However, fuzzy controllers are basically non-linear, and effective enough to provide the desired non-linear control actions by carefully adjusting their parameters. The fuzzy logic control (FLC) has been an active research topic in automation and control theory since the work of Mamdani proposed in 1974 based on the fuzzy sets theory of Zadeh (1965) to deal with the system control problems which are not easy to be modeled [1].the characteristics fuzzy logic summarized by:

- No need for a mathematical model
- Provides a smooth transition between members and nonmembers
- Relatively simple, fast and adaptive
- Can implement design objectives, difficult to express mathematically, in linguistic or descriptive rules.

By using of fuzzy logic technique objective of the work is to control of position and velocity for manipulator robot actuated by pneumatic actuators muscles using the bang-bang motion generation.

The paper is organized as follows. Section II presents the robot platform and its identification. Section III discusses the fuzzy logic controller, simulation results are presented and discussed in section V. we finally by the conclusion

II. Robot Presentation And Identification

A. robot description

Our platform, it's the three degree of freedom manipulator robot when it is actuated by the pneumatics muscles they so-called McKibben muscles, this pneumatic muscles robot is a special Robosoft product dedicated to research and development actions. This product has been designed as a set of modular robotics elements. The pneumatic muscles used are the MAS-40- N300, produced by FESTO [4].

Fig.1. a FESTO fluidic muscle.

Pneumatic actuators are a class of devices or mechanisms that convert pneumatic power into useful mechanical work or motion. Because the artificial pneumatic muscles are unidirectional actuators, two antagonistic coupled artificial pneumatic muscles are needed to actuate a revolute joint as shown in Figure 1; the mechanical motion produced by a variation of the joint variable can be obtained by modifying the pressure ΔP in the each muscle. The motion principle is shown in the figure 1. We chose these actuators for the reason that is suitable for application in domestic environments.

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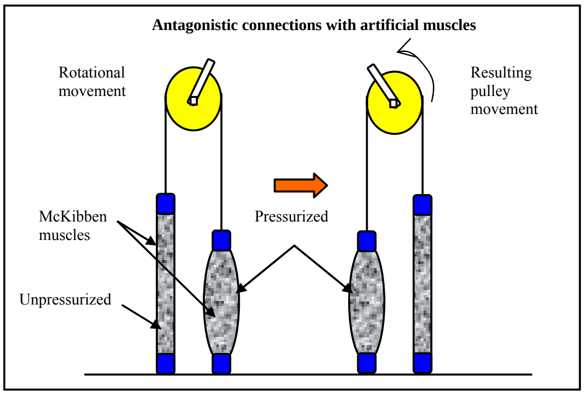

Fig.2. Example of the principle of pneumatic artificial muscle.

The main advantages of pneumatic muscles are**:**

- Low in price;
- High power/weight ratio;
- Usage in rough environments (e.g. sandy, wet conditions);
- Maintenance free.

C. parameters identification

We notice that the response is not noisy except for the assumed small quantization noise. For this reason, we will choose a simple *ARX* model (Autoregressive with exogenous input). A general *ARX* model is represented as in following figure [13]:

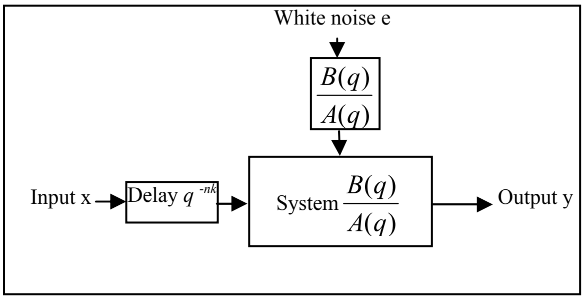

Fig.3. *ARX* system structure.

$$A(q)y(t)=B(q)x(t_{-nk}T)+e(t) \quad (1).$$

Where the two polynomials are of the *ARX* model are:

$$A(q)=1+a_1q^{-1}+.........+a_{n_a}q^{-n_a}$$
$$B(q)=b_1+b_2q^{-1}+.........+b_{n_b}q^{-n_b+1} \quad (2).$$

a_i and b_i presents the parameters of the system, n_k is the number of period delays, e is a white noise.

The dynamic behaviour of the system-muscles, valves and the joint-was characterized by open-loop step input response tests: small steps involve command signal was imposed and the resulting angular displacement was measured. We have experimented different values of n_a, n_b and n_k, the best

results have been obtained for: n_a= 2, n_b=1, and n_k = 0. The corresponding polynomial parameters are gives in the table 1, then the robotic manipulator system dynamics may he described by the second-order linear differential equation given in equation (3), this led to the following model:

$$\ddot{q}+a_{i1}.\dot{q}+a_{i0}.q=bi.u. \quad (3).$$

Due to the modelling errors and uncertainties parameters, the parameter a_{i1}, a_{i0} and b_i are not exactly known, and then the uncertain parameter a_{i1}, a_{i0} and b_i are assumed to be about 20% uncertain:

$$a_{i0}^*-\Delta a_{i0}<a_{i0}<a_{i0}^*+\Delta a_{i0}.$$
$$a_{i1}^*-\Delta a_{i1}<a_{i1}<a_{i1}^*+\Delta a_{i1}. \quad (4).$$
$$b_i^*-\Delta.b_i<b_i<b_i^*+\Delta.b_i.$$

Where a_{i0}*, a_{i1}* and b_i* are the parameters estimated with variation of intervals Δa_{i0}, Δa_{i1} and Δb_i.

By using matlab *ident* function for the identification of the parameter of the each like are given by:

TABLE 1.PARAMETRES OF MODELS

parameters / **Axes**	***BI***	***ai1***	***ai2***
Axe1	0.14	-0.013	0.00573
Axe2	0.12	-0.053	0.0155
Axe3	1.25	-0.55	0.00223

The obtained models for each axe of robot are uses for the design of sliding mode controller and fuzzy sliding mode controller, will presented in the following section

III. THE PROPOSED FUZZY CONTROLLER

A fuzzy controller consists of: a set of rules, an inference engine, a fuzzifier and a defuzzyfier. Rules may be provided by an expert (i.e. a human) or can be extracted from numerical data. The fuzzifier maps crisp numbers into fuzzy sets. Its job is to activate rules associated (through linguistic variab1es) with fuzzy sets. Fuzzy inference is expressed in terms of fuzzy variables that are ambiguous or imprecise. Depending on the input values, fuzzy variables become active and the inference engine creates a fuzzy set for the output fuzzy variables. Thus inference engine maps fuzzy sets into fuzzy sets. The resulting output fuzzy set is given as input to a defuzzyfier, which transforms the set into crisp numbers (i:e:a control action). The inference engine is the core of the fuzzy system which handles the way in which rules are combined, representing the knowledge base of the system. Just as we humans use many different types of inferential procedures to understand all our observations. Unlike with crisp sets, an element in fuzzy logic can belong to more then one set to different degrees of similarity. A fuzzy set is characterized by a linguistic variable that is a variable whose value is not a number but a words or sentence

in a natural or artificial language. Since a variable may belong to several linguistic variables, the membership functions, but the most commonly used are: triangular, Gaussian, trapezoidal and piecewise linear. One of the strengths of. Fuzzy logic is that membership functions can be made to overlap each other.

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The fuzzy controller is shown in Fig.4. The first input is the error of the robot; the second input is the variation:

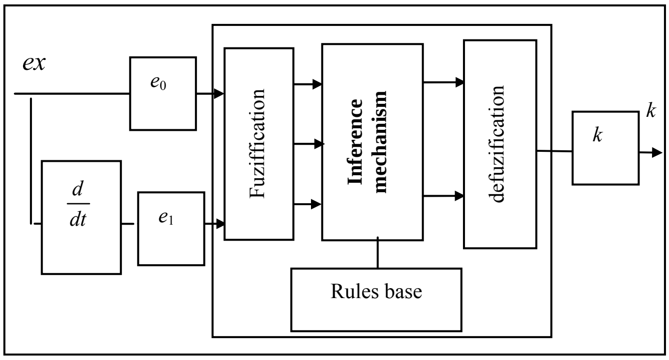

Fig.4. Fuzzy controller bloc.

Whit e_0 , e_1 and k are the gain of normalisation of e and $\dot{e}$ respectively determined by the tests, the design of the fuzzy logic controller needed there steps (fuzzification, inference and defuzzification) detailed in the following section:

The inputs (e) and ($\dot{e}$) and output is the control low (u) fuzzy variables are defined with 15 linguistic labels and the membership functions of the fuzzy variables are chosen to be fully overlapped, triangular, trapezoidal and symmetric.

Step 1: Fuzzification

The fuzzification module it turns real input values into fuzzy values, i.e. a set of (fuzzy set label, membership degree). We define the fuzzy sets of first inputs as {pb (Positive Big), pm (Positive Middle), ze (Zero), nm (Negative Middle), and nb (Negative Big)}. We perform symmetric membership functions on the controller's input universe of discourse. As shown in Fig.5, the universe of discourse for error (-1, +1):

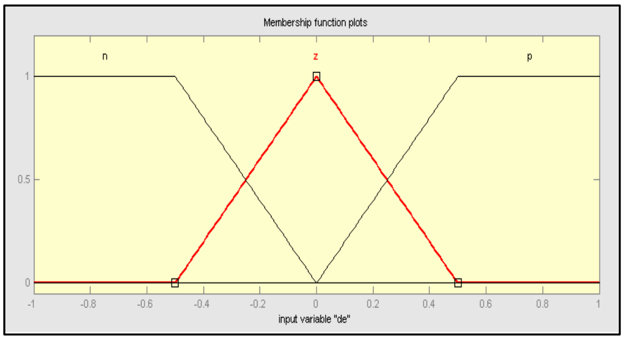

Fig.5.Input controller *e*.

The last inputs {p (Positive), z (Zero), and n (Negative)}. We perform symmetric membership functions on the

controller's input universe of discourse. As shown in Fig.6, the universe of discourse of the second input $\dot{e}$ is (-1, +1):

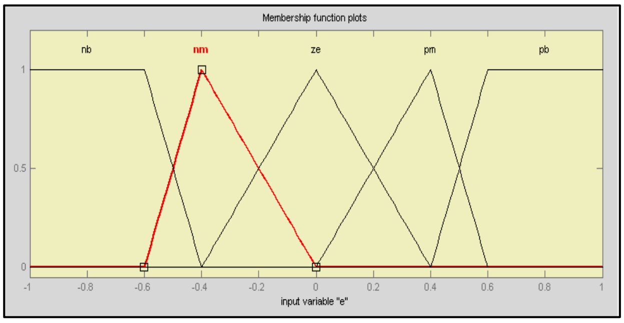

Fig.6.Input controller ($\dot{e}$).

The fuzzy sets of output as {posb (Positive big), posm (positive Middle), Zero (Zero), negm (negative Middle) negb (negative big)} the universe of discourse for the output is (-1, +1).

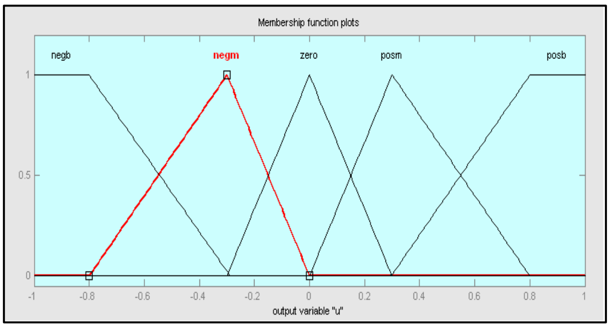

Fig.7. output u_{fuzzy}.

Step 2: inference

The inference is the kernel of the fuzzy controller. By using the knowledge base and fuzzy logic, it determines the fuzzy commands to apply to the process. In this step, we use the linguistic quantification to specify a set of rules that describe the expert's knowledge about how to control the objective. The fuzzy rules are shown in Table 2.

TABLE.1. FUZZY BASE RULES

parameters / **Axes**	NB	NS	ZE	PS	**PB**
P	*UG*	*UF*	ZE	*DF*	*DG*
Z	*UG*	*DF*	ZE	*UF*	*DG*
N	*UG*	*DG*	ZE	*DG*	*DG*

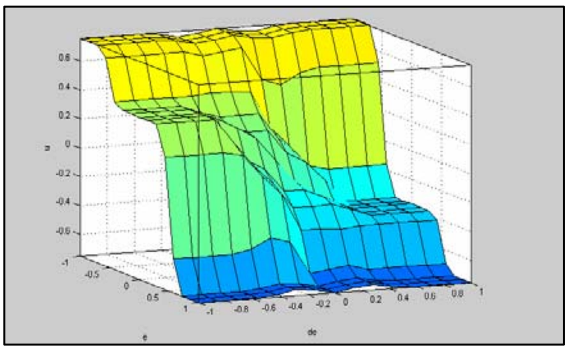

Fig.8. View of surface.

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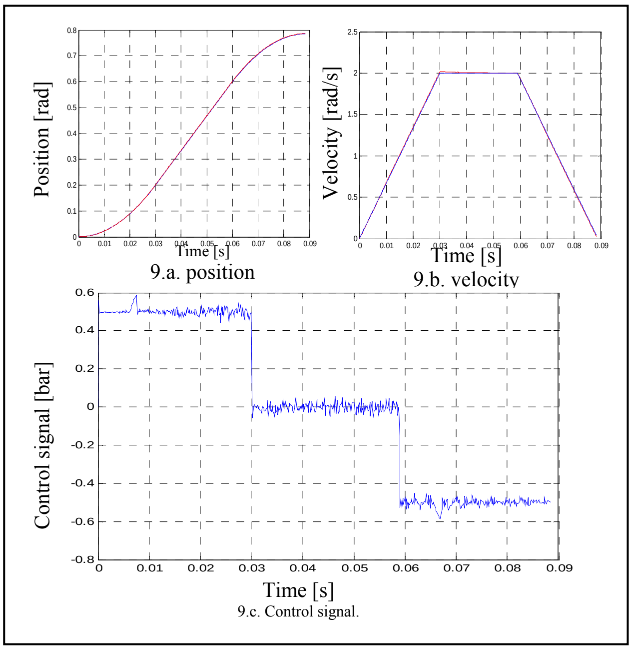
Step 3: Defuzzification

The defuzzification module it turns fuzzy commands into actual commands for the actuators of the process. The defuzzification procedure was based on the centre of area method.

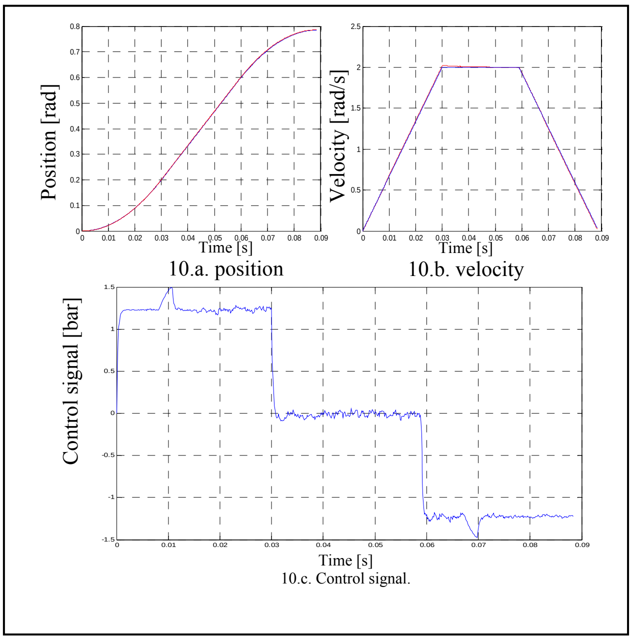
IV. Simulate Results and Discussion

Based on the bang-bang motion generation, this section presents the simulation results of the position and velocity control of the manipulator robot based on fuzzy logic control.



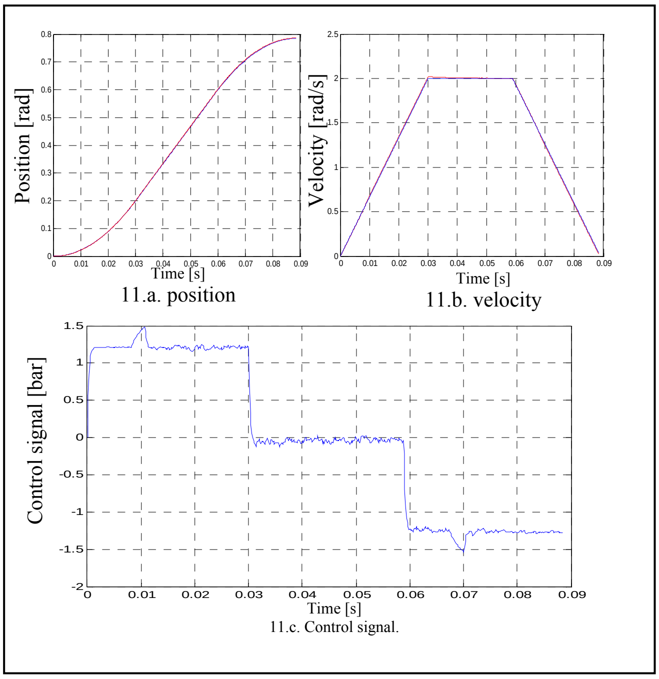
9.a. position 9.b. velocity
9.c. Control signal.

Fig.9. fuzzy sliding mode controls of axe1.



10.a. position 10.b. velocity
10.c. Control signal.

Fig.10. fuzzy sliding mode controls of axe2.



11.a. position 11.b. velocity
11.c. Control signal.

Fig.11. the fuzzy sliding mode controls of axe3.

The simulation results of proposed fuzzy logic controller due to position and velocity control of three degree of freedom manipulator robot shown in the figure 4, Figure ((9.a,9.b) (10.a,10.b), and (11.a,11.b)) presents the position and velocity for the input (bleu) and the output (red) of each axe of robot we remark the net tracking for the all axes, figure (((9.c) (10.c), and (11.c)) show the proposed command law is able to controlled the robot with the smoothing signal control.

V. Conclusion

In this paper, we addressed the position and velocity control problem of the manipulator robot actuated by artificial muscles taking into account the dynamics. From the results, it can be seen that fuzzy logic control can be applied to arm robot. The difficulty in the design of controllers due to modelling uncertainty and disturbances of unknown origin can be reduced significantly if the fuzzy logic is used. A solution based on the fuzzy logic control method is proposed. Through simulation results, it can be seen that fuzzy logic control can be applied to the control of our manipulator robot.

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