DYNAMICAL FUZZY CONTROL WITH BLOCK BASED NEURAL NETWORK

Mehmet KARAKÖSE
mkarakose@firat.edu.tr
Erhan AKIN
eakin@firat.edu.tr
Fırat University, Department of Computer Engineering, 23119, Elazığ, Turkey

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ABSTRACT

In this paper, a different fuzzy control algorithm, which is used dynamical fuzzy logic system and block based neural network, is proposed for dynamical control problems. The proposed algorithm is a general method, which can be applied to great variety of real-world problems. The effectiveness of the proposed method is illustrated by simulation results for dc motor position control problem.

I. INTRODUCTION

Fuzzy logic has attracted much attention as a powerful tool to control of many systems during the past two decades [1]. The fuzzy logic systems designed using fuzzy logic implements human reasoning that has been programmed into membership functions, fuzzy rules and rule interpretation. As well known, the fuzzy logic system involves four main stages: fuzzification, rule base, inference mechanism and defuzzification as shown in figure 1. Fuzzification and defuzzification stages are needed to convert and reconvert real world crisp signals into fuzzy values and vice versa. The inference mechanism determines the matching degree of the current fuzzy input with respect to each rule and decides which rules are to be fired according to the input field. Next, the fired rules are combined to form the control actions [2].

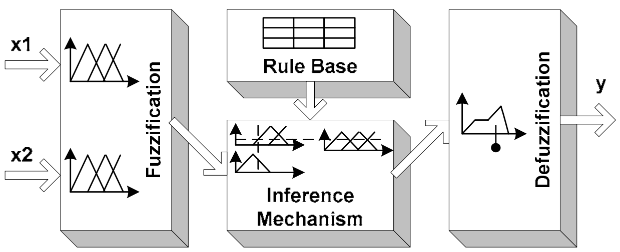


Figure 1. Structure of a fuzzy system

Fuzzy control based on fuzzy logic decision making to arrive at the control actions. The fuzzy controller uses pair of the values error and change of error and calculates the control signal as shown in figure 2 [3].

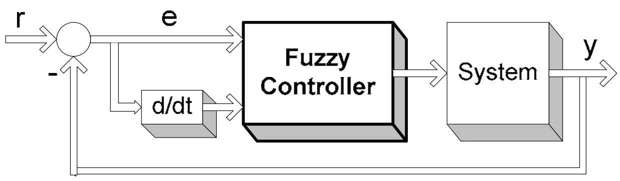


Figure 2. Block diagram of a fuzzy controlled system

Physical systems are generally dynamic. Therefore, this provided a new approach called as dynamic fuzzy logic systems in dynamic system control task. The dynamic fuzzy logic systems consist of the static fuzzy system and a dynamic element with positive feedback constant as shown in figure 3. The dynamic fuzzy logic systems initially investigated by Lee and Vukovich [4]. Murty [4] proposed an extended dynamic fuzzy logic system based indirect stable adaptive control of nonlinear systems.

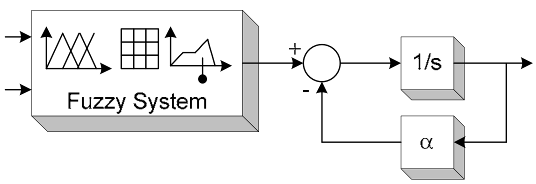


Figure 3. Dynamic fuzzy logic systems

Artificial neural networks have been successfully applied to many engineering problems [5]. There are different structures of artificial neural networks as multilayer feedforward, recurrent networks and Kohonen [6]. The block based neural network as a different structure proposed in [7] for practical purposes. The block based neural networks can achieve simultaneous optimization of network structure and connection weights using genetic algorithms [7].

The structure of the block based neural network allows signal flow forward and backward directions. Each of the basic blocks that have different signal flows corresponds to a simple feedforward neural network. Figure 4 shows the basic blocks that have four different types of internal configuration [7].

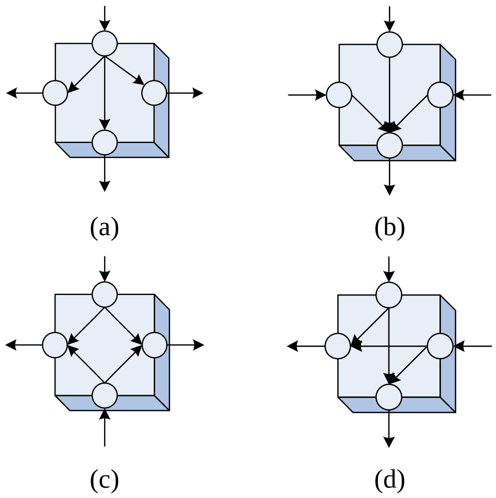


Figure 4. Internal configuration types of fundamental blocks for block based neural networks

In this paper, a dynamical fuzzy logic control system with the block based neural network is proposed in order to eliminate effects of disturbances in the system and provide scaling task in inputs of fuzzy controller. Some simulation results are considered for performance comparison using dc motor position control problem.

II. PROPOSED ALGORITHM

In closed loop control systems, the reference signal and/or the measurement signal as inputs of fuzzy logic controller can have some disturbances. There are some studies to eliminate disturbances in the literature [8-9]. In these studies, type-1 and type-2 fuzzy sets have been used in inputs of fuzzy logic system. But these studies are static solutions for control problems.

As well known, control systems are generally dynamic systems. The dynamic fuzzy logic systems can be use to control of dynamic systems. First research works in dynamic fuzzy logic systems had been studied by Lee and Vukovich. One of these studies deals identification and control for nonlinear systems using dynamic fuzzy logic systems [4].

There are some uncertainties and noises in the control systems. These uncertainties and noises are important for inputs of fuzzy logic systems. The main criteria of a control system consist of the difference between reference and measurement values as shown in figure 2. Therefore, elimination of uncertainties and noises is very useful for control task.

The scaling factors play an important role for the fuzzy logic controller design in order to achieve a good behavior in both transient and steady state. These scaling factors can be constant or variable. As shown in figure 5, there are three scaling factors (K1, K2 and K3) for a fuzzy logic controller. Tuning of scaling factors in fuzzy controllers has been studied by many researchers in the literature [10-12].

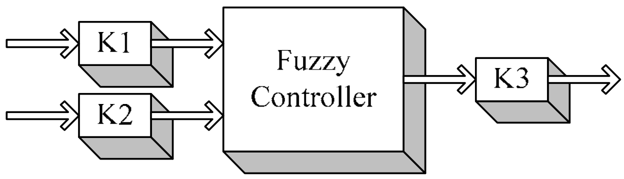


Figure 5. The scaling factors for a fuzzy controller

Advantages of the dynamic fuzzy logic systems and the block based neural networks can be combined to obtain a more effective control system. Figure 6 shows block diagram of proposed algorithm in this study. As shown in figure 6, the block based neural network structure is used for inputs of a dynamical fuzzy logic system. Thus, the block based neural network eliminate uncertainties and some noises and it provide input scaling task. Structure of the block based neural network obtains using genetic algorithms.

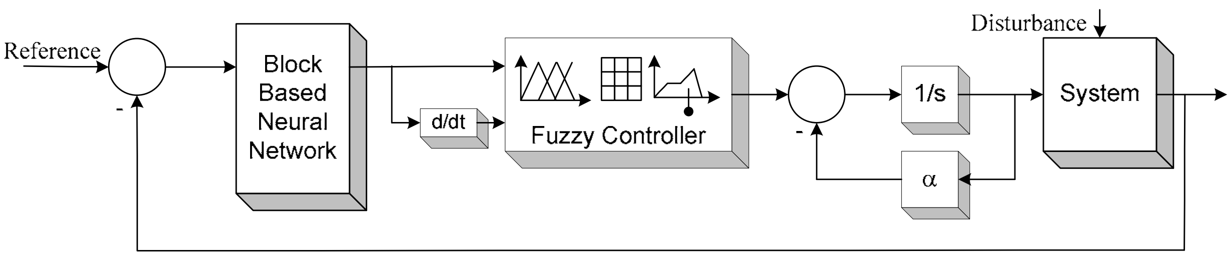


Figure 6. Block diagram of proposed algorithm

III. SIMULATION RESULTS

To demonstrate effectiveness of the proposed algorithm, a dc motor position control problem is chosen. The dynamical fuzzy controller is used for position control of a dc motor. In the simulations, the position of 360° is normalized to 1. System is simulated with the fixed sampling time T=0.0002 sec.

The proposed algorithms were investigated by means of simulations in the MATLAB/Simulink. A transfer function of dc motor position control system can be given in equation (1) in order to analyze behavior of dynamical fuzzy controller with the block based neural network. The block diagram of dc motor is shown in figure 7. Table 1 shows parameters of this dc motor.

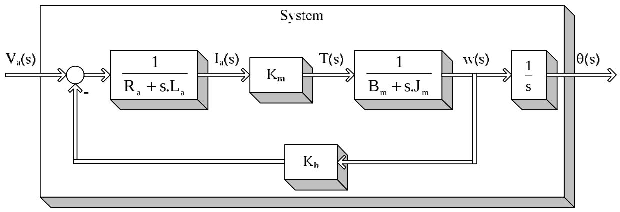


Figure 7. Block diagram of armature controlled dc motor

$$G(s) = \frac{2.2}{s\left(8.959x10^{-6}s^2 + 7.268x10^{-3}s + 0.9449\right)} \qquad (1)$$

Table 1. DC motor parameters	
L_a	5.27 mH
R_a	3.9 Ω
J_m	0.0017 $Kgfcm^{-1}sec^{-2}$
B_m	0.121 $Kgfcm^{-1}sec^{-1}$
K_m	2.2 $Kgfcm^{-1}A^{-1}$
K_b	22.5 $Vkrpm^{-1}$

Figure 8 shows structure of the block based neural network obtained with genetic algorithms. As shown in figure 8, two blocks are used in the block based neural network.

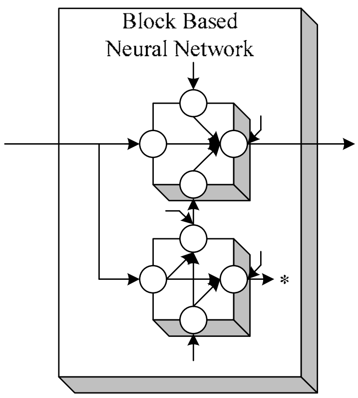
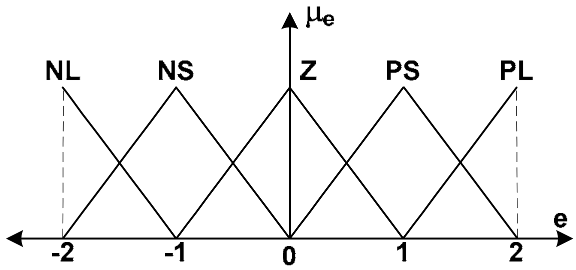
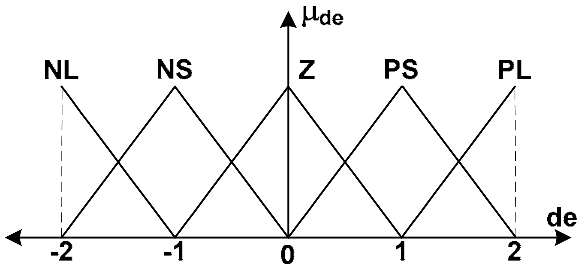


Figure 8. Structure of the block based neural network

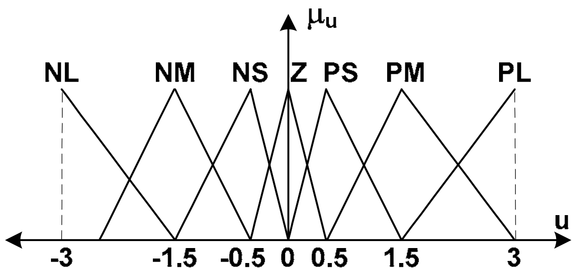
The membership functions and rule table of dynamic fuzzy logic controller are given in figure 9. Figure 9(a-b) shows the membership functions for inputs and figure 9(c) shows the membership functions for output of the dynamic fuzzy controller. Five triangular membership functions are chosen for simplicity. The max-min inference algorithm is selected to complete the fuzzy procedure, and the fuzzy logic controller output is obtained by the gravity centre defuzzification method.



(a)



(b)



(c)

e \ de	NL	NS	Z	PS	PL
NL	NL	NL	NM	NS	Z
NS	NL	NM	NS	Z	PS
Z	NM	NS	Z	PS	PM
PS	NS	Z	PS	PM	PL
PL	Z	PS	PM	PL	PL

(d)

Figure 9. The membership functions and rule base of the dynamic fuzzy logic system

Figure 10 shows the simulation results for 1 (pu) position reference in dc motor. As shown in this figure, the dynamic fuzzy controller with block based neural network gives better results than conventional fuzzy controller. Figure 11 shows the simulation results with %5 noise for 1 (pu) position reference. The dynamic fuzzy controller with the block based neural network provides smooth system output according to conventional fuzzy controller.

Although a control system is chosen for simulations, the block based neural network can be used for inputs all fuzzy logic systems to eliminate noises and provide scaling. Proposed algorithm is very simple and effective.

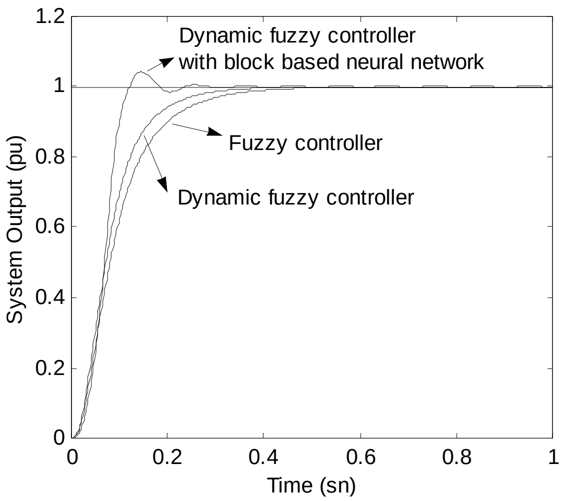


Figure 10. System output response for 1 pu reference position

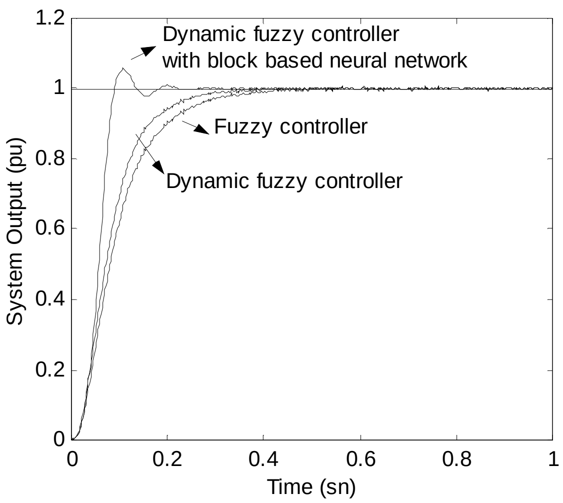


Figure 11. Simulation results with %5 noise for 1 (pu) reference position

IV. CONCLUSIONS

In this paper, a dynamic fuzzy control structure with the block based neural network. The proposed algorithm uses the block based neural network to eliminate some disturbances and scaling task in inputs of the dynamical fuzzy logic system. The proposed algorithm has been successfully verified on dc motor position control problem by means of simulations.

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