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Design and Implementation of DC Motor Speed Controller Using Fuzzy-Adaptive Controllers

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Abstract : -As adaptive control systems have parametric construction and high accuracy against disturbances, and fuzzy control systems can compensate deficiency of dynamic parameters in time [1], in this paper fuzzy–adaptive controllers is used. Drive method is PWM and 8955 microcontroller is used for DC motor speed controlling. Simulation studies has been performed by MATLAB SIMULINK6.1 and SIDE51 (ver1.04R11) software by C language is used for program of controller and its compiler is used for making hex file to program 8955 microcontroller by EPROM PROGRAMMER (PGM89)[6,7] . The DC motor is VGFMED-BSMIB52 and driving IC is L298 IC.

Key words: -Fuzzy-adaptive control, Microcontroller, DC motor .

1 Introduction

Motor speed control or round control is one of the important subjects in robotics and military industries[1,2].
The conventional control methods are robust control and classic control methods, however fuzzy–adaptive and adaptive methods are rarely used. Non-adaptive methods are not suitable in industries, because it is not possible to adapt with changes of parameters and if total dynamic system is not in access, parameters of controllers does not change with model parameters. Even in neural networks with sensitivity analysis, change of controller parameters is very complex. However, in fuzzy-adaptive system, defined control parameters change easily to decrease system error. Fuzzy adaptive system is a model-free system and it can control any system with every dynamism and it is possible to use dynamic parameters of system because of its fuzzy property. In this paper basis 2 fuzzy adaptive control is used for accurate speed control of a DC motor. Simulation is performed by 8955 microcontroller and L298 switches as driver.

2 Fuzzy Controller Design

the general construction shown in fig.1 is used for controller design.
In this diagram , a non-linear system with differential equation (1), where f is an unknown function and b is a constant coefficient:

$$X^{(n)}=f(x,x^{0},\ldots,x^{(n-1)})+bu \qquad (1)$$

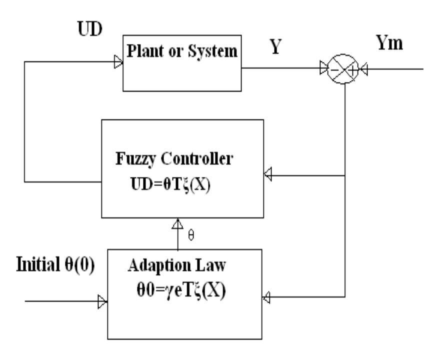

Fig.1- General Construction of fuzzy adaptive control.

In this method, the aim is to design of a feedback controller for speed motor control (Y). θ is adaptive parameter and $U_D=\theta^T\xi(X)$ is fuzzy adaptive controller as shown in fig.1[3,4,5].

3 Fuzzy – Adaptive Laws

The first law is revealed in eq.(2):

$X_1=P^r{}_1$, $X_n=P^r{}_n$ then $U=Q^r$ (2)

The controller is $u_D(X, \theta)$ as shown in eq.(3):
$U_D(X, \theta) =\theta^T\xi(X)$ (3)

Where:

$$\xi(X)_{l1,..,ln} = \prod_{i=1}^{n} \frac{\mu_{Ai}^{li}(Xi)}{\sum_{l1=1}^{P1} \cdots \sum_{ln=1}^{Pn} \prod_{i=1}^{n} \mu_{Ai}^{li}(X_i)}$$

(4)

μ_{Ai} constants are defined as fuzzy curves or functions.
Initial value of θ parameters are selected by law (1), as (5) for adaptation law by using liapanov equation ,is (6):

$\theta^0= \gamma e^T P_n \xi(X)$ (5)
$V=1/2(e^T Pe)+b(\theta^* - \theta)^T(\theta^* - \theta)/2\gamma$ (6)

Where,

θ^*=Ideal parameter of adaptation when $u=u^*$.
u^*= Ideal control parameter when error is very small.
P=a positive liapanov matrix.
γ=a positive constant.
b>0 and V>0 and $e=Y_m-Y$

Then $\overset{\circ}{V}<0$ and fuzzy adaptive system control is stable[8].

4 Simulation

Model of DC motor based on response to step voltage input is obtained in (7).

$\omega(s)/V(s)=4.05e^{-0.13s}/(s+2)$ (7)

Where,
$\omega(s)$ = speed of DC motor and
$-90r/min<\omega<90r/min$
V(s) = step voltage in input.

This model is selected according to a typical machine model. It is a first order model by delay and its constants depend on machine parameter e.g. inertia[7].

In this controller X= ω and μ_{Ai} are (8) untill (13) .

For very right round direction :
$\mu_{A1} = 1/(1+\exp(0.2(\omega -40)))$
$\omega=90$ (8)

For middle right round direction :
$\mu_{A2} = \exp(0.003(-(\omega -33.75)^2)))$
$\omega=70$ (9)

For a few right round direction :
$\mu_{A3} = \exp(0.003(-(\omega -11.25)^2)))$
$\omega=50$ (10)

For a few left round direction :
$\mu_{A4} = \exp(0.003(-(\omega -11.25)^2)))$
$\omega=-50$ (11)
For middle left round direction :
$\mu_{A5} = \exp(0.003(-(\omega +33.75)^2)))$
$\omega=-70$ (12)

For high left round direction :
$\mu_{A6} = 1/(1+\exp(0.2(\omega +40)))$
$\omega=-90$ (13)

The simulation by MATLAB-SIMULINK6.1 is shown in fig.2 until fig.7.

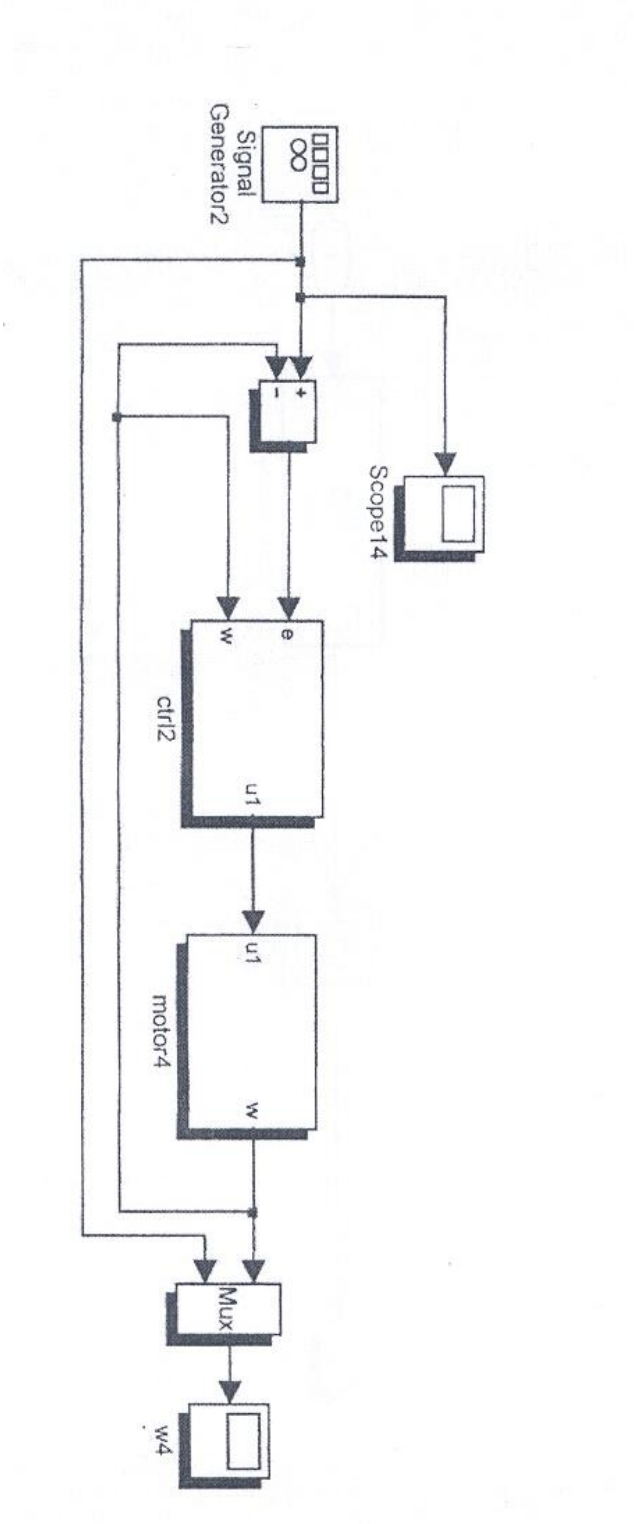

Fig.2 –Simulation of DC motor fuzzy adaptive controller.

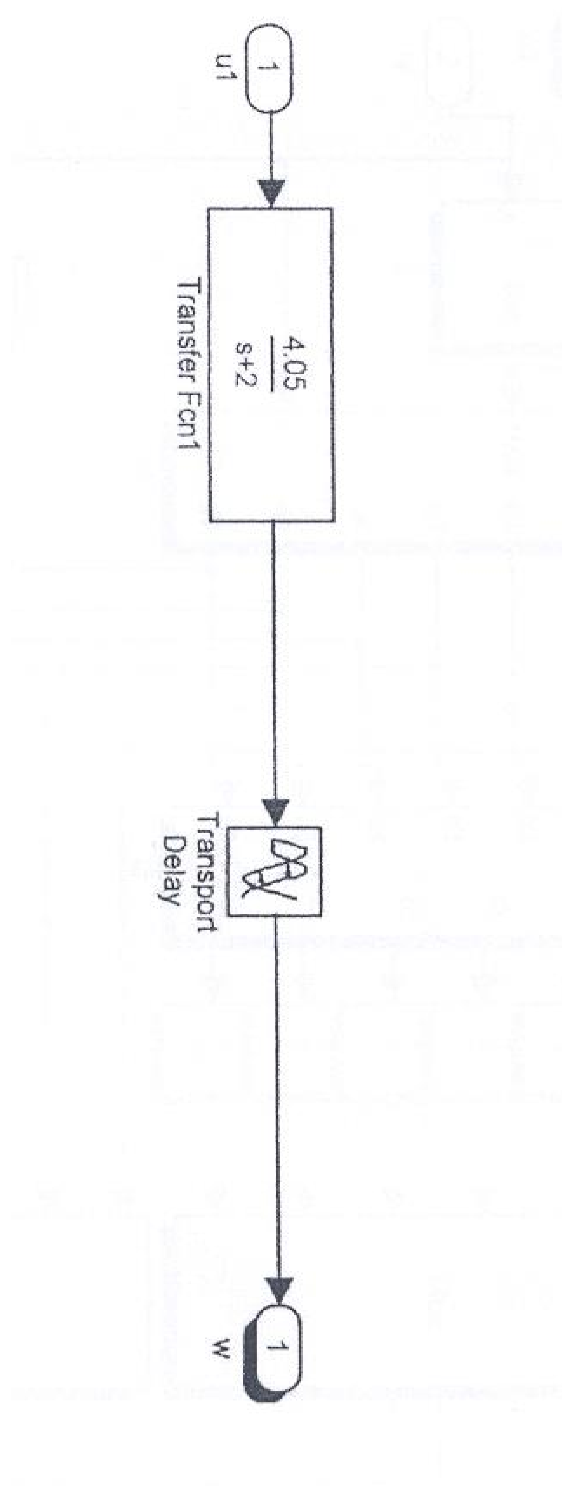

Fig.3 –Simulation of a typical DC motor model.

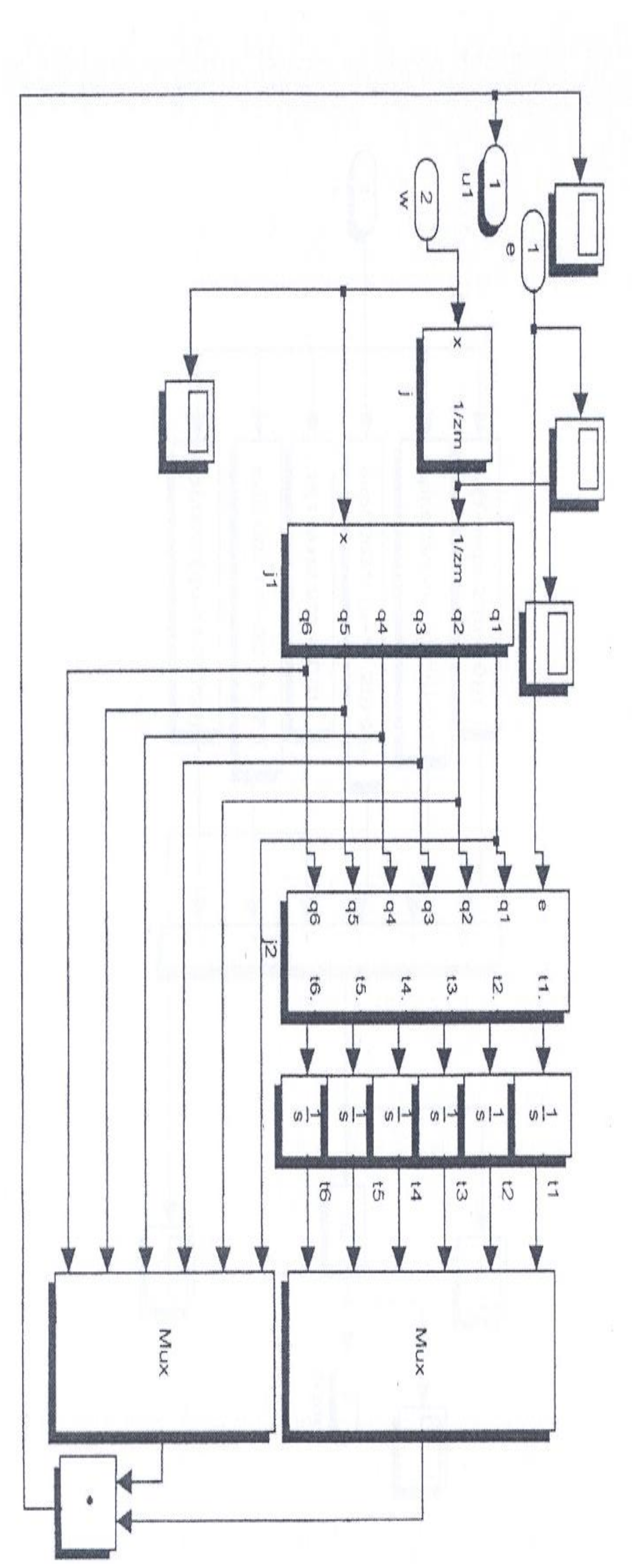

Fig.4 –Simulation of controller.

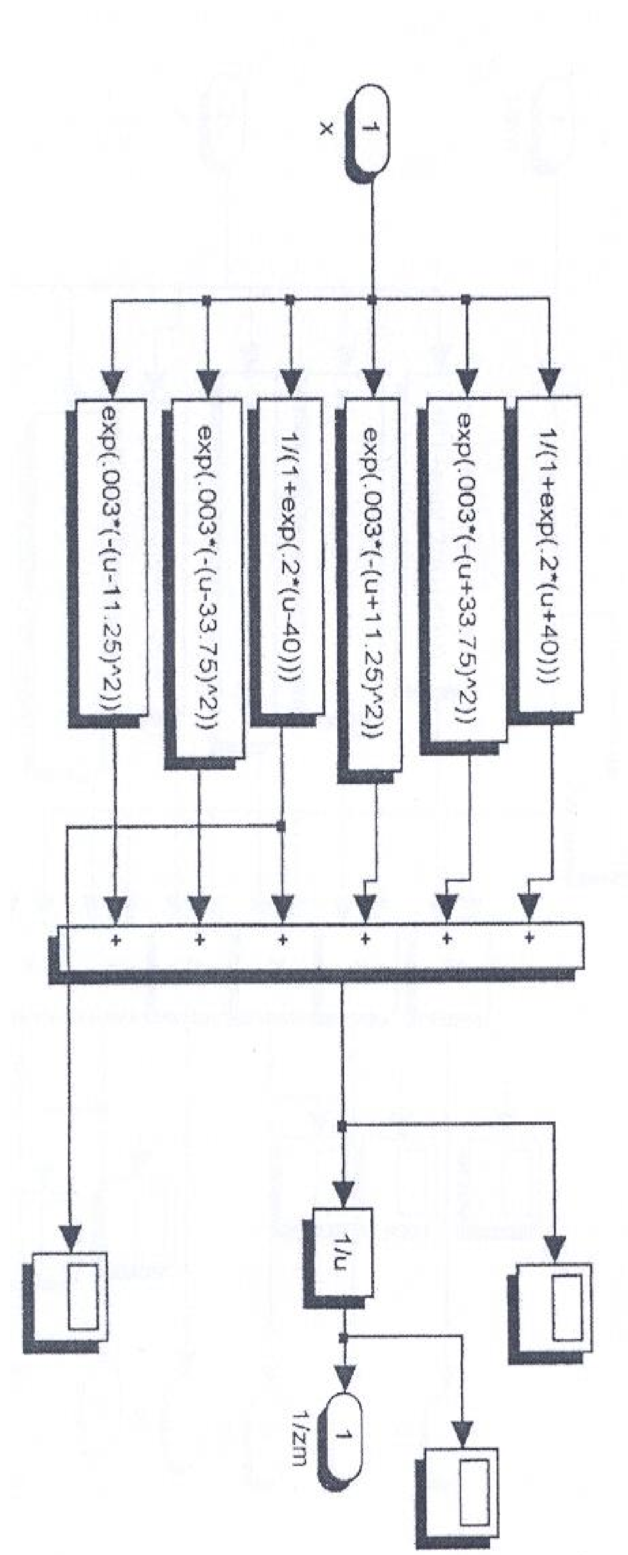

Fig.5 –Simulation of j.

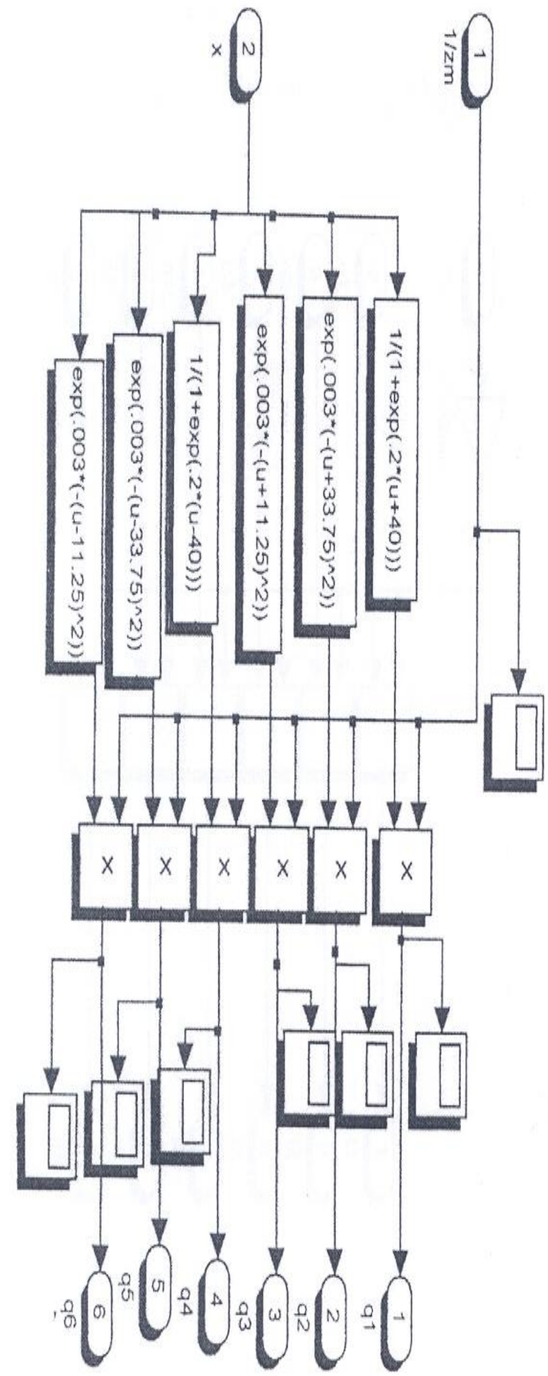

Fig.6 –Simulation of j_1.

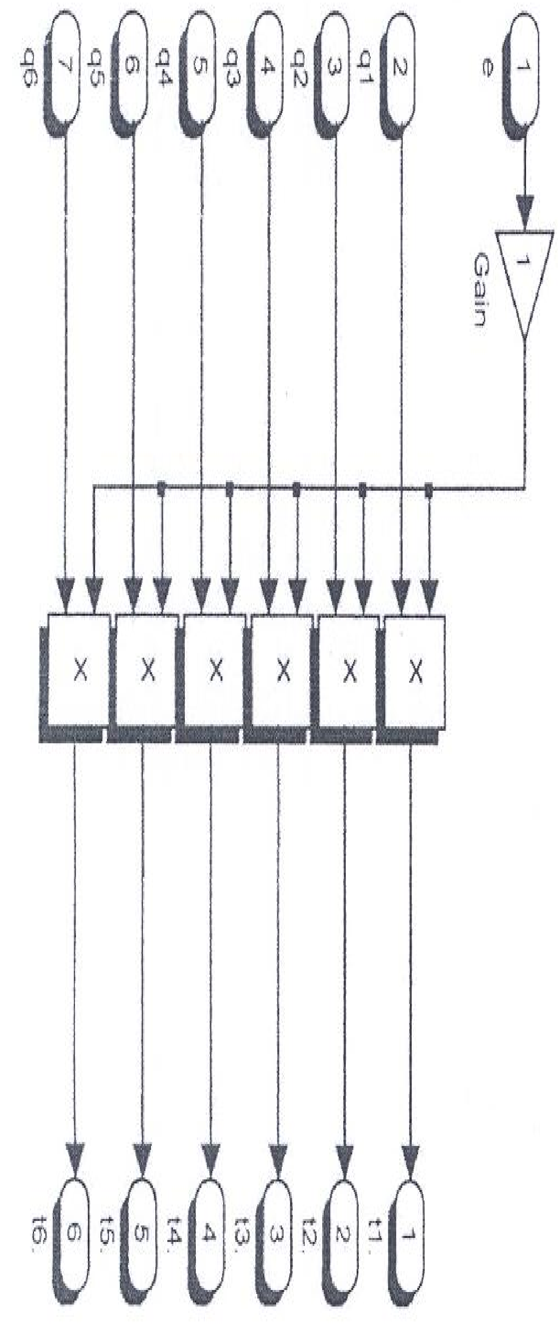

Fig.7 –Simulation of j_2.

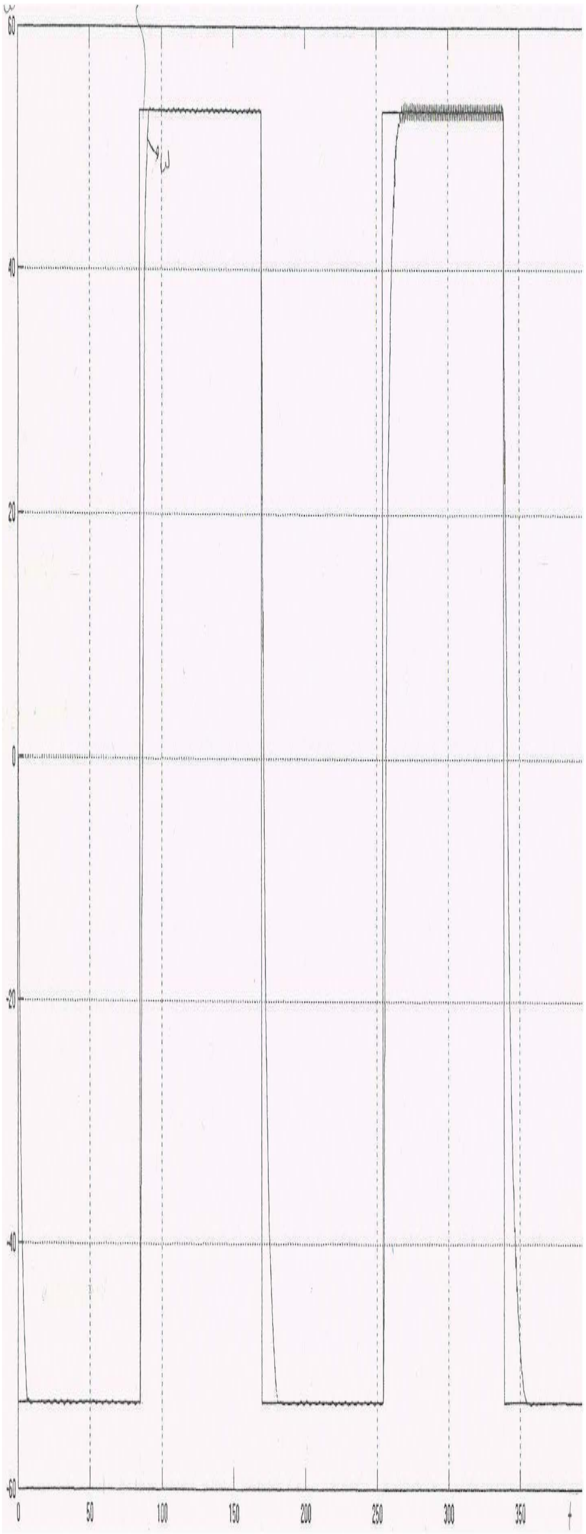

Fig.8 –Curves of output and input speed.

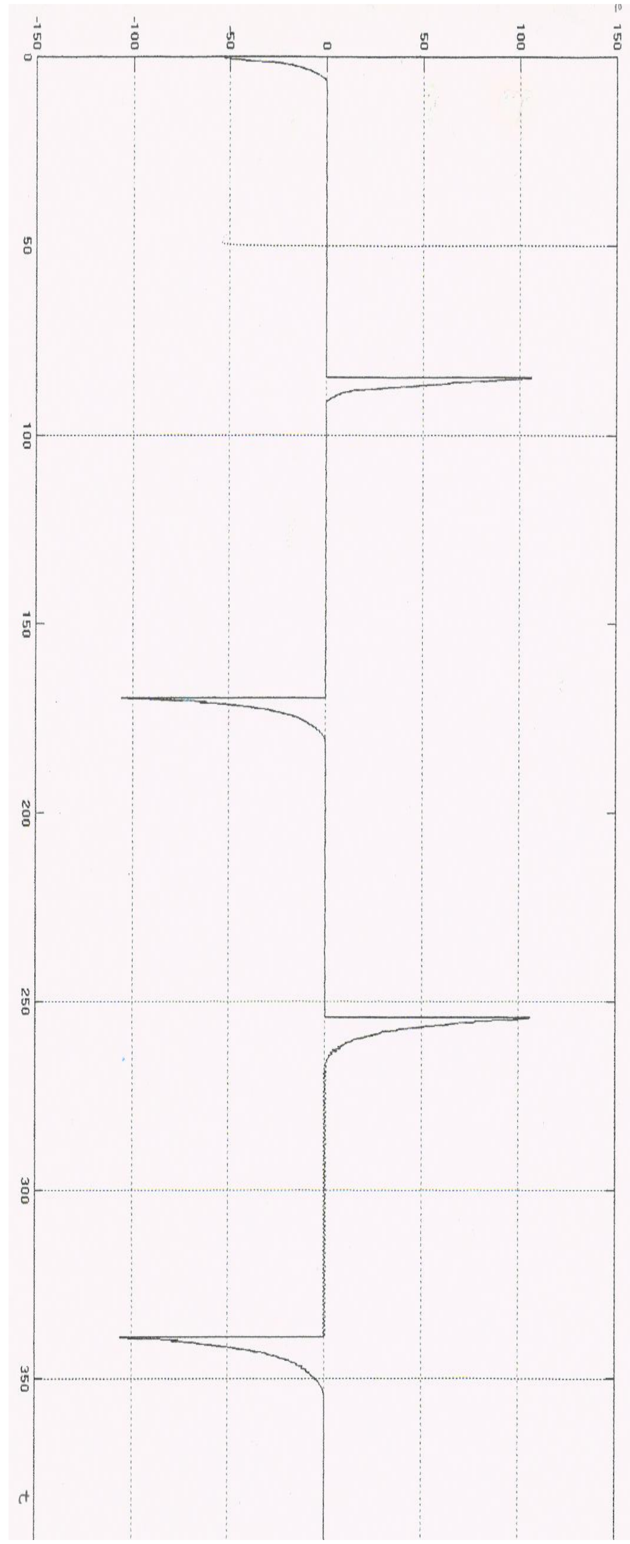

Fig.9 –Curve of speed error.

Input and output speed is shown in fig.8.
In this figure the average delay between input and output signals is nearly 8.3s and it because of model (7) that has a defined delay about 7.69s and it shows that the controller is very accurate with 0.61s time delay. Curve of speed error is shown in fig.9.

5 Control Design and Implementation

The picture of implemented controller is shown in fig.10.
A Russian VGFMED-BSMIB52 is used that has lighting shaft encoder H970F9240 according to fig.11 and speed of motor is controlled by controller shown in fig.10 by 8955 microcontroller. In this microcontroller port one-pin zero (P1.0) is connected to input of driver for providing PWM pulse and port one-pin one (P1.1) is connected to shaft encoder wire and port two is used for counting rounds of motor per second or speed of motor.
The duty cycle of PWM pulse is provided by software and is exerted to L298 driver input according to fig.10 and fig.12 and fig.13 to control the switching process.
Algorithm of controlling is presented in fig.14.
The results of speed determination by duty cycle variation are presented in table 1.

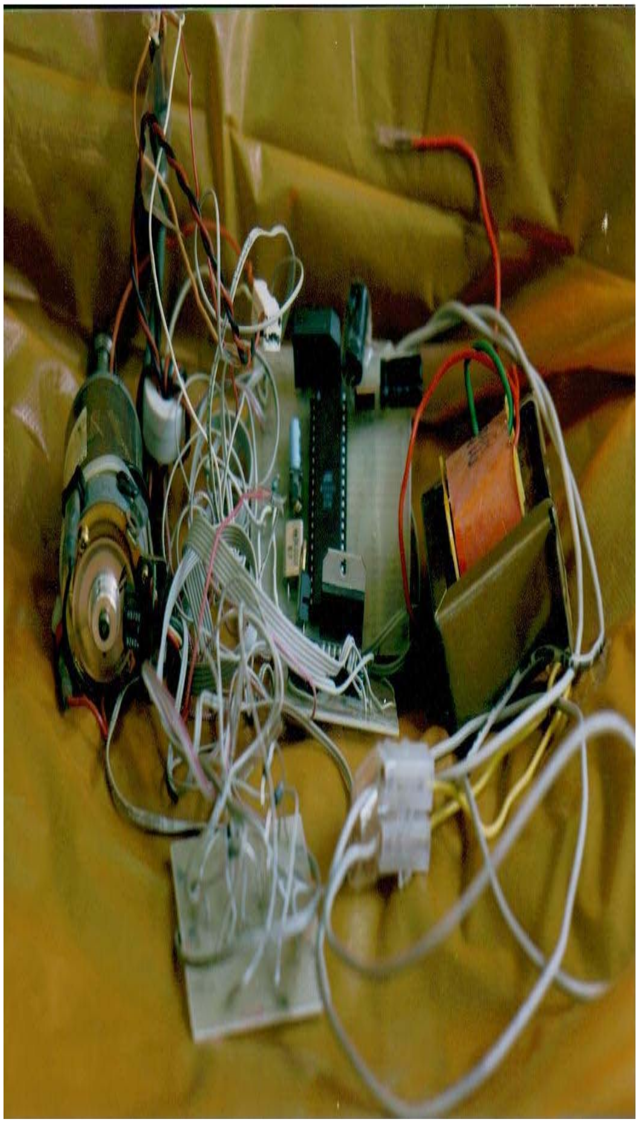

Fig.10 – Picture of implemented fuzzy-adaptive DC motor controller.

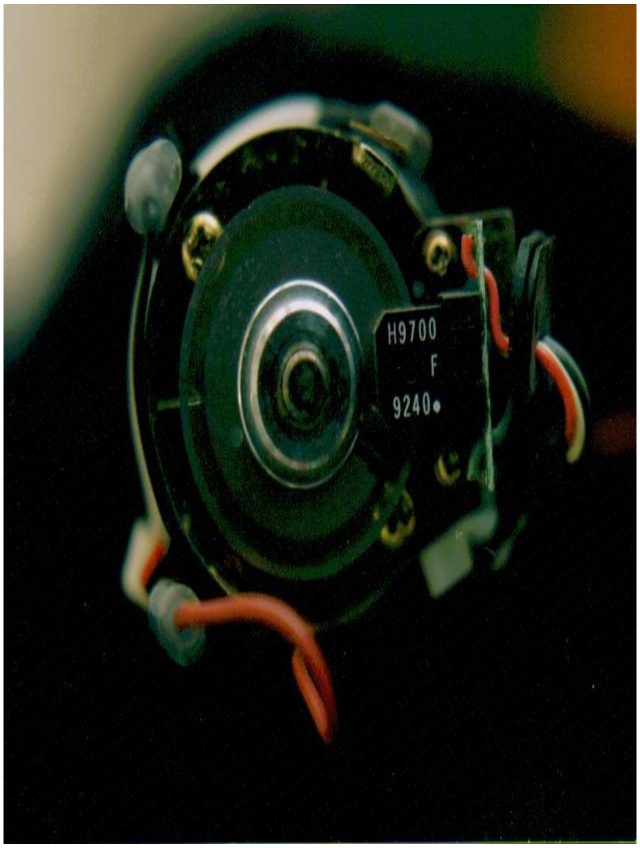

Fig.11 – Picture of lighting shaft encoder.

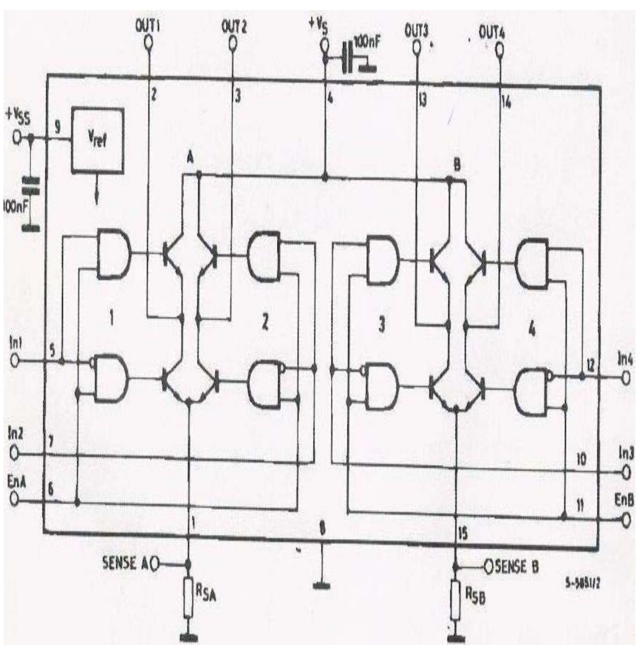

Fig.12 – Picture L298 circuit.

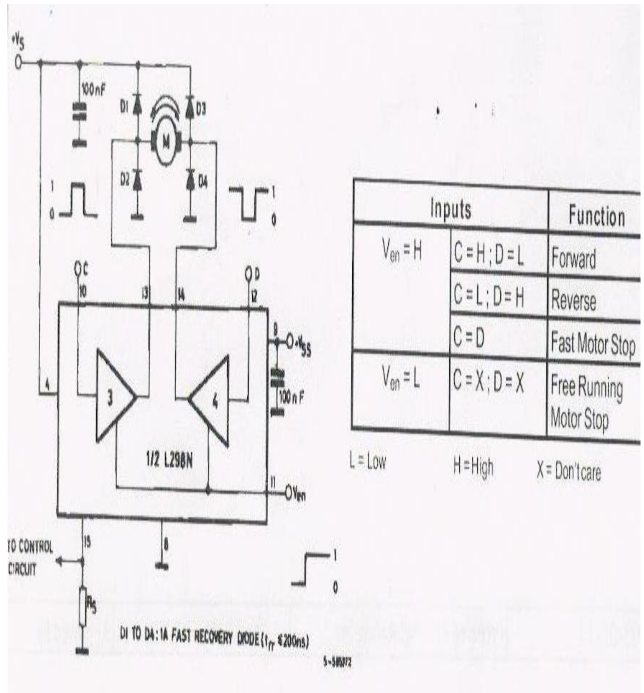

Fig.13 – Picture of L298 circuit in bidirectional DC motor control.

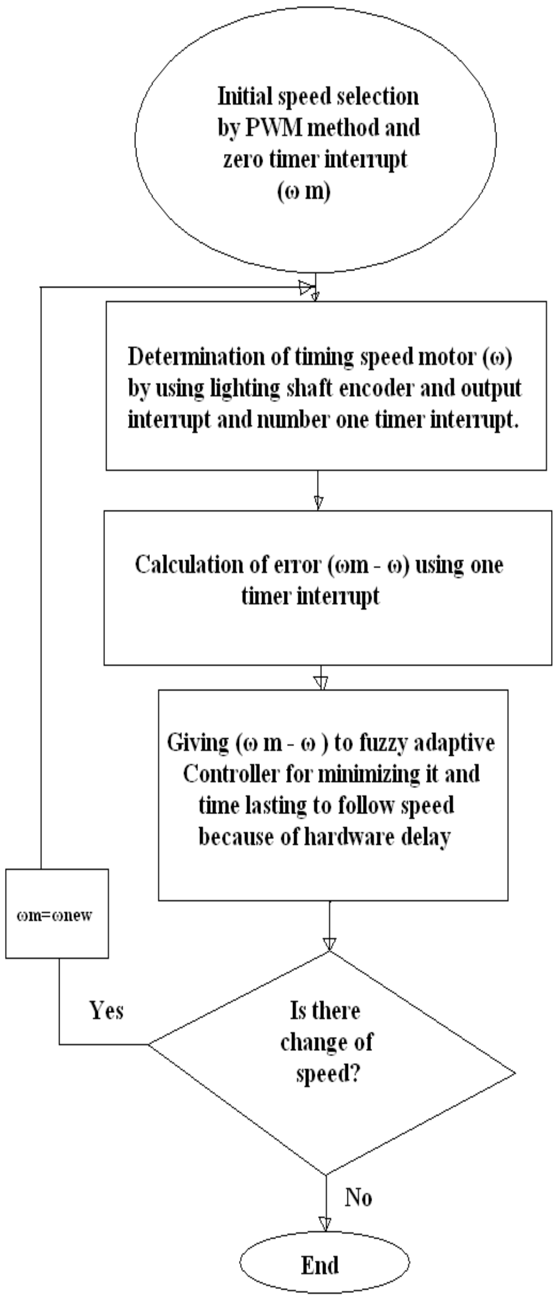

Fig.14 – Algorithm of fuzzy-adaptive DC motor controlling.

Table 1- Look Up table for relation of speed and PWM pulse duty cycle

PWM pulse duty cycle (%)	DC motor speed (r/second)
10	0
20	1
30	3
40	5
50	6
60	7
70	8
80	10
90	11

According to speeds in table1 fuzzy functions are exerted to controller with versatile constants because the range of speed is different from that of is used in simulation.

6 Results

The results are:

It is shown that there is fast system control adaptation even when load of motor changes or speed changes.

Using a model-free control system decreases complexity and computational burden (For example: Motor model and load model).

Using 8955 microcontroller with 24MHZ input crystal as clock pulse [5,6] increases speed of processing and decreases time of following output and error.

Using PWM method as drive method by switching circuit decreases total power loss.

Suggestions are:

Applying this controller to another motor to compare the results.

Selecting a better IC driver with better technology instead of TTL (MOSFET instead of BJT) because of current consumption.

Selecting a better driving method instead of PWM for decreasing losses.

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