Single-neuron PID Type control method for a MM-LDM with vision system (ICCAS 2003)

Kim Young Lyul*, Ki Hwan Eom*, Joong Kyu Lim*, Dong Seol Son**, Sung Boo Chung***, Hyun Kwan Lee****

*Dept. of Electronic Eng., Dongguk University, Seoul, Korea
(e-mail : kimyl007@hanmail.net)
** Dept. of Electronic Eng., Yuhan College, Seoul, Korea
***Dept. of Electronic Eng., Seoil College, Seoul, Korea
****Dept. of Internet Programming, Honam University,Kwangju,Korea

Abstract: In this paper, we propose the method to control the position of LDM(Linear DC Motor) using vision system. The proposed method is composed of a vision system for position detecting, and main computer calculates PID control output which is deliver to 8051 actuator circuit in serial communication. To confirm the usefulness of the proposed method, we experimented about position control of a small size LDM using CCD camera which has a performance 30frames/sec as vision system.

Keywords: Single-neuron , vision , MM-LDM ,PID

1. INTRODUCTION

A highly accurate, high speed positioning device can be constructed by using the linear motor with small size. The linear motor has become of major interest as a direct drive type actuator that can realize linear motion. The linear dc motor (LDM) has been used widely for the robots, semiconductor manufacturing systems, and X-Y driving devices, etc[1][2].

In this paper we present a single-neuron PID type controller of a moving magnet type linear dc motor (MM-LDM) that uses vision system. The proposed control method uses neural network algorithm determining the PID coefficients. Each coefficients corresponds with each weight of the neuron. The learning algorithm, known as delta rule, updates the weights.

The LDM system considered in this paper is a moving magnet type linear dc motor (MM-LDM). The armature coils are fixed in yoke. The driver circuit of the related armature coil turns on and the current flows into the armature coil. Then, the moving magnet is moved toward the direction according to Fleming's left hand rule. The armature current direction is changed with the change of the polarity of the driving force regardless of the direction of the coil current.[3]

The structure of this system is very simple and practical. The vision system processes about 30 images (frames) per second. To detect the point of the moving magnet we use a linear search method that compares the contrast of the pixels and returns the position of the dark value.

In order to verify the effectiveness of the proposed control method, we performed simulations and experiments. The results showed that the proposed control method improves considerably on the performance of the conventional PID controller.

For the verification of the method to propose, We could confirm the result usefulness which Apply tries to do in actual system.

2. THE STRUCTURE OF THE SYSTEM TO PROPOSE

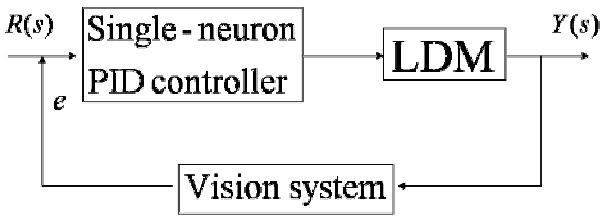


Fig. 1 Structure of the proposed System.

2.1 The design of PID controller using single-neuron

PID controller, the bread and butter of control engineering practice, are found in large numbers in all industries. They come in many different forms, are packaged as standard products, and are manufactured by hundred thousands yearly. PID controllers are also embedded in all kinds of special purpose control systems. They have survived many changes in technology ranging from pneumatics to electron tubes, transistors, integrated circuits, and microprocessors.

The PID controller is by far the most common control algorithm. Most feedback loops are controlled by this algorithm or minor variations of it. It is implemented in many different forms, as a stand-alone regulator or as a part of a DDC package or hierarchical distributed process control system[6].

PID algorithm has the following form.

$$u(t) = K[e(t) + \frac{1}{T_i}\int e(s)ds + T_d \frac{de(t)}{dt}]$$

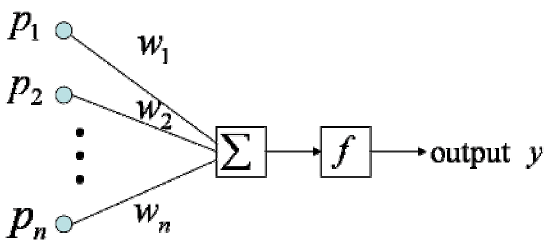
Where u is the control variable and e is the control error, which is the difference between set point r and measured value y. The control variable is thus a sum of three term: the P-term(which is proportional to the error), the I-term(which is proportional to the integral of the error), and the D-term(which is proportional to the derivative of the error). The controller parameters are proportional gain K, integral time T_i , and derivative time T_d .

We can plan the PID controller which hits to a system by adjusting each of the PID coefficient. But PID coefficient adjustment's dependency about the experience is big and the work to find the suitable PID coefficient of the system is not easy.

In this paper, We use a neural network to find PID coefficient[6].

The neural network which is utilized a identification ,control and modeling of complex non-linear system has complex structure becuause of connectting many elements which deal the signal by a linking burglar.

Generally , as increase the number of neuron which organizes the neural network, we can make the precision of the computation. But it is not suitable for a real-time control of high speed because of many operation quantity. So we use a single-neuron and draw a plan PID controller which puts the key point in an execution real-time control.



$$y = f(\sum_{i=1}^{n} p_1 w_1)$$

Fig. 2 Architecture orf the Single Neuron.

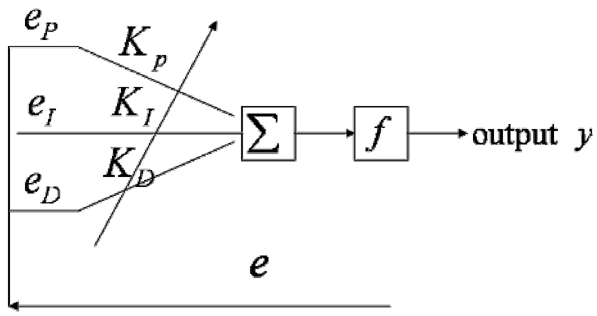


Fig. 3 Proposed Single Neuron PID controller.

In proposed method, the neuron's inputs are e_P , e_I , e_D .

$$e_P = e(t) - e(t-1)$$
$$e_I = e(t)$$
$$e_D = e(t) - 2e(t-1) + e(t-2)$$

$e(t)$ is error value in time t.

and neuron's weight strength is K_P, K_I, K_D .

$$K_P(t+1) = K_P - \eta \frac{\partial e}{\partial K_p} \quad (1)$$

$$K_I(t+1) = K_I - \eta \frac{\partial e}{\partial K_I} \quad (2)$$

$$K_D(t+1) = K_D - \eta \frac{\partial e}{\partial K_D} \quad (3)$$

η : learning rate.

By the Chain rule, (1), (2), (3) are as fallow.

$$\frac{\partial e}{\partial K_p} = \frac{\partial e}{\partial y}\frac{\partial y}{\partial u}\frac{\partial u}{\partial x}\ \frac{\partial x}{\partial K_P} = -(y_d - y)\frac{\partial y}{\partial u} f'(x)\ e_P \quad (4)$$

$$\frac{\partial e}{\partial K_I} = \frac{\partial e}{\partial y}\frac{\partial y}{\partial u}\frac{\partial u}{\partial x}\ \frac{\partial x}{\partial K_P} = -(y_d - y)\frac{\partial y}{\partial u} f'(x)\ e_I \quad (5)$$

$$\frac{\partial e}{\partial K_D} = \frac{\partial e}{\partial y}\frac{\partial y}{\partial u}\frac{\partial u}{\partial x}\ \frac{\partial x}{\partial K_P} = -(y_d - y)\frac{\partial y}{\partial u} f'(x)\ e_D \quad (6)$$

In single neuron, $\frac{\partial y}{\partial u} = 1$.

Neuon's output is as fallows.

$$y = f\,(K_P\, e_P + K_I\, e_I + K_D\, e_D\,)$$

3. SIMULATION AND EXPERIMENT

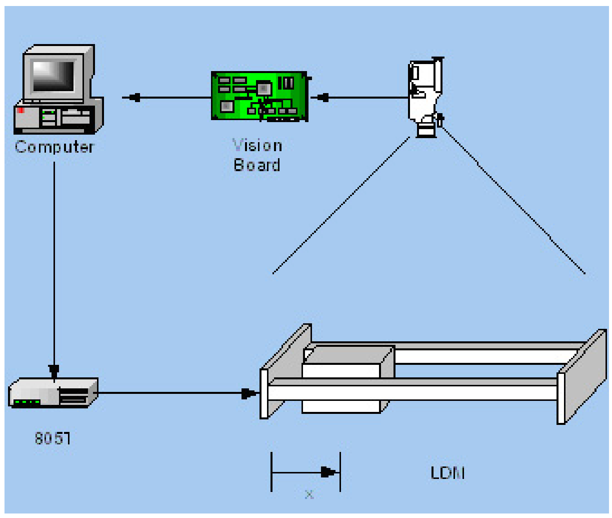


Fig. 4 Proposed Single Neuron PID controller.

3.1 A system structure for the experiment.

An image processing board and CCD camera which operates in the total system by position sensor have a processing speed of 30frames/s.

8051 circuit receives PID control value which is calculated in a main computer by serial communication and check the current of LDM[5].

To minimize the distortion of the prize to be formed at the camera, We immobilized the camera from LDM at the place which about 25cm falls off.

A basis structure of LDM which is used at the experiment is seen Fig. 4

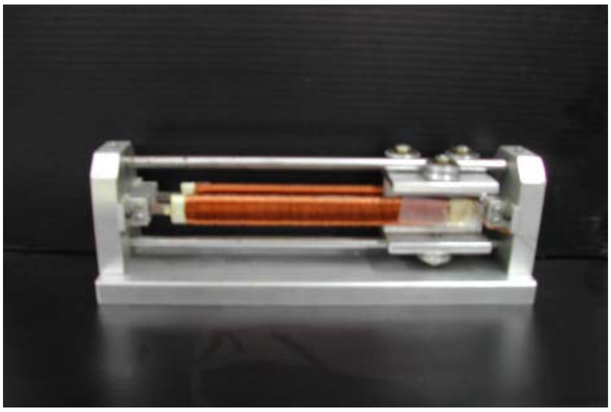


Fig. 5 MM-LDM.

A main specification of LDM expressed at a table 1.

Table 1 A main specification of LDM.

voltage source V	**12 V**
thrust F	**1 N**
speed V	**1.2 m/s**
magnetic flux density B	**0.26 Wb/m^2**
An activate distance X	**0.1 m**
Mass of needle M	**0.32 kg**
counter electromotive force constant Ke	**1.5 Vs/m**
thrust constant Kf	**0.153 kgf/A**

Thrust force F = $N_l lBI = k_f I$ (N)

N_l = magnetic flux number.

l = permanent magnet width.

B = permanent magnet flux density.

I = current.

Speed of needle $s = \dfrac{V - RI}{N_l lB}$

R is the resistance of electromagnet.

It shows the F with function of speed and S with lower part it is same[2][3].

$$F = \frac{k_f (V - k_e s)}{R}$$

We put upside expressions together and rescued theoretical situation space equation of LDM which is used at the experiment.

$$\begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -1/T \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} 0 \\ K_m / T \end{bmatrix} V \quad (7)$$

$$T = \frac{RM}{K_e K_f} \ , \ K_m = \frac{1}{K_e}$$

$\dot{X}_1$ is the distance which LDM moves and $\dot{X}_2$ is the speed of LDM.

3.2 Simulation.

We used a step response and rescued the PID coefficient to the experimental.

$K_P = 27$

$K_I = 0.0001$

$K_D = 10$

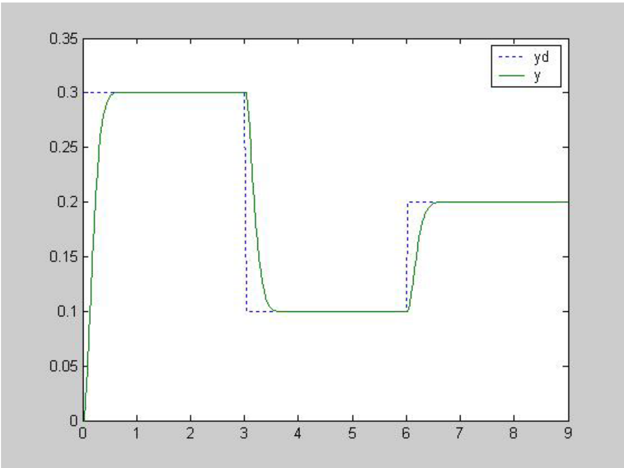


Fig. 6 common PID controller

Fig. 7 is the simulation result of MM-LDM position control using proposed method, single neuron PID controller.

Single neuron's initial weight and input are all 0. Learning rate is 0.05.

Initial condition:

$K_P = 0$

$K_I = 0$

$K_D = 0$

$\eta = 0.05.$

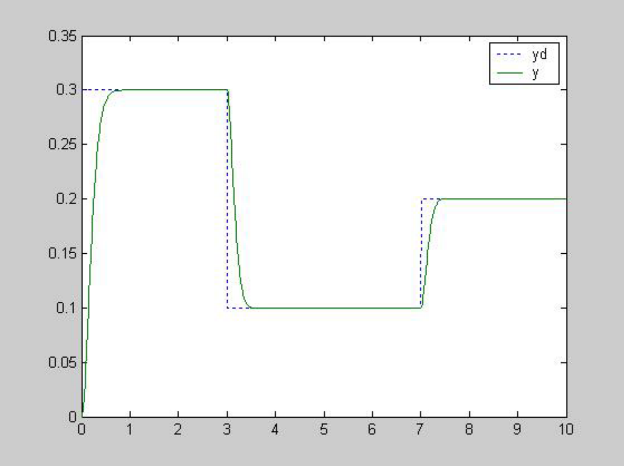


Fig. 7 single neuron PID controller.

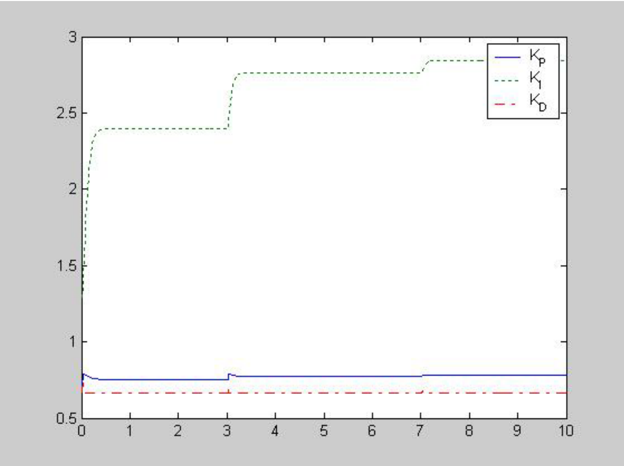


Fig. 8 PID coefficient trace.

After training , Single neuron PID coefficient is as fallow.

$K_P = 0.7791$

$K_I = 2.8451$

$K_D = 0.6672$

In result of simulation, a settling time was reduced in the method to propose than general PID control.

But K_P and K_D are change very little compare with K_I.

3.3 Experiment.

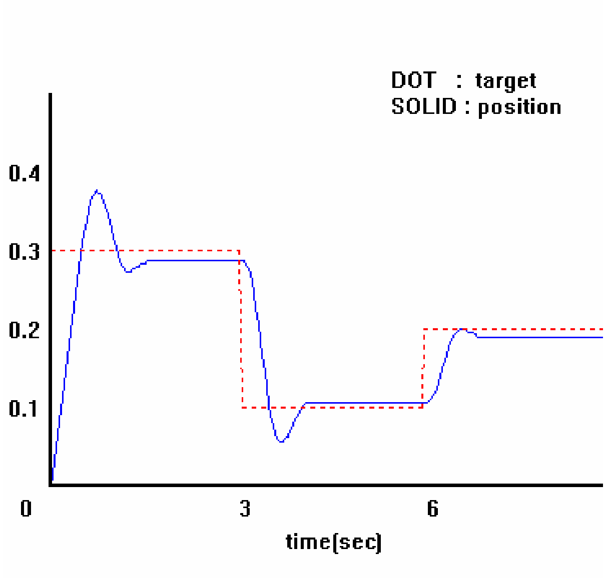


Fig. 9 common PID controller

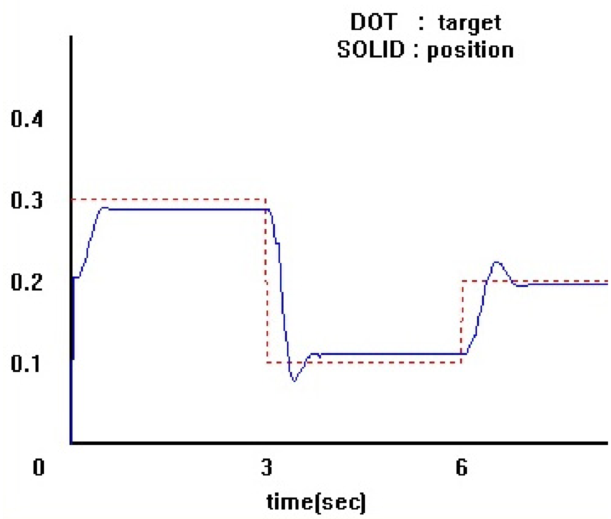


Fig. 10 single neuron PID controller

In a actual experiment result, overshoot and steady state error were reduced in the method to propose than general PID

4. CONCLUSION

We used a vision system in this paper for a position control of LDM and found PID coefficient which is suitable for the purpose using single neuron.

We could confirm the usefulness of the proposed method when it applies in actual system to be composed of LDM with CCD camera.

In the future with piece must complement, We need method for a noise overcome in an image processing and improvement of actual hardware.

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