A Design of I-PD Controller using CDM

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Abstract

This paper proposed and designed I-PD Controller using Shunji Manabe's CDM. The designed controller is applied to a level control system. The designed I-PD controller is smaller steady state error and get a specific response. A simulation results, the designed controller was better than a Fuzzy I-PD controller on a level control system.

1. Introduction

In process control system, the PID family controllers, such as PI, PID or I-PD have been employed to meet the desired performances by tuning those controller parameters appropriately. In literature, Zeigler-Nichols tuning formula or coefficient diagram method has been utilized for designing the appropriate parameters of the controllers. In Ziegler Nichols method, the step system response has quarterly decayed overshoot. The fuzzy logic control has been used in control system when the mathematical model of the interested process is vague or exhibits uncertainties. However, due to the popularity and simplicity of PID type controller, the fuzzy PID controller has been employed in control system by combining the merits of both controllers. Recently, a fuzzy I-PD controller, which is the modification of the conventional I-PD structure is presented. The conventional I-PD structure is first divided into a I controller and a PD controller part. Then the structure of I and PD controllers after rearranging will be constructed as a Mamdani Fuzzy I controller and a Mamdani fuzzy PD controller. In this paper, the CDM method gives the low-damped and fast response.

2. A design of Controller

2-1 Fuzzy I-PD Controller

The structure of the proposed fuzzy I-PD controller is shown in Fig. 1. It consists of a process and a fuzzy I-PD controller which consists of Mamdani fuzzy controller and Mamdani fuzzy PD controller. Therefore, the control signal u of the system is Eq. 1.

$$u = u_I - u_{PD} \qquad (1)$$

A Fig. 2. are shown a membership functions and rule tables. A Defuzzification is a center of gravity.

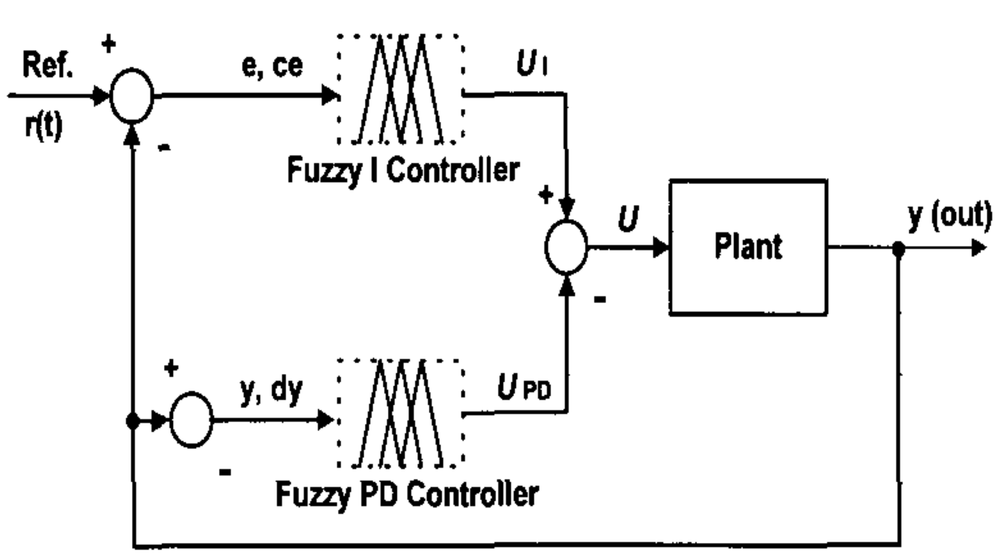
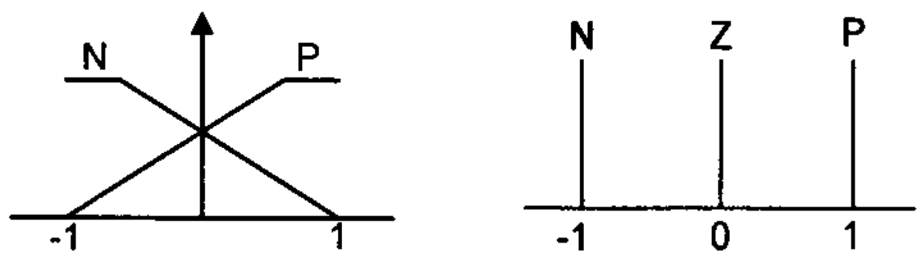


Fig.1 A Block diagram of Fuzzy I-PD Controller



(a). e, ce, y, dy (b). u, y

Fig. 2. A membership functions

2-2 CDM (Coefficient Diagram Method)

A controller designed by CDM has safety and strength to step response. Generally, a controller designed by CDM has low degree forward a plant. A Fig. 3. is showed by block diagram for I-PD controller using CDM.

$$A_p(s) = p_k s^k + p_{k-1} s^{k-1} + \cdots + p_0 \quad (2a)$$

$$B_p(s) = q_m s^m + q_{m-1} s^{m-1} + \cdots + q_0 \quad (2b)$$

A controller's polynomials is,

$$A_c(s) = l_\lambda s^\lambda + l_{\lambda-1} s^{\lambda-1} + \cdots + \lambda_0 \quad (3a)$$

$$B_c(s) = k_\lambda s^\lambda + k_{\lambda-1} s^{\lambda-1} + \cdots + k_0 \quad (3b)$$

$$B_0(s) = k_0 \quad (3c)$$

Where,

$A_p(s)$: denominator of plant

$B_p(s)$: numerator of plant

$A_c(s)$: de-numerator of controller

$B_c(s)$: numerator of controller

where, $\lambda < k$, $m < k$, $B_0(s)$ is selected k_0 using that a steady state error to step input can be made zero.

$$\begin{aligned} P(s) &= A_c(s) A_p(s) + B_c(s) B_p(s) \\ &= a_n s^n + a_{n-1} s^{n-1} + \cdots + a_0 \\ &= \sum_{i=0}^{n} a_i s^i \end{aligned} \quad (4)$$

Where, $a_0, a_1, \cdots a_n$ are coefficient of specific polynomial a stability expedient γ_i, a equivalency time constant τ, and limit exponent γ_i^* is

$$\gamma_i = \frac{a_i^2}{a_{i+1} \cdot a_{i-1}} \quad (here\ i = n-1) \quad (5)$$

$$\tau = \frac{a_1}{a_0} \quad (6)$$

$$\gamma_i^* = \frac{1}{\gamma_{i+1}} + \frac{1}{\gamma_{i-1}} \ : \ \gamma_0, \gamma_n = \infty \quad (7)$$

From the above equation, a stability, exponents standard value and a equivalence time constant is selected

$$t_s = 2.5\tau \sim 3\tau \quad (8)$$

$$\gamma_{n-1} = \cdots = \gamma_3 = \gamma_2 = 2, \gamma_1 = 2.5 \quad (9)$$

A stability exponent and a limit exponent are correlated by

$$\gamma_i > 1.5\gamma_i^* \quad (10)$$

From equation (5)~(7), a_i is written by

$$\begin{aligned} a_i &= a_0 \tau^i \frac{1}{\gamma_{i-1} \cdots \gamma_2^{i-2} \gamma_1^{i-1}} \\ &= a_0 \tau^i \prod_{j=1}^{i-1} \frac{1}{(\gamma_{i-j})^j} \end{aligned} \quad (11)$$

Therefore, a specific polynomials equation is shown,

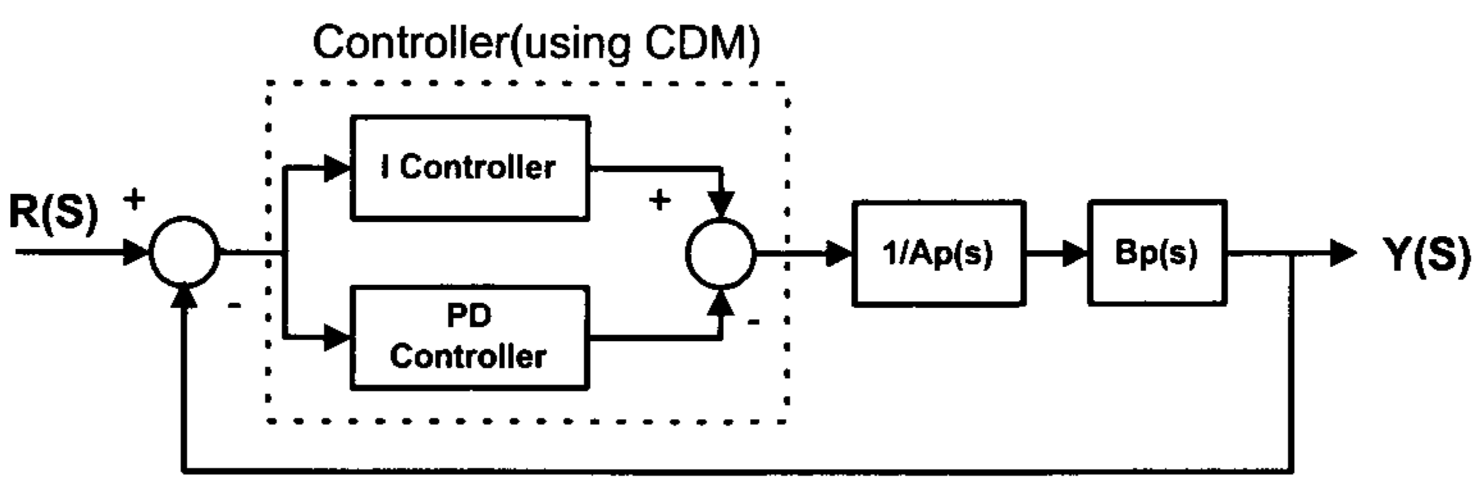


Fig. 3. CDM standard block diagram for the SISO system

$$P(s) = a_0\left[\left\{\sum_{i=2}^{n}\left(\prod_{j=1}^{i-1}\frac{1}{\gamma_{i-j}^{j}}\right)(\tau s)^{i}\right\} + \tau s + 1\right] \quad (12)$$

3. A Simulation

In this part, the simulation results of the proposed I-PD controller using CDM and fuzzy I-PD controller for controlling a level process will be shown. The controller designed for a process $G_p(s)$ at the level 35cm~40cm respectively.

The response of the fuzzy I-PD controller are shown Fig. 4, 5 at level 35cm and 40 cm and

The simulation results by the I-PD controller using CDM are shown fig. 6 and 7. at level 35cm ~ 40cm.

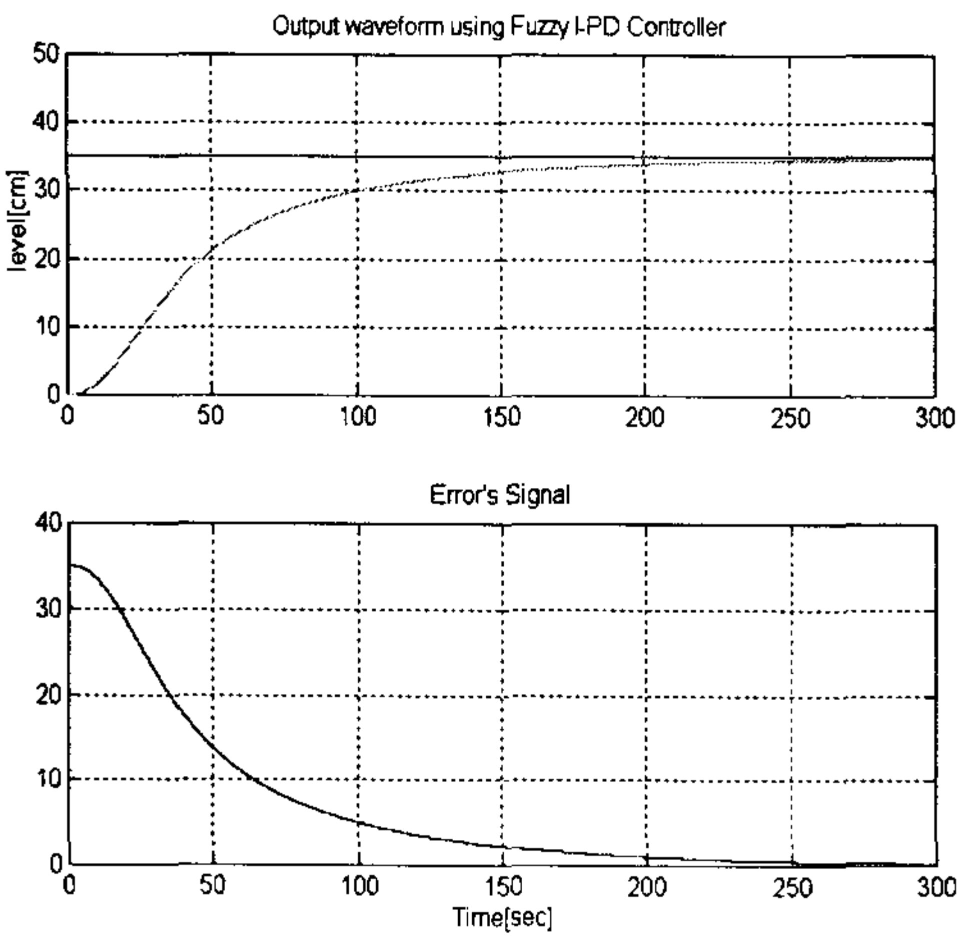


Fig. 4. Controller Fuzzy I-PD (level 35cm)

4. A conclusions

In this paper, we simulated a level control of I-PD controller using CDM

The simulation results are excellent a I-PD controller using CDM than a fuzzy I-PD controller. But, this controller is not applied to occur disturbance on plant or changed plant because the designed on a optimized Fuzzy-PID controller a is so many simulation and trial and error.

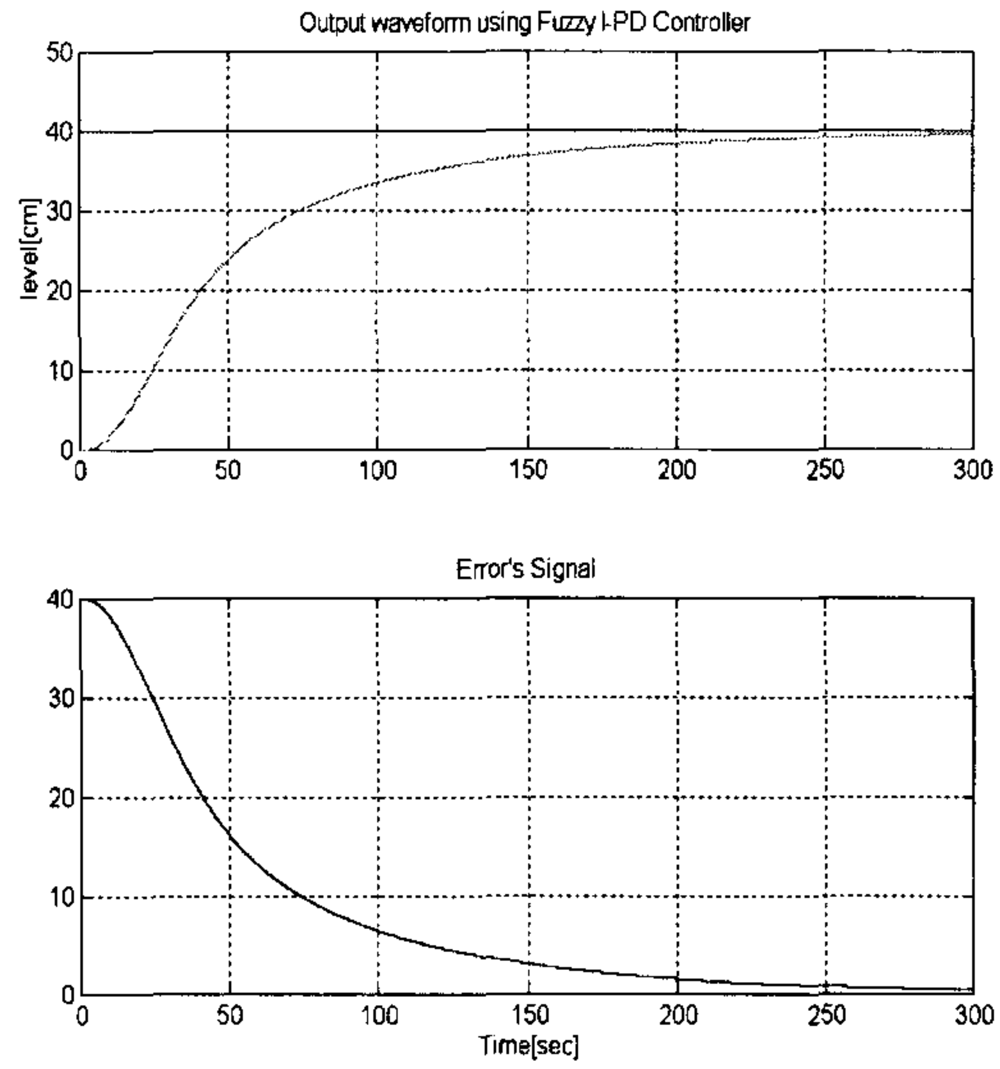


Fig. 5. Controller Fuzzy I-PD (level 40cm)

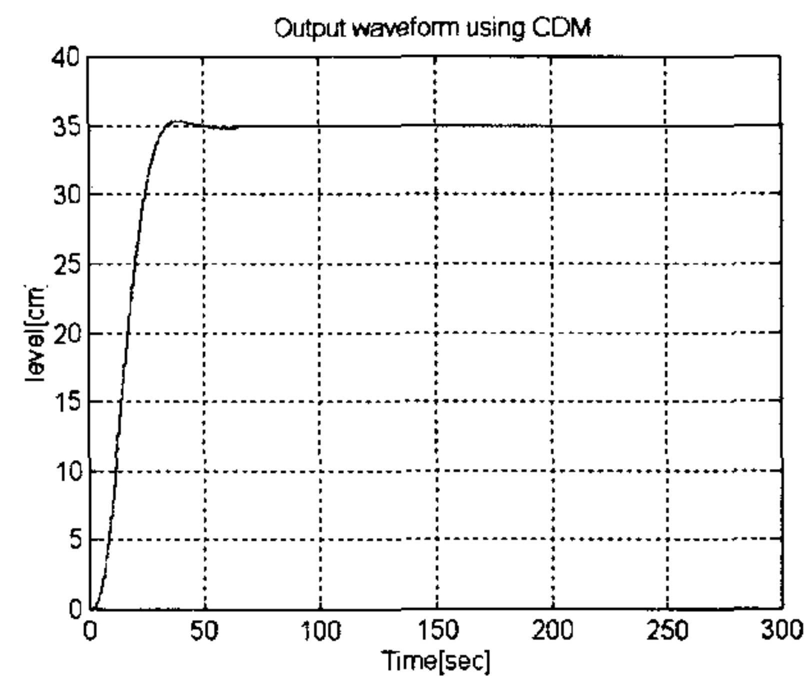


Fig. 6. Output Signal using CDM (level 35cm)

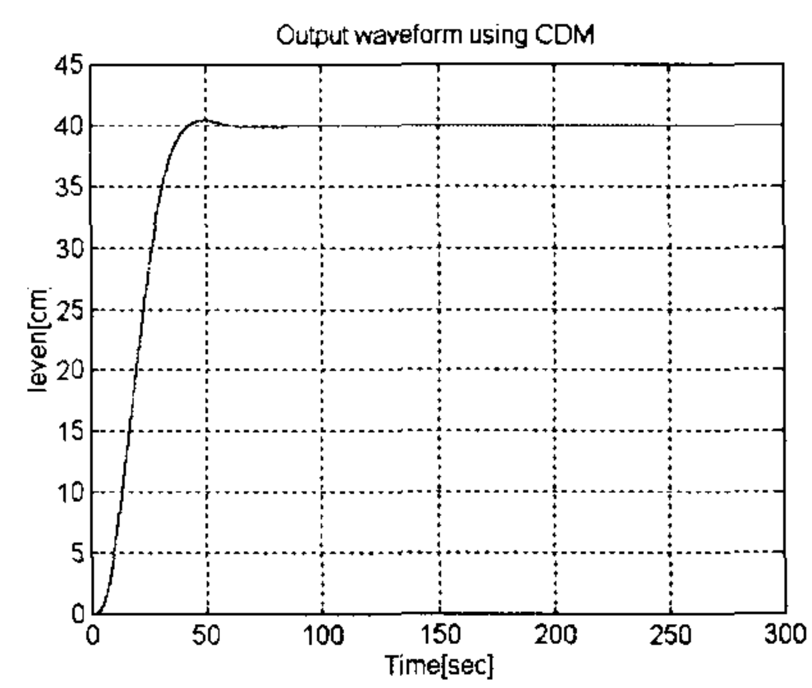


Fig. 7. Output Signal using CDM (level 40cm)

The next study term, we will design of complementation controller and to observe the performance applied to real plant based on this simulation result.

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