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Performance Comparison of PID and FLC Controller for Submarine Depth Control using LabVIEW

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Abstract: ***In the ocean environment, controlling certain parameters is an important task to keep the submarine at certain level below the sea surface. In this paper, the online simulator for the depth control of submarine has presented .The Fuzzy controller and PID controller are used to control the submarine and to maintain at certain level below the sea. Fuzzy logic controller and PID controller was implemented and simulated with LabVIEW program. Also comparison between Fuzzy logic and PID controlled system has presented***.

Keywords: LabVIEW, PID, FLC controller

1. Introduction

In this paper, an overview of online simulator for submarine depth control is presented. In ocean environment, controlling certain parameters is an important task to keep the submarine at a certain level below the sea surface. Submarines operating at deep submergence can be considered to be in a disturbance-free environment. Under these conditions the design of depth-keeping controllers is a straightforward task. At shallow submergence under rough sea conditions and at low speed, accurate depth-keeping controller designs require particular attention. In these circumstances, the submarine is subject to several disturbances, imposing additional restrictions on the designer. So, the systems which are act under the sea must reach reference depth with minimum oscillation in a short time.

This work describes the controlling the depth of the submarine using PID controller and Fuzzy logic controller. The design and implementation of this process is done using LabVIEW software.PID and Fuzzy controller is implemented to measure the depth of the submarine and LabVIEW is used to control the depth and ensure that the depth does not go beyond a certain set point.

2. Mathematical Model

Figure1 shows the closed loop of submarine. G1 and G2 are submarine pitch; G3 is the transfer function representing the depth of submarine. Equation (1) and (2) represents submarine system mathematical model. The transfer function of the system is obtained by the Equation (3)

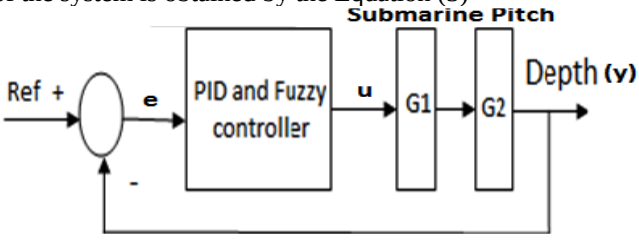

Figure 1: Closed loop of submarine depth control system

$$G1 = \frac{4}{S^2+8S+16} \quad (1)$$

$$G2 = \frac{1}{S} \quad (2)$$

$$G3 = G1 * G2 = \frac{4}{S^3+8S+16S} \quad (3)$$

If controller gain is equal K then closed-loop transfer function is

$$T.F = \frac{K * G3}{1 + K * G3} = \frac{K * 4}{S^3 + 8S^2 + 16S + 4K} \quad (4)$$

If K=1, then the state space model of Submarine is

$$\frac{dx}{dt} = \begin{bmatrix} -8 & -4 & -1 \\ 4 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} x(t) + \begin{bmatrix} 0.25 \\ 0 \\ 0 \end{bmatrix} u(t) \quad (5)$$

$$y(t) = [0 \quad 0 \quad 4]x(t) + [0]u(t) \quad (6)$$

Equation (5) and (6) represents the state space of the system.

3. Implementation of PID and FLC Controller using LabVIEW:

3.1 Implementation of PID controller using LabVIEW

A. Front panel of PID controller:
Figure 2 shows the front panel of the PID controller and root locus of Submarine system.

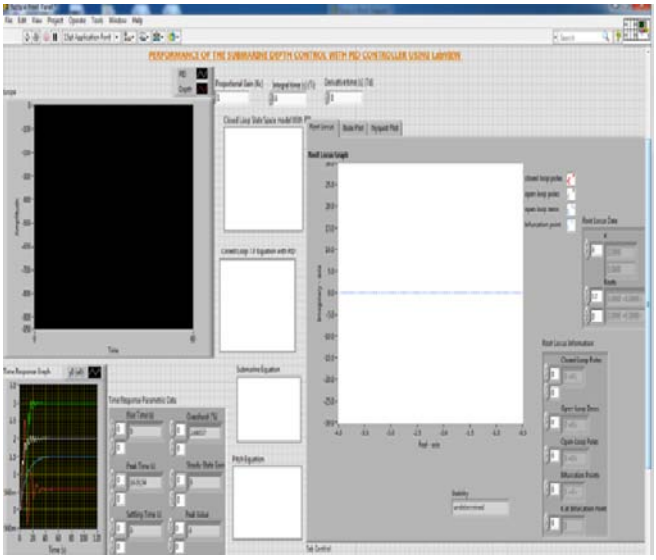

Figure 2: Front panel of PID controller

B. Block Diagram:

Figure 3(a), 3(b) shows the block diagram of the PID controller and root locus of Submarine system.

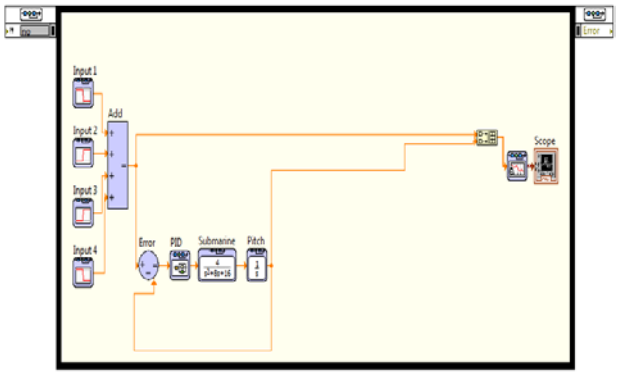

Figure 3(a): Block diagram of PID controller

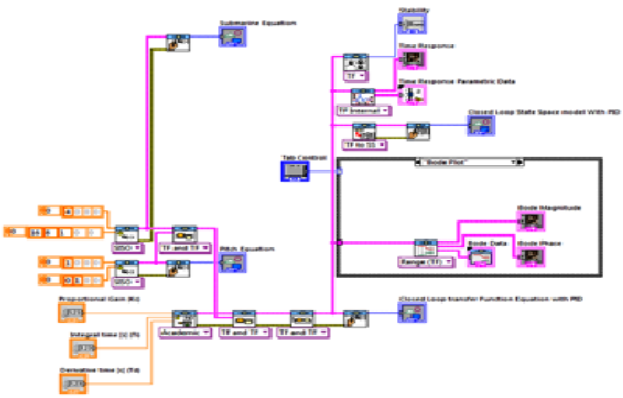

Figure 3(b) Block diagram of root locus

Operation:

First, let's take a look at how the PID controller works in a closed-loop system. The variable (e) represents the error, the difference between the setpoint value (r) and the process variable output (Y).

e = SP- PV (7)

This error signal (e) will be sent to the PID controller, and the controller computes both the derivative and the integral of this error signal. The equation (8) shows the controller gain

$u(t) = K_c e + \frac{K_c}{T_I}\int_0^t e\,dt + K_c T_D \frac{de}{dt}$ (8) (8) Where Kc is controller gain

The signal (u) just past the controller is now equal to the proportional gain (Kp) times the magnitude of the error plus the integral gain (KI) times the integral of the error plus the derivative gain (KD) times the derivative of the error.

This signal (u) will be sent to the transfer function, and the new output (Y) will be obtained. This new output (Y) will be sent back to the sensor again to find the new error signal (e). The controller takes this new error signal and computes its derivative and its integral again. This process goes on and on. The system's root locus is shown in Figure 3(b).Stability analysis was performed, and the system is stable

3.2 Implementation of FLC using LabVIEW

A. Front panel of FLC controller:

Figure 4 shows the front panel of Fuzzy logic controller. The front panel contains a graph to show the output of Fuzzy controller.

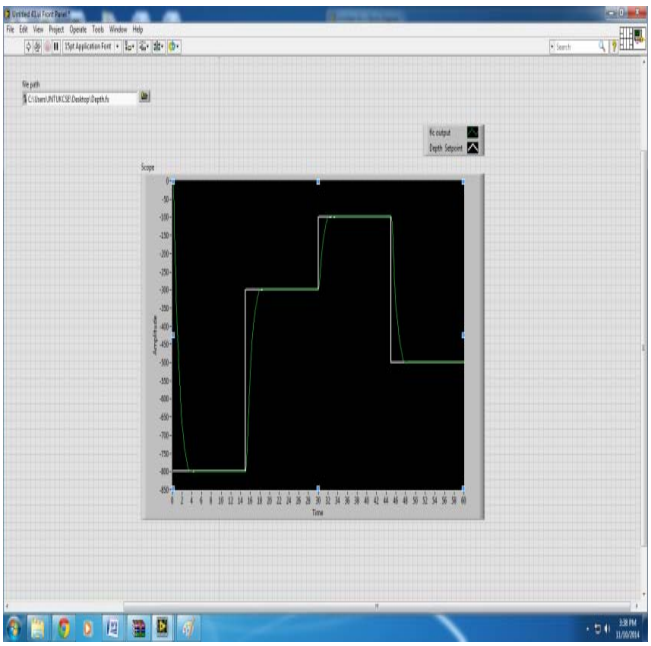

Figure 4: Front panel of Fuzzy logic controller

B. Block Diagram

Figure 5 shows the block diagram of Fuzzy controller. Block diagram consists of graphical source code of LabVIEW. Each object in the LabVIEW is wired using wire tool.

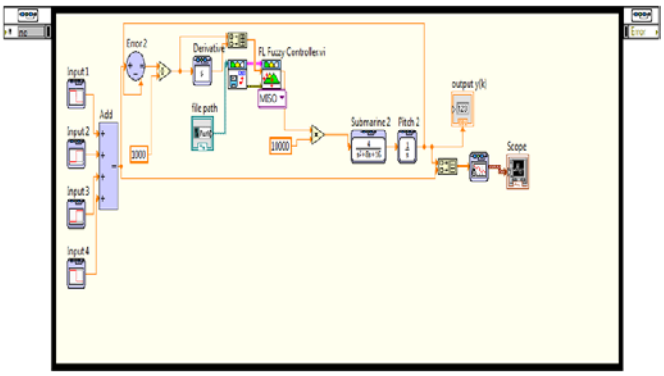

Figure 5 Block diagram of Fuzzy controller

Operation

The control input variables for the proposed fuzzy controller are chosen as error (*e*) and change of error (Δe). The control output variable (*U*) is defined as the output for fuzzy controller. They are fuzzy linguistic variable represent the actual depth error (*e*), change of actual depth error (*Δe*) and the output control effort (*u*) respectively. The actual variable expression given as

$$e(k)= r(k)-y(k) \quad (9)$$

$$\Delta e(k)=e(k)-e(k-1) \quad (10)$$

$$u(k)=f[e(k),\Delta e(k)] \quad (11)$$

Where r(k) and y(k) are the set-point and the actual output value at the *kth* sampling interval, respectively and *f* (,) denotes the input-output relation function. The time responses of error signals can be used to represent information related to the system output responses. As the error signals approach zero the output signals move towards reference. Depending on the performances of controllers used, the error signals may or may not become zero. The error signal of a controlled system will be sufficient to derive the controller rules since it contains the necessary information about the outputs.

After evaluating the input and output variables of the controller, it is required to converts each piece of input and output data into degrees of membership by a lookup in one or several membership functions. For each input and output variable described by seven fuzzy sets: NB, NM, NS, Z, PS, PM and PB. When the membership function has been designed, the following has been taken into consideration:

i) Choose the membership function curve with low resolution when the error is large and high one when error is small.
ii) The degree of interaction between different fuzzy sets is generally given between 0.4-0.8.

The fuzzy logic controller is a rule-based controller and the rules are in the if-then format e.g. "If error is Ai, and change in error is Bi then output is Ci".The rules to designed fuzzy controller are given in the Table 1. Table 1 uses seven linguistic variables for the error and change in error with 49 rules.

Table 1: Rule base fuzzy logic controller

Error(e)/ Derivative of error (Δe)	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

From the rule table 1, the rules are manipulated as – "If error is NB and change in error is NB, then output is NB". The submarine depth is fed back and is compared with set point. After comparison, error signal and the change in error are calculated and are given as input to fuzzy controller. In this work, the error is normalized to per unit value with respect to the set point. This helps in using the fuzzy controller for any set point. The fuzzy controller will attempt to reduce the error to zero by changing signal.

4. Simulation result for Submarine Depth

Figure 9 shows the output of PID and Fuzzy logic controller. The white line represents the real depth process of the submarine, the green and red line corresponds the desired path of the PID and Fuzzy logic controller.

Online simulator for the depth control of submarine has been implemented using PID controller and Fuzzy logic controller. The system is simulated with LabVIEW program. The settling time taken as criterion, the system with Fuzzy Logic Controller gave almost near to the set point which is shown in figure. Peak Overshoot, Settling Time, Steady state error are shown in table 2

Figure 6: Output of PID controller

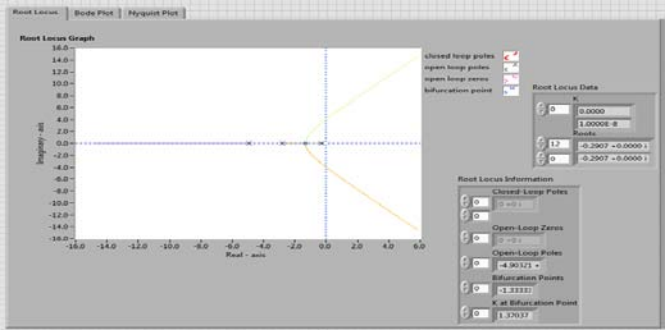

Figure 7: Output of Root locus

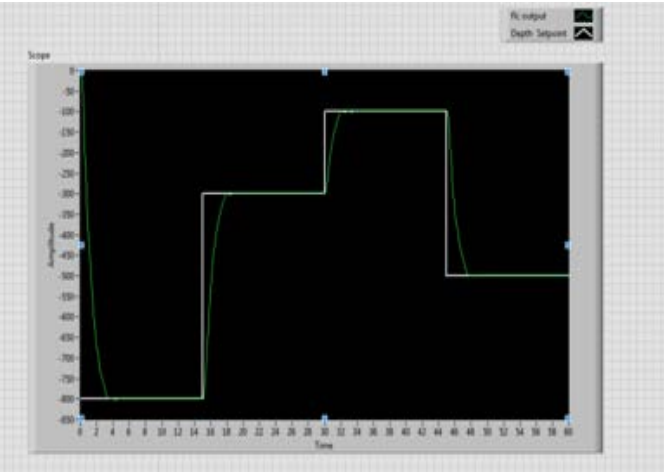

Figure 8: Output of FLC

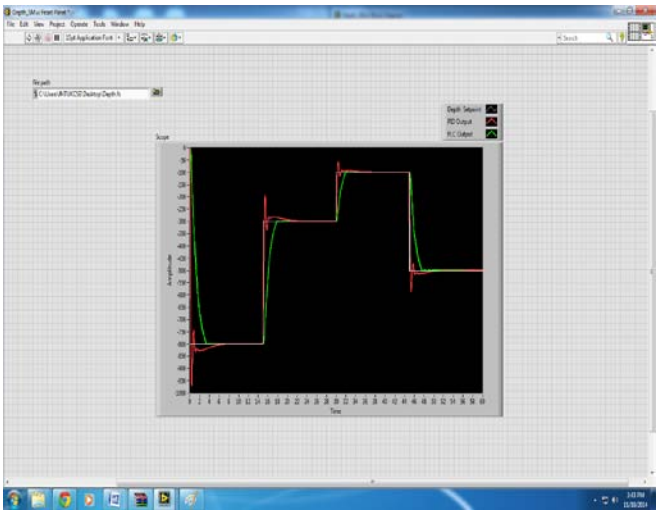

Figure 9: Comparison between PID and FLC controller

Table 2: PID and FLC effect

Sr. No	*PID*	*Fuzzy controller*
Steady state error	1.0%	0.35%
Settling time	6 sec	3.8 sec
Peak overshoot	22%	18%

5. Conclusion

In this paper, Submarine depth control system is implemented with PID and Fuzzy controller and simulated with LabVIEW program. Comparison between the performances of PID controller Fuzzy logic controller is studied and as result time response of simulation results show that the Fuzzy logic controller performance is better in respective of steady state error, settling time and peak overshoot. The simulation result of Fuzzy logic controller confirms that the FLC provides dynamic response. User can analyze root locus graph and stability of the system.

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