A study of lambda (λ) tuning approach of Single Input Fuzzy Logic (SIFLC) for Remotely Operated Vehicle (ROV) depth control

Fauzal Naim Zohedi[1,2*], Mohd Shahrieel Mohd Aras[1,2], Hyreil Anuar Kasdirin[1]

[1]Fakulti Kejuruteraan Elektrik, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia.
[2]Underwater Technology Research Group (UTeRG), Center for Robotics and Industrial Automation (CERIA),
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[*]Corresponding author's email: fauzal@utem.edu.my

ABSTRACT: This paper presented a simulation study of lambda (λ) tuning approach of Single Input Fuzzy Logic (SIFLC) for Remotely Operated Vehicle (ROV) depth control. ROV is a vehicle replacing human in doing underwater exploration. ROV commonly suffer from high overshoot due to uncertainty of waves and current that could promote damage to the ROV or its surveillance site. A SIFLC controller was designed tuned by lambda (λ) to cater this overshoot problem. SIFLC was normally tuned directly from fuzzy logic (FLC) controller. This paper proposing tuning of SILFC by using its lambda (λ) value. Five (5) models of ROV were tested with this tuning method for overshoot control. All shows good result in annihilating the overshoot problem.

Keywords: *Remotely Operated Vehicle (ROV); Depth Control; SIFLC*

1. INTRODUCTION

This paper focus on investigation and analysis SIFLC controller tuning for depth movement of ROV. As shown in Figure 1, the depth controlled is the translation of heave or z axis. This movement is one of the basic controls for ROV. The depth control is important to ensure the ROV may maintain at certain position while the ROV operator is doing surveillance or repairing job. Surveillances of underwater is important for sustainability of resource and underwater research.

Uunderwater environment is uncertain due currents and waves[1]. These two (2) factors affected the movement of ROV in all ways. For depth control, to maintain at certain depth is very challenging. A good controller needs to be designed to ensure accomplishment in underwater task. Fast response, almost zero steady stated error and zero overshoot must be taken into consideration in designing a controller. Currently the basic controller used to control ROV depth are proportional, integral and derivative controller (PID), fuzzy logic controller (FLC), neural network controller (ANN) and sliding mode control (SMC) [2]. PID is a linear controller and the easiest to implement as it can be tuned automatically using MATLAB Simulink. The problem is it cannot cope with imprecise modelled. FLC has the ability to adapt with disturbance [3]. It can cope with imprecise model but complex to be tuned. ANN is data based controller where it react by using historical data or online data [4]. The ANN suffers from slower response. SMC is implementing limitation concept following a slide path [5] to control any system. As it is using bang-bang method, it suffers from jitter. This paper proposed Single Input Fuzzy Logic (SIFLC) to ROV controller as it has the ability of FLC but with simpler tuning concept. A new tuning approach of SIFLC based on lambda (λ) was implemented to five (5) models of ROV to validate the tuning concept.

2. METHODOLOGY

The SIFLC method is based on FLC method introduced by Lotfi A. Zadeh in 1965. The decisions are based on human perspective. Theoretically SIFLC output result should be identical to FLC. The difference of SIFLC and FLC is the input of FLC is normally two (2) while the input of SIFLC is only one (1). It makes it easier to be tuned. Figure 1 shows the block diagram of SIFLC controller.

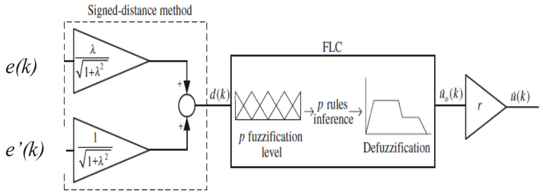

Figure 1: Basic SIFLC block diagram.

Two (2) input of FLC; error (e) and differential of error (e') were converted to d using signed distance method (SDM). 'd' is the distance between two (2) points; Q and P as shown in Figure 2. Line 'a' and 'b' are the line created based on pattern in the Table 1. 'a' is the main diagonal line while 'b' is the first 1st diagonal line to the right. Equation 1 is the main diagonal line.

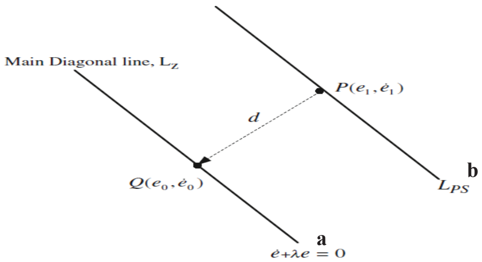

Figure 2: Derivation of d, distance between point Q and P

$$e' + (e)\lambda = 0 \tag{1}$$

$$d = \left(e(k) \times \frac{\lambda}{\sqrt{1+\lambda^2}}\right) + \left(e'(k) \times \frac{\lambda}{\sqrt{1+\lambda^2}}\right) \tag{2}$$

Table 1: FLC Rules table for depth control of ROV

Table 1: FLC Rules table for depth control of ROV

err vs du/dt	PL	PM	PS	Z	NS	NM	NL	
NL	Z	NS	NM	NL	NL	NL	NL	
NM	PS	Z	NS	NM	NL	NL	NL	
NS	PM	PS	Z	NS	NM	NL	NL	
Z	PL	PM	PS	Z	NS	NM	NL	
PS	PL	PL	PM	PS	Z	NS	NM	
PM	PL	PL	PL	PM	PS	Z	NS	b
PL	PL	PL	PL	PL	PM	PS	Z	a

2.1 Tuning SIFLC

In this research project, the lambda (λ) of line was varying heuristically to tune the output response. Figure 3 shows the simulation block diagram for this research project.

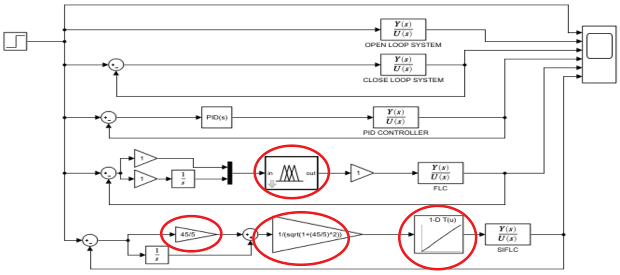

Figure 3: Block diagram for step input, open loop, closed loop, PID, FLC and SIFLC.

The circled blocks in Figure 3 shows the affected tuning block that affected by the tuning of lambda (λ) value. For this research, five (5) ROV models was tested using this tuning approach. The overshoot and time rise of the output result was analysed and recorded to validate the tuning approach.

3. RESULT AND DISCUSSION

Figure 4 shows one of the transient results of SIFLC tuned using lambda (λ) for ROV.

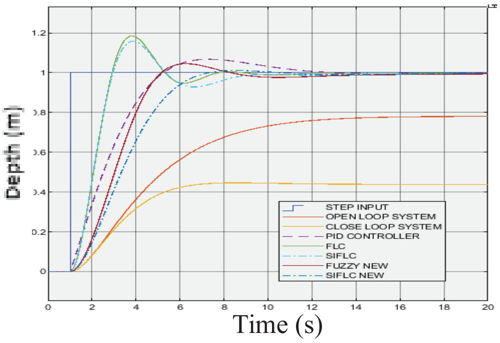

Figure 4: Transient results of SIFLC tuned using lambda (λ) for ROV

From Figure 4, SIFLC shows the best result with 1.531% overshoot and 3.7s time rise. Fuzzy new mentioned in Figure shows the result of retuned FLC using lambda (λ) value in SIFLC. Table 2 shows the summarize of overshoot (%OS) and time rise (Ts) result of the five (5) models controlled using lambda (λ) tuned SIFLC compared to basic PID and FLC. Steady state error (SSE) was not discussed as PID and SIFLC produced small value that can be neglected. From table 2, all five models show improvement in the %OS result without affecting the performance of Tr(s).

Table 2: Summarize result of five (5) models implemented with lambda (λ) tuned SIFLC

ROV model	Controller	%OS	Tr (s)
Model 1 **(λ=3.29)**	**PID**	6.989	3.003
$\frac{0.2466s + 0.1251}{s^3 + 1.8101s^2 + 0.9412s + 0.1603}$	**FLC**	18.452	1.298
	SIFLC	1.531	3.696
Model 2 **(λ=1)**	**PID**	5.851	0.376
$\frac{0.1782s^3+74.37s^2+958s+3995}{s^3+406.1s^2+986.3s+2564}$	**FLC**	5.851	0.0936
	SIFLC	2.577	0.145
Model 3 **(λ=5)**	**PID**	7.9	23.872
$\frac{0.426s+0.1982}{s^2+s+0.03637}$	**FLC**	21.341	0.3278
	SIFLC	0.603	0.561
Model 4 **(λ=0.67)**	**PID**	3.646	0.432
$\frac{0.02082}{s^2 + 2.18s + 5.7}$	**FLC**	8.152	0.533
	SIFLC	1.531	0.688
Model 5 **(λ=3)**	**PID**	4.945	0.4836
$\frac{0.03096s^3+4.028s^2+121.7s+491.2}{s^3+75.05s^2+136.1s+295.8}$	**FLC**	9.341	0.0991
	SIFLC	4.737	0.119

4. CONCLUSION

The implementation of lambda (λ) tuning to five (5) models shows tremendously improvement in the output response of ROV controller. The average improvement of %OS is 4.79% while Tr(s) average is 4.672s. This proved that tuning the lambda (λ) in the SIFLC can be implemented to ROV model to get a better output result.

ACKNOWLEDGEMENT

We wish to express our gratitude and appreciation the support granted by Universiti Teknikal Malaysia Melaka in pursuing this research specially to Underwater Technology Research Group, Faculty of Electrical Engineering, Centre of Research and Innovation Management for supporting this research.

REFERENCES

[1] N. Kumar and M. Rani, "An efficient hybrid approach for trajectory tracking control of autonomous underwater vehicles," *Appl. Ocean Res.*, vol. 95, no. October 2019, p. 102053, 2020

[2] M. . Aras, M.S.M., Abdullah, S.S. , Baharin, K.A. Nor, A.S.B.M. ,Mohd Zambri, "Model identification of an underwater remotely operated vehicle using system identification approach based on NNPC," *Int. Rev. Autom. Control*, vol. 8, no. 2, pp. 149–154, 2015.

[3] M. Wahyuddin, N. Azmi, M. Shahrieel, M. Aras, M. Khairi, and M. Zambri, "Comparison of Controllers Design Performance for Underwater Remotely Operated Vehicle (ROV) Depth Control," no. January, 2018.

[4] N. Weake, M. Pant, A. Sheoran, A. Haleem, and H. Kumar, "Optimising parameters of fused filament fabrication process to achieve optimum tensile strength using artificial neural network," *Evergreen*, vol. 7, no. 3, pp. 373–381, 2020.

[5] H. Yu, C. Guo, and Z. Yan, "Globally finite-time stable three-dimensional trajectory-tracking control of underactuated UUVs," *Ocean Eng.*, vol. 189, no. March, p. 106329, 2019,