DEVELOPMENT OF FUZZY LOGIC CONTROLLER FOR TRAINER KIT BASED ON MICROCONTROLLER

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ABSTRACT

Informatics and Business Institute Darmajaya Bandar Lampung especially Bachelor of Computer System Program will apply FLC subjects on new curriculum in 2015. To increasing knowledge and motivation of students learning of Fuzzy Logic Controler/FLC is needed a trainer kit.

This study aimed to developed FLC module for trainer kit. The membership function use a triangle. The singleton fuzzification use as fuzzifier. FLC module is designed to have three subset with 9 rules. Fuzzy inference machine use max-min operator while defuzzification use the Centre of Average. Fuzzy system implemented on ATmega 32 microcontroller then output converted to analogue using a DAC.

Testing is done by providing input voltage variations and measure the outputs and retrieve data from each of the fuzzy operations through data acquisition program. The test show the modules can work in accordance with the fuzzy operation, the output voltage of FLC module in accordance with changes in input voltage.

KEY WORDS

trainer kit, fuzzy logic controller, microcontroller

1. Introduction

Fuzzy controller (Fuzzy Logic Controller/FLC) is still a topic of research interest and continues to grow today. FLC has also been applied in home appliances and industrial control equipment complements such as Fuzzy Logic Controller PLC. Fuzzy logic was introduced by Prof. Zadeh, than Mamdani and Assilian introduced FLC. Response of FLC is slower than a PID controller [1.2]. Although FLC response was slow, but certain systems where tolerance and response times are not so critical, or in cases that do not require high accuracy FLC can be applied [3]. FLC more appropriately used on a system that is hard to define, which can be controlled by the operator without knowing the dynamic characteristics in the system [4].

The continued development of the application of FLC, the university put that in the curriculum, to which the FLC in the category of intelligent control. Similarly, the Institute of Informatics and Business Darmajaya Bandar Lampung, in the 2015/2016 courses computer system will implement a new curriculum to include new subjects namely fuzzy logic controller. To increasing knowledge and motivation of students learning of FLC is needed a trainer kit.

To learn to design and simulate the FLC can use MATLAB software, while for previous applications using personal computers, making it less effective and efficient. With the development of technology in particular microcontroller memory capacity, then the current fuzzy systems can be embedded in the microcontroller. Implementation of fuzzy systems on the microcontroller conducted by several researchers thus level control of hopper-conveyor plant [4]. Fuzzy system based on microcontroller can design and build FLC in modular form and can be applied to various systems.

Fuzzy system can be embedded in the microcontroller has been successfully applied, then how to design the wake FLC in modular form. Input and output of the module is a DC voltage that can be developed and applied to other process control. The purpose of this study is to design a wake FLC microcontroller based modular form.

2. Fuzzy Logic Controller

FLC is a fuzzy system that applied specifically to control system. The FLC is more humane than conventional control, that present the operator or expert knowledge in process control. Fuzzy system is works with the value of fuzzy and using fuzzy logic. In the fuzzy system, the numerical input values should be first converted into the corresponding fuzzy representations by 'fuzzifiers'. The knowledge base is a set of fuzzy rules to determine the output in this case the output controllers. Finally, the fuzzy output can be converted back into their relevant numerical (crisp) outputs through 'deffuzifiers' [2]. Basic configuration of fuzzy systems with fuzzifier and defuzzifier is shown in Figure 1.

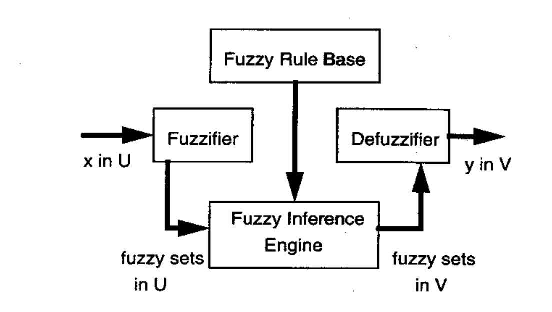


Figure 1. Basic configuration of fuzzy systems [2]

2.1 Fuzzification

Fuzzification is the process of transforming a numeric value to the value of linguistic or mapping the input space into fuzzy set defined on the universe of discourse. Singleton fuzzification frequently used, that membership value 1 at x* and 0 at other points [2], formulated:

$$uA'(x)\begin{cases} 1\ if\ x = x' \\ 0\ otherwise \end{cases} \quad (1)$$

In the fuzzy system each linguistic value of a variable declared with the fuzzy membership. Some form of fuzzy membership functions that can be used is a triangular, trapezoidal, gaussian and bell shaped. Triangular membership function is basically a combination of the two lines (linear), as in figure 2.

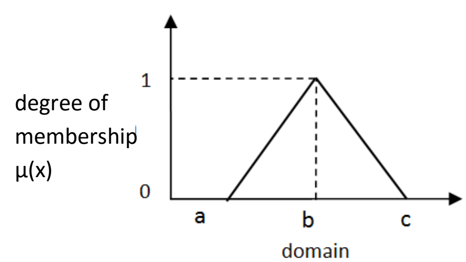


Figure 2. Triangular membership

Where,

$$\mu(x) = \begin{cases} 0; & x \le a \text{ atau } x \ge c \\ \frac{x-a}{b-a}; & a \le x \le b \\ \frac{c-x}{c-b}; & b \le x \le c \end{cases} \quad (2)$$

To terminate the membership function chart is generally used for the shoulder, as in figure 3.

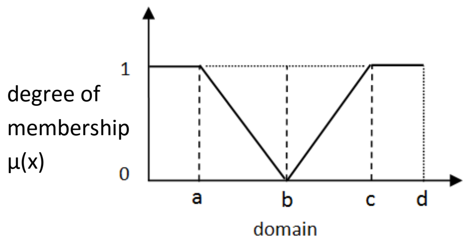


Figure 3. Curve shoulder membership

Where,

$$\mu(x) = \begin{cases} 1; \ 0 \le x \le a \ \text{atau} \ c \le x \le d \\ \frac{b-x}{b-a}; \quad a \le x \le b \\ \frac{x-b}{c-b}; \quad b \le x \le c \end{cases} \tag{3}$$

2.2 Fuzzy Rule Base

Fuzzy rule base is set of rules consist proposition after IF called antecedents, while the proposition after THEN is called the consequent.

$$IF (x \ is \ A1) AND \ (y \ is \ B1) THEN \ (z \ is \ C1) \tag{4}$$

One of method determining the rules constructed by the system response [5,6].

2.3 Fuzzy Inference Engine

Inference is the process of changing the input fuzzy by following the rules (IF-THEN) as determined on the basis of fuzzy knowledge. In other words, do the aggregation that combines the output of IF-THEN fuzzy into a single set.

Some operations (operators) were used that combined operations (union) or OR of fuzzy sets A and B is expressed as AUB in fuzzy logic is called Max and Operation slices (intersection) or AND of fuzzy sets A and B is expressed as A ∩ B in logic fuzzy called Min [8].

2.4 Defuzzification

Defuzzification is the process of converting the output obtained from the fuzzy inference engine into a value. Defuzzification frequently used method is the method Center Of Area (CoA). In the case the discrete of universe discourse formulated:

$$z^*_{CoA} = \frac{\sum_{j=1}^{n} \mu_C(z_j) z_j}{\sum_{j=1}^{n} \mu_C(z_j)} \tag{5}$$

Where, n is the number of quantization levels variables, z_j is the numerical value quantization level and μ_j is the degree of membership z_j in the set C .

Mean of Maximum Method (MoM) determines the action represented by the mean value of the membership function reaches its maximum. In the case of the discrete universe of discourse is expressed in the following equation:

$$z^*_{MoM} = \sum_{j=1}^{m} \frac{z_j}{m} \tag{6}$$

3. Design and Realization.

The design of hardware and software refers to previous studies [4] with modifications to the input and output terminals and adding input voltage and output display. Input of FLC Single Input Single Output (SISO) is the error (e) and delta error (ΔE) and the output control signal changes (Δu), the error is the difference between the set point (Y_{SP}) with actual output value (y), then formulated:

$$e(t) = y_{sp}(t) - y(t) \tag{7}$$

$$\Delta e(t) = e(t) - e(t-1) \tag{8}$$

Fuzzification use a singleton with triangular membership functions. Set error range of -1.5 to +1.5 volts, set delta error of -0.36 to +0.36 volts and set the output from 0 to 10 volts. Set point at the level of the voltage of 0-4 volts.

Membership function for error and delta error use triangle ends with shoulder than output use triangle. Figure 4 shown membership function three subsets.

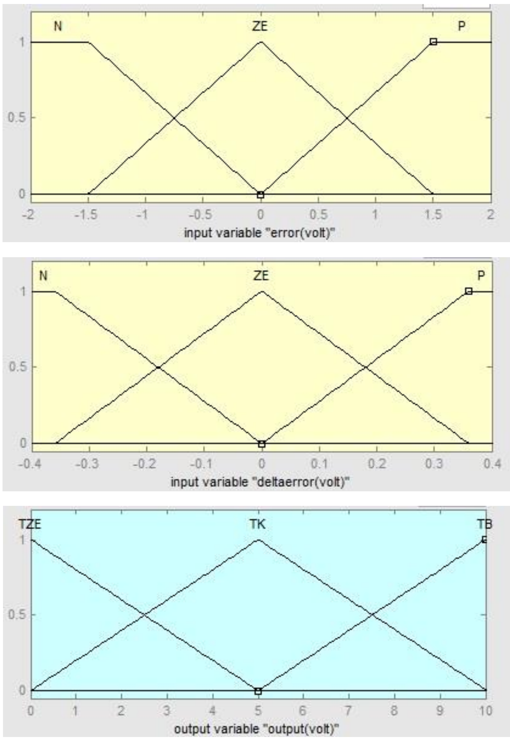


Figure 4. Membership function three subsets.

Designing a good fuzzy logic rule base is key to obtaining a satisfactory controller for particular application. A general method in designing a fuzzy logic rule base following the process state and control variables, shown in figure 5. Rules for three subset shown in table 1. If FLC designed reducing the rise time has the form "if e positive and negative Δe then positive Δu ". If FLC designed with the aim to reduce overshoot, has the form "if e is negative and Δe is negative, than negative Δu". Inference mechanism using *max-min* operator, than defuzzification using CoA method.

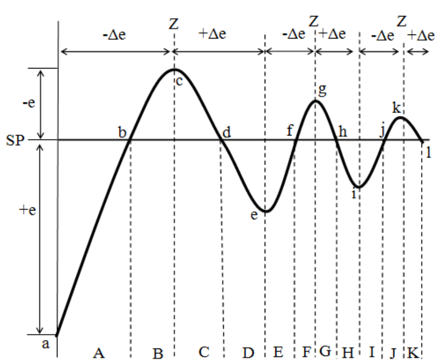


Figure 5. System response

Table 1

Rules of three subsets

Rules	E	ΔE	CU
1	P	ZE	TB
2	ZE	N	TK
3	N	ZE	TK
4	ZE	P	TB
5	ZE	ZE	TZE
6	P	N	TB
7	N	N	TK
8	N	P	TK
9	P	P	TB

FLC software designed to using BASCOM AVR, flowchart software process shown in figure 6.

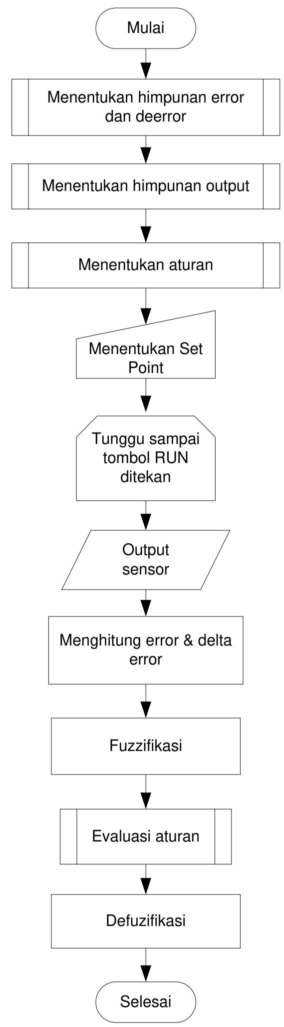


Figure 6. Flowchart software process

Hardware consist three part, minimum microcontroller ATmega 32, LCD display and Digital to Analogue converter. Here is an explanation minimum system of hardware:

- Input using the internal ADC in Port A.0.
- Port B used for downloader.
- Port C as a controller output via DAC, analog output DAC 0808 is designed to have the output voltage from 0-10 volts with amplifier Op-Amp LF351.
- Port D used as an input button select the set point, run and stop.
- As a display using the LCD 16 columns x 2 lines, 4 bits, which is controlled at port A.

The FLC hardware block diagram shown in figure 7 and hardware realization of FLC shown in figure 8(a) modular form, 8(b) final realization.

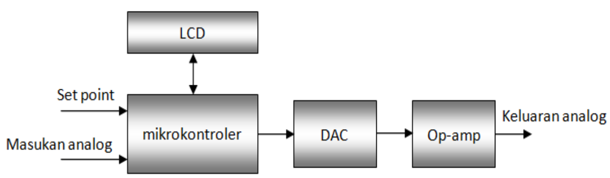
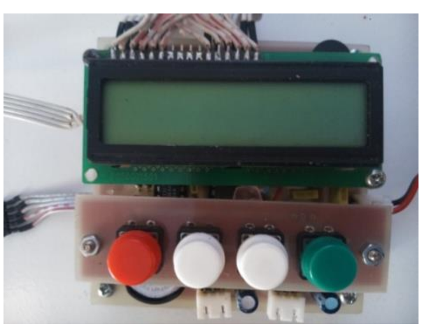
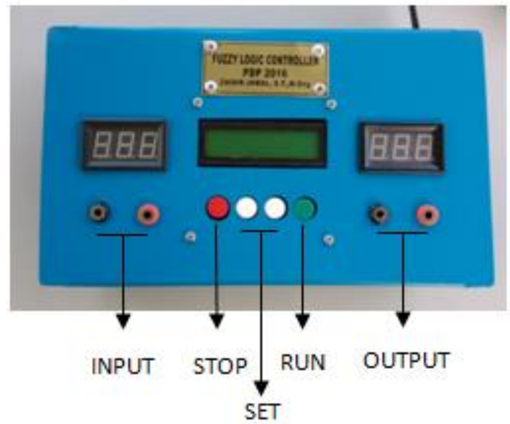


Figure 7. FLC hardware block diagram [4].



(a)



(b)

Figure 8. Hardware realization

Where, specification:

- Power source : AC 220 Volt
- Input Voltage : 0-5 Volt DC
- Output Voltage : 0-10 Volt DC
- Set Point : 4 Volt udjastable.
- Fuzzification : Singleton
- Subsets/Rules : 3/9
- Inference: Max-Min
- Defuzzification : Center of Average (CoA)

3. Testing Result

This testing is to determine whether the FLC modules work according to design. Testing is done by providing input voltage of 0-5 volts in steps of 0.5 volt via potentiometer, the output is connected to a digital volt meter. Serial communication connected to a laptop to determine the program works well using the data acquisition program. The test result shown table 2 and figure 9.

Table 2. Testing result

Set Point (volt)	Input Voltage (volt)	Output Voltage (volt)	
		Data Acquisition	Measurement
4	0	10	10
	0,5	10	10
	1	10	10
	1,5	10	10
	2	10	10
	2,5	9.88	9.7
	3	6.83	6.6
	3,5	3.91	3.3
	4	3.11	0.1
	4,5	3	1.7
	5	3.42	3.3

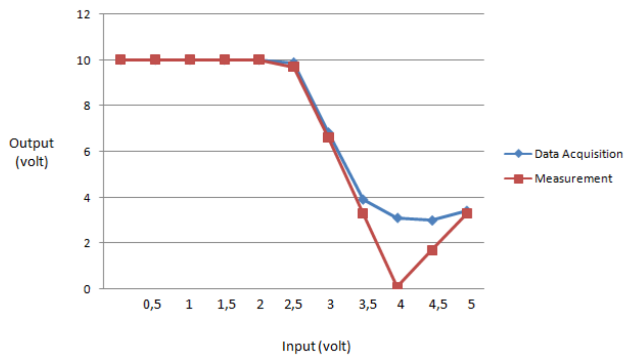


Figure 9. Result testing

The test results showed FLC has worked well, from 10 step only 2 input voltage step on the input voltage of 4 volts to 4.5 volts the output voltage differences. That is caused there is a difference of observation time when turning the potentiometer and observe the measuring instrument. FLC already realized can be implemented on the control of processes such as the control of liquid level and solid as in figure 10 [4].

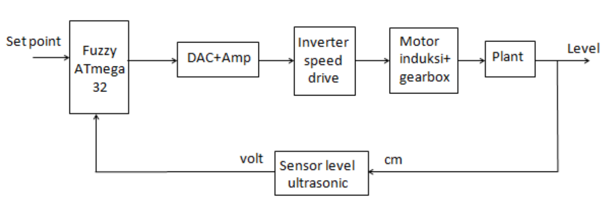


Figure 10. Implementation example [4]

4. Conclusion and Future work

The test results show the module works very well appropriate with the operating fuzzy system. The voltage output module smaller when the input voltage approaches the set point. Future work, The module will develop by adding a miniature water tank system and data logger for FLC trainer kit.

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