Development of Automation System for Room Lighting Based on Fuzzy logic Controller

Aryanto Hartoyo and Seno Darmawan Panjaitan

Abstract—**This paper describes the development of fuzzy logic controller for room lighting system using AT89S51 microcontroller. The fuzzy logic system has two membership functions for the light sources as inputs and one membership function for the output. The first light source is from the outside and the second light source is available in the room. The other input to the control system is from the occupation sensor. The output membership function of the control system is used to determine the number of compact fluorescent lamp (CFL) that must be turned on. The control system will switch the CFL on or off according to the condition of the illuminance in the room. The room illuminance is based on Indonesian National Standard which is about 250 Lux. In case the room is empty, the controller will turn all lamps off. The result of experiment showed 23.9 % in power saving and 4.1 % in difference of control system output to the reference.**

Index Terms—**Fuzzy logic, membership function, lighting system, microcontroller**

I. Introduction

In the life of human-being, lighting is something needed either night time or day time. However, human-beings always give a little attention only to the operation of the lamp, they always forget to switch the lamp off as the room is empty or to decrease the number of lamps to be switched on, if the incoming light to the room is going brighter. In general, the electricity consumption for the lighting will be around 25% - 50% [10]. Nowadays a great portion of our source of energy is from fossil energy or fuel that will be exhausted soon. So efficiency of lighting energy usage is an important effort to do by human being. One of the lighting energy efficiency researches is using lighting control method. The controller will control the number of lamps to be switched on while maintaining the suitable illuminance for the specific condition of the room. By the use of an automatic controller then lighting energy consumption can be reduced.

Based on the experience, knowledge and ability of learning, an operator can control some process successfully. Fuzzy logic implies the knowledge base and linguistic phrases is able to represent the operator work. There are many papers presented by researcher in fuzzy logic lighting control in [11-14] which were focused on power density or dimming in illumination level control. Nowadays, most of room lighting use Compact Fluorescent Lamp (CFL), because CFL is more efficient then incandescent lamp.

In this paper, fuzzy logic is proposed as the control method for a room lighting system with CFLs as the controlled objects. The number of lamps depends on the condition of the room function and the standard illumination level which was based on the Indonesia National Standard SNI 03-6197-2000 [15]. By using fuzzy logic controller, there are three benefits contributed, those are: (1) implementation of a low-cost control hardware by using microcontroller based system, (2) an automatic control system based on fuzzy logic with occupation and illumination sensing, (3) easiness of installation and expansion for a bigger system. There are two scopes of lighting control system design which are the hardware with a microcontroller based system and the software based on the fuzzy logic.

II. System Requirements

In order to perform the design process, some parameters and measurement method must be performed to fulfill the system requirements. The assignment and definition consist of:

A. Determination of Illumination Level for the Room

In this research the lighting control was puposed for a classroom function. According to SNI 03-6197-2000 [15], the illumination for classroom is 250 lux.

B. Measurement and Calculation of Room Parameter

The room parameters are wall color, reflection factor, room area and height.

C. Lamp Position Arrangement and Measurement of Illumination Uniformity

Illumination uniformity is an important factor for human being eyes in order that eyes fatigue can be avoided. One of the methods to achieve illumination uniformity is by fulfilling the spacing criterion (SC). SC is the ratio between center of luminaries and the distance to the work plane or mounting height. SC is set 1.5 means the maximum distance between every light is equal to 1.5 times mounting height.

D. Calculation of the Number of Lamps in the Room

This calculation was to fulfill the illumination level of the room, i.e. 250 lux. The formula used in the calculation is:

$$E = \frac{\Phi \times CU \times LLF}{A} \quad (1)$$

where,

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The authors are with the Electrical Engineering Department, Faculty of Engineering, Tanjungpura University, Pontianak 78124, Indonesia (e-mail: hartoyoanto@yahoo.co.id,seno.panjaitan@untan.ac.id,senopanjaitan@gmail.com).

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E : illuminance (Lux)
Φ : Luminance (Lumen)
CU : Coefficient of Utility
A : area of illumination (m^2)
LLF: Light Loss Factor.

III. Fuzzy Inference System

The processes done in the fuzzy inference system (FIS) consist of:

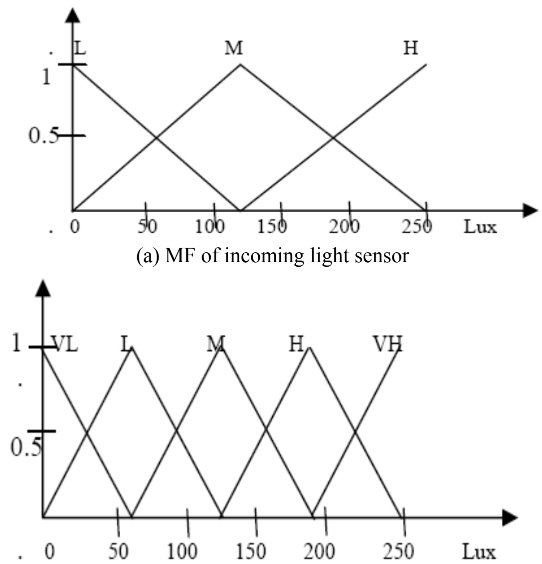
1) *Fuzzification*, which is the process of mapping of crisp value to a degree of membership. The crisp values are presented by sensors,
2) *Fuzzy operator* (AND or OR) implementation to obtain one number that represent the result of the antecedent for that rule,
3) *Implication method* (min or prod) to the result of if-then rule,
4) *Aggregate* (max, probor or sum) of all implication result,
5) *Defuzzification* process to obtain the crisp value.

The membership function used were triangular and trapezoidal function, while the approximate reasoning given by equation (2) and the method used in defuzzication was center of area (COA) as shown in equation (3).

$$\mu_c(w) = \mu_{c1} V \mu_{c2} = [\alpha_1 \Lambda \mu_{c1}(w)] V [\alpha_2 \Lambda \mu_{c2}(w)] \quad (2)$$

$$z_o = \frac{\sum_{j=1}^{n} \mu_z(w_j) w_j}{\sum \mu_z(w_j)} \quad (3)$$

The membership function (MF) grouping for input variables and MF for output variable are shown in Fig. 1 and Fig. 2. The membership functions are grouped as Very Low (VL), Low (L), Middle (M), High (H) and Very High (VH).



(a) MF of incoming light sensor

(b) MF of inside room light sensor
Fig 1. MF of input variable.

Table I shows the rules for the lighting system control, the rules are stated as follows:

R(n): IF *x1* is *A1n* and *y1* is *B1n* THEN *z* is *Qn* (4)

For n = 1, 2, ..., *r*.
where *r* : number of rule

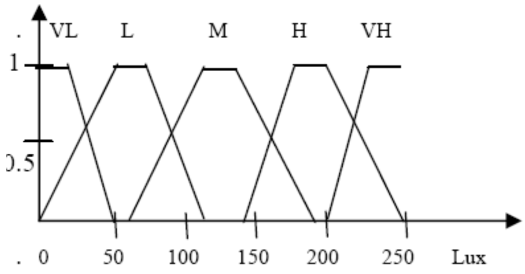


Fig. 2. MF of output variable

According to the Table I, there are 15 rules that are proceeded by the fuzzy logic computation. This logical design was embeded microcontroller to decide the control ouput.

TABLE I: Fuzzy Rules for Lighting Control System

Input X_1	Input y_1				
	VL	L	M	H	VH
L	VH	H	H	H	M
M	H	M	M	D	L
H	M	L	L	L	VL

IV. Hardware and Software Design

A. Hardware Design

The block diagram of the system hardware is shown in Fig. 3. The microcontroller system receives two input signals, one was from the incoming light to the room sensor and the other was from the inside room sensor. These signals were put through multiplexer and Analog to Digital Converter (ADC) interface to the microcontroller system. The other inputs are occupation sensor, which were used to sense the people going into or out of the room. The communication between the occupation sensors to the microcontroller system was accomplished through the system interrupt. The output signals of the microcontroller system are connected to the driver for controlling the switching of TRIACs those function to switch the CFL on or off.

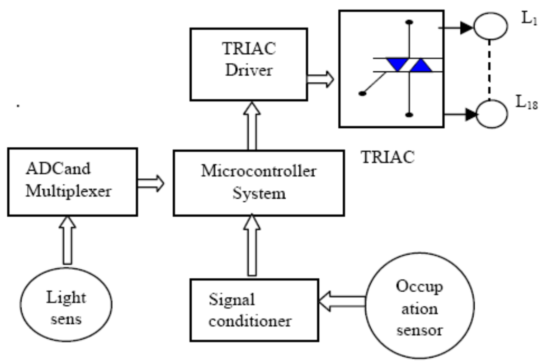


Fig.3 Hardware block diagram

The layout of the lamps position in the room was shown in Fig. 4. The number of lamps was determined based on the maximum need of illumination once there is no light in the room either from artificial lamps or environment. It was then calculated the number of lamp that could reach the illumination standard, i.e. 250 Lux. The total number of lamps for the room was calculated by the formula (1), by determining the illuminance E = 250 lux, CU = 0.69, LLF = 0,8 and room area A = 43.2 m^2 , it was obtained:

$$\Phi = \frac{E \times A}{CU \times LLF} = \frac{250 \times 43.2}{0.69 \times 0.8} = 19605.98 \quad Lumen \qquad (5)$$

By using 20 Watt fluorescent lamp (CFL) with 1100 Lumen each lamp in new condition, then the total lamps for the room was 19605.98/1100 = 18 lamps.

The calculation is as follows:

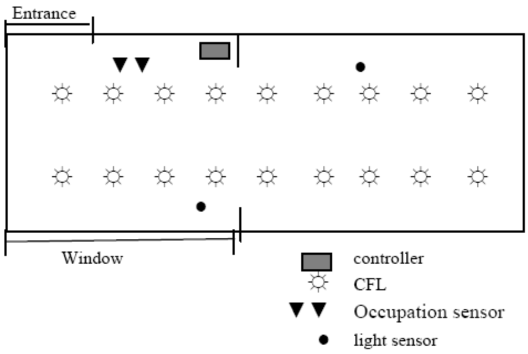


Fig. 4. Lamps layout in the room

There are two methods to measure the illumination level in a room, either by grid pattern or by measure the dominant location points in the room representing the average illumination level. Fig. 5 shows the grid pattern of illuminance measuring points, each point is 0.6 m spaced. The room had the dimension of length= 12 m and width= 3.6 m so the total of the measuring points are 95. There were four times of measurement per day, and the illuminance representation of each day measurement was the average value of all measurement points.

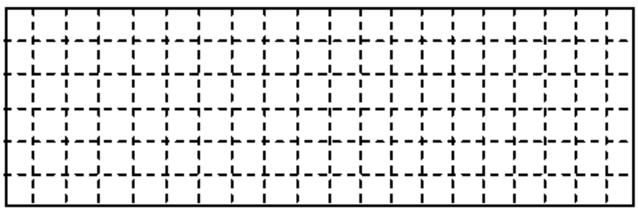


Fig. 5. Grid pattern for illuminance measurement points.

B. Software Design

The design of control system software algorithm is shown in Fig. 6. The algorithm involves the following working steps: Firstly, initialization of the I/O port and system interrupt. This step is purposed to determine the I/O ports that are assigned either as input or output, also for the interruption. Secondly, check the Counter (CT), if CT=0 then switch off all lamp, otherwise do sensor reading. This step is purposed to detect the occupation of the room in order to activate the lighting system once the room is occupied. Thirdly, fuzzification of inputs is performed where it will convert the crisp value from the illuminance sensor to the fuzzy value in the software. This fuzzy value is a variablle in the membership function input. The value later on will be used to decide the fuzzy value of the membership function output. Fourthly, application of the if-then rule is performed to select which rule(s) that will be used in the computation. Fifthly, defuzification is done anf the value is converted to crisp value which is used as output control signal for lamps. Sixthly, if the program was stop it finish otherwise looping to check counter.

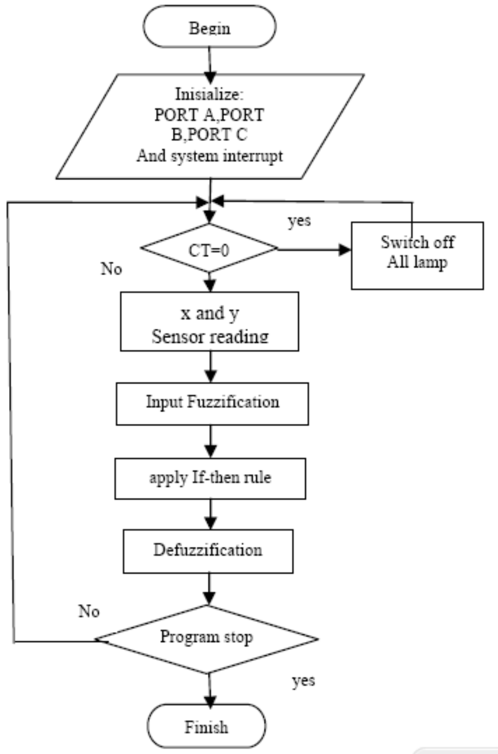


Fig. 6. Software algorithm

V. Analysis of System Performance

The analysis of the system performance consists of testing the sub system (functional block) and whole system hardware. Testing was done by measuring the output of the subsystem and the whole system. One of the hardware sub-system testing is shown in Fig.7. The multiplexer 4051 functions to select an input at a time and passes the input signal to ADC. The ADC converts the analog signal to be a digital number and feed it to the microcontroller system to be processed. The sensor of incoming light to the room had output voltage range from 1.1 – 4.25 Volt, while light sensor inside the room had output voltage range from 1.3 – 3.5 Volt. The occupation sensors sent interrupt signal to the microcontroller system that caused the increment or decrement of an eight bit register as counter.

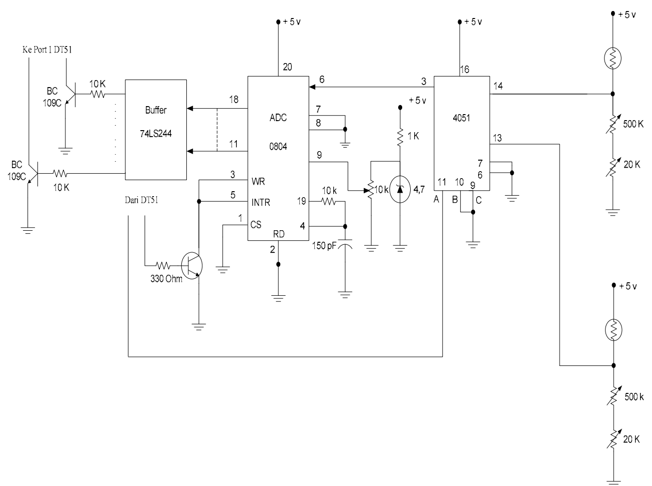


Fig. 7. Measuring point of light sensor, ADC, and Multiplexer

For the whole system output testing, measuring was focused on the controlled room illuminance with the variation of incoming sun light to the room, by which condition in the morning, noon, afternoon and night time. From the collected data, analysis could be carried out in some points of view. It was deviation or error of the room illuminance from set point, the percentage of lighting power saving and the number of lamps usage.

There were total of 95 measuring points of the room that measured by lux-meter, the data used in analysis was the average value.

VI. Result and Discussion

The total number of lamps for the room as calculated above was 18 lamps with each lamp's power was 20 Watt and 1100 Lumen in new condition. The result of measurement was shown in Table II.

The data used in the analysis was collected in seven days and presented in graphic form.

TABLE II: Average Dayly Illuminance Measurement

		Days of measurement						
	Unit	1	2	3	4	5	6	7
With controller	Lumen	240	239.8	240.2	240.1	240.5	239.5	235.4
	Watt	260	280	280	280	280	260	280
Without controller	Lumen	340	350	325	360	360	350	340
	Watt	360	360	360	360	360	360	360

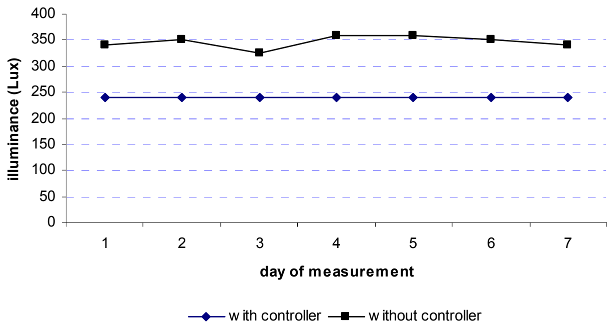


Fig. 8. Room illuminance with and without controller

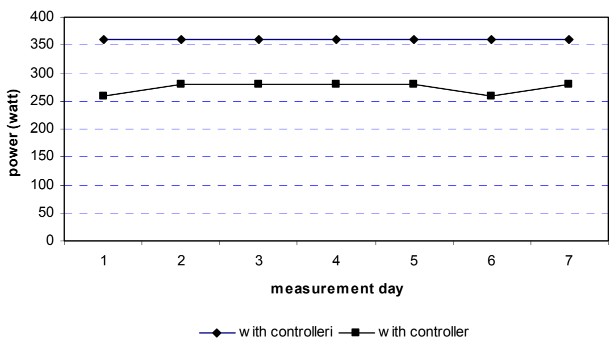


Fig. 9. Power saving with controller implementation

From Fig. 8 it was seen that the illuminance of the room without controller was above the standard level (250 lux), it was 38 % in average, while with controller it was 4.1 % in average below the standard level.

In Fig. 9 it was seen that the power consumed without controller was 360 Watt, while with controller it was 274 Watt in average or 23.9 % power saving in a day.

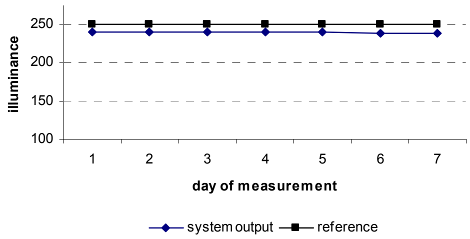


Fig. 10. Deviation of controller output from reference

From Fig. 10 it was seen that the output of the controller was around 4 % in average deviate from the reference.

VIII. Conclusion

This paper has elucidated a fuzzy logic controller to control the on/off of CFL which are currently used in most of buildings. The lamps were controlled individually by switching them on or off by the controller while maintaining the room illuminance around 250 lux as the SNI standard level for office/classroom. On the other side, by using the controller it can save the energy around 23.9 %. These results proved that the proposed controller could contribute a benefit in increasing energy usage efficiency.

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Aryanto Hartoyo was born in Pontianak Indonesia on Sept. 15, 1954. He received Ir. (Bachelor) degree in control engineering in 1984 and M.T. (Master) degree in energy management in 2010 from The University of Tanjungpura Pontianak Indonesian. He is a Senior Lecturer at Department of Automatic Control Engineering at The University of Tanjungpura. His researches are mostly in digital control engineering especially in microprocessor or microcontroller based system. Ir. Aryanto, MT. is a member of MASDALI Indonesia Control Engineering Society.

Seno Darmawan Panjaitan was born in Pontianak Indonesia on July 16, 1975. He received S.T. (Bachelor) degree on Electrical Engineering from Tanjungpura University (Pontianak, Indoneia) in 1984 and M.T. (Master) degree on Electrical Engineering from Bandung Institute of Technology (Bandung, Indonesia) in 2001. He received his doctoral degree (Dr.-Ing.) on electrical and computer engineering from University of Kaiserslautern (Germany) in 2007. He is now a Senior Lecturer at Department of Electrical Engineering, Tanjungpura University, in Automatic Control Engineering research group. His research focuses on automatic control and industrial informatics, bio-energy, energy optimization, and mechatronics. He was a member of Indonesia Control Society (MASDALI). Now, he is a member of IEEE.