PROTOTYPE OF STREET LIGHT CONTROL SYSTEM USING FUZZY MAMDANI METHOD

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Abstract

Street light usually set to turn on at night based on fixed time setting. In rainy condition, it will be better that the street light turned on and the color of light is yellow instead of white for effectiveness of human sight. In this research, a system which could control the street light will be designed by considering environmental light intensity, rainy condition, and time setting. Fuzzy Mamdani method is used to adjust the level of the street light intensity. The experiment results show that the system work properly. The light intensity of the street lights can change automatically adapting the brightness of environmental light and rainy or non-rainy conditions through the fuzzy process with the highest light intensity about 248.93 (in 0-255 PWM range) with an average error between experiment results and simulation using Matlab about 0.05%. In rainy condition, the color of the street light will turn to yellow from default color (white).

Keywords: street light, fuzzy mamdani, control.

I. INTRODUCTION

Along with the high population growth in Indonesia, the human need for electricity plays an important role in human life, one of which is that electricity is used for good lighting at homes on the streets and others. Without realizing it, every day we often see street lights that turn on only at night which have been set using time controls. Over time, the development of street lighting is very significant, it is seen that there are street lights that use LED lights, but it is still unfortunate that the use of these LED lights has not been evenly distributed, only in a few points.

In the morning when the street lights are no longer needed, there are several street lights that are still on and illuminating the streets so that the energy expended to illuminate the road is in vain, in contrast to the afternoon when conditions are cloudy and lighting is very much needed, seen only lamps that are equipped with a good control system on the street lights are on and some that are not equipped with light control do not turn on, so the lighting is considered very ineffective. When the light sensor condition in the street lighting does not work, the light on and off will also be affected. In other conditions, when it rains heavily and results in reduced visibility of the rider, the sight of road users is less than optimal if the color of the lights shining on the road is white, but it will be more optimal if the street lighting is yellow.

Several studies on automatic light intensity control have been done before, such as a study conducted by [1] designed a tool to control the brightness level of street lights based on the number of vehicles passing the road. The tool can also display lamp brightness levels on the Web for monitoring purposes. The test results show that the maximum PWM (Pulse Width Modulation) value for setting light intensity is 224.51 and the minimum value is 27.49. Another research designed a light intensity control device in the room using the fuzzy logic method by utilizing light sensors from outside and motion sensors that detect movement in the room. The tool made can adjust the light intensity automatically based on the data obtained from the sensor. Fuzzy logic output in the form of a PWM signal is transmitted to the driver circuit (L298N). The test results show that the tool can work optimally in adjusting the light intensity of the room [2]. Research conducted by [3], the research used the fuzzy mamdani method to adjust the lights based on the number of vehicles passing on the road that is fitted with lights. The test results show that the fuzzy mamdani method can work well in regulating the light intensity of the lights and successfully adjusts the light formation. Research conducted by [4], the research designed a street lighting system (PJU) using light sensors and solar cell panels as a source of voltage. The system can also be controlled via the android application. The system test results show the lights can automatically turn on and off according to the light sensor readings. The Arduino microcontroller can receive commands from an Android smartphone either with or without obstruction with a maximum distance of 15 meters. Research conducted by [5], the research designed a monitoring and control system for street lighting through an android-based internet network. The android application will send and receive information signals via the internet network using a modem to the website so that the data is received by the ethernet shield module which is then processed by Arduino to control the street lighting. The system test results show that the on condition indicates the light is on and the off condition indicates the light is off. The average accuracy of the comparison of current measurements is 100%, while the average accuracy of the comparative measurement of voltage is 95.23%.

In this research, a street lighting control system using a microcontroller will be designed to adjust the brightness level of the lamp based on the light intensity of the environment around the road received by the light sensor. The system is also equipped with a timer device to set the schedule for the lights to turn on at a predetermined time, which aims to ensure the lights stay on at the time the lights absolutely need, such as at night. A rain sensor has also been added to adjust the color of the lights where the lights will turn yellow when it rains so that it can optimize the vision of road users in rainy conditions. The method used to adjust the level of lamp brightness based on light intensity in the environment around the road and rainy conditions or not is the Mamdani fuzzy method.

II. SYSTEM DESIGN AND METHODOLOGY

In this section, we will discuss in general the concepts and workings of the system. Figure 1 is a system block diagram.

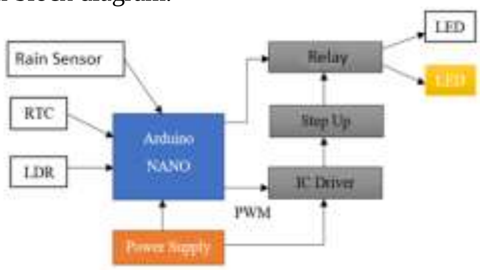

Figure 1. Block System

On Fig. 1, the microcontroller (arduino nano) receives input data from two sensors, namely the rain sensor and the light sensor (LDR). The data from the two sensors is fuzzy input data. The timer (RTC) in the system is used to set the time to turn on the lights at night. The final result of the fuzzy logic process on the microcontroller is a PWM signal which is used to adjust the brightness of the LED lights. The color of the LED lights up depends on the rain sensor input value. The arduino and the driver IC are supplied with voltage from the power supply.

1. Fuzzyfication

In the fuzzification process, it is carried out to change the input with a definite truth value (crisp input) into fuzzy input in the form of linguistic values whose semantics are determined based on certain membership functions. Mamdani fuzzy input uses two variables, namely the light intensity fuzzy set and the rain intensity fuzzy set. The fuzzy set of light intensity is shown in Figure 2.

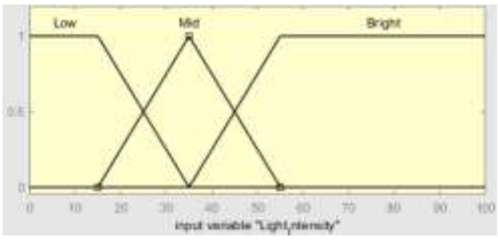

Figure 2. The fuzzy set of light intensity

The 'low' membership function is shown in (1).

$$\mu|x| = \begin{cases} 1, & x \le 15 \\ \frac{(35-x)}{(35-15)}, & 15 < x < 35 \\ 0, & x \ge 35 \end{cases} \tag{1}$$

The 'Mid' membership function is shown in (2).

$$\mu|x| = \begin{cases} 0, & x \le 15 \; atau \; x \ge 55 \\ \frac{(x-15)}{(35-15)}, & 15 < x < 35 \\ \frac{(55-x)}{(55-35)}, & 35 < x < 55 \\ 1, & x = 35 \end{cases} \tag{2}$$

The 'low' membership function is shown in (3).

$$\mu|x| = \begin{cases} 0, & x < 55 \\ \frac{(x-35)}{(55-35)}, & 35 < x < 55 \\ 1, & x \ge 55 \end{cases} \tag{3}$$

The fuzzy set of Rain is shown in Figure 3.

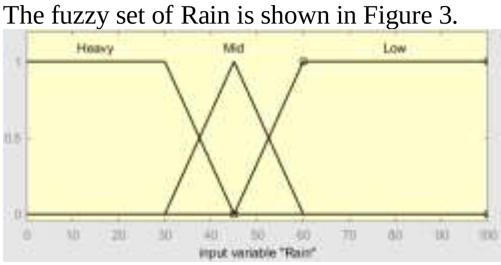

Figure 3. The fuzzy set of rain intensity

The 'low' membership function is shown in (4).

$$\mu|x| = \begin{cases} 1, & x \le 30 \\ \frac{(45-x)}{(45-30)}, & 30 < x < 45 \\ 0, & x \ge 45 \end{cases} \tag{4}$$

The 'mid' membership function is shown in (5).

$$\mu|x| = \begin{cases} 0, & x \le 30 \; atau \; x \ge 60 \\ \frac{(x-30)}{(45-30)}, & 30 < x < 45 \\ \frac{(60-x)}{(60-45)}, & 45 < x < 60 \\ 1, & x = 45 \end{cases} \tag{5}$$

The 'low' membership function is shown in (6).

$$\mu|x| = \begin{cases} 0, & x < 60 \\ \frac{(x-45)}{(60-45)}, & 45 < x < 60 \\ 1, & x \ge 60 \end{cases} \tag{6}$$

After knowing the membership function of each set, the next step is to find the degree of membership of each set from the sensor input values. The value of the degree of membership of each set will be processed using the min fuzzy operation. At the output of the fuzzy set, there is one variable, namely the LED-Output set. This LED-Output set is shown in Figure 4.

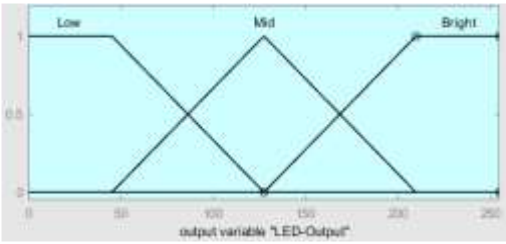

Figure 4. The set of LED-Output

2. Inference

In the inference stage, the results of the degree of membership in the fuzzification process are applied the Mamdani fuzzy method with the Min implication function, before later entering the rule composition process with the Max method from the predefined fuzzy rules. The fuzzy rules are as follows:

1. If (light intensity is bright) and (rain is low) then (LED-Output is low)
2. If (light intensity is bright) and (rain is mid) then (LED-Output is low)
3. If (light intensity is bright) and (rain is heavy) then (LED-Output is low)
4. If (light intensity is mid) and (rain is low) then (LED-Output is Mid)
5. If (light intensity is mid) and (rain is mid) then (LED-Output is Mid)
6. If (light intensity is mid) and (rain is heavy) then (LED-Output is bright)
7. If (light intensity is low) and (rain is low) then (LED-Output is bright)
8. If (light intensity is low) and (rain is mid) then (LED-Output is bright)
9. If (light intensity is low) and (rain is heavy) then (LED-Output is bright)

3. Defuzzyfication

A fuzzy set obtained from the composition of fuzzy rules in the previous process will be processed using the centroid method. In this centroid method, the crisp value solution is obtained by taking the center point (z *) of the fuzzy area. The equation for calculating the output value of the defuzzyfication process is shown in (7).

$$z^* = \frac{\int z \,.\, \mu c(z)\, \mathrm{dz}}{\int \mu c(z)} \tag{7}$$

III. RESULT

Prototype of street light is shown in Fig. 2.

Figure 1. Prototype of street light

Experiment is carried out to determine whether the system's work performance is working properly or not. Experiment is carried out in two scenarios, non-rainy condition experiment and rainy condition experiment.

1. Non-rainy condition experiment

Data were collected in the morning, afternoon and evening. The results of system testing during the morning, afternoon, and evening as a whole are shown in Table 1.

Table 1. Experiment and Simulating Result

No	Time	Input (Light Intensity) (0-100)	Input (Rain) (0-100)	Output (LED-Out) (0-255)	Matlab Output	Error
1	04:58 am	8 (Low)	97 (Low)	248.93 (Bright)	249	0.07%
2	05:30 am	20 (Mid)	94 (Low)	190.27 (Mid)	190	0.27%
3	05:38 am	35 (Mid)	94 (Low)	55.67 (Mid)	55.7	0.03%
4	11:03 am	97 (Bright)	99 (Low)	0 (Low)	0	0
5	12:01 pm	94 (Bright)	99 (Low)	0 (Low)	0	0
6	05:51 pm	48 (Bright)	97 (Low)	0 (Low)	0	0
7	05:59 pm	34 (Mid)	99 (Low)	70.2 (Mid)	70.2	0
8	06:03 pm	25 (Mid)	98 (Low)	154.99 (Mid)	155	0.01%
9	06:11 pm	15 (Low)	99 (Low)	248.93 (Bright)	249	0.07%
Error Rate						0.05%

Based on the experiment result shown in Table 1, at the time of 04:58 am, the light sensor input has a value of 8. This proves that the system detects that the condition at 04:58 am is still dark. At 05:30 am it started to get a little bright and at 05:38 it was getting bright, shown by the dimming of the LED lights. During the daytime from 11:03 am to 05:51 pm the system detects that the day is still bright, this is indicated by the input value that the light sensor reads not less than 36. At 05:59 pm the light sensor shows a value less than 36 which means the light has started to dim, so the lamp starts to activate with a PWM value of the LED lamp of 70.2.

Average error between experiment results and simulation using Matlab about 0.05%.

2. Rainy condition experiment

In rainy condition experiment, it is done by performing a rain simulation. Rain simulation is being carried out by slowly dripping water onto the rain sensor surface. This experiment produces a rain sensor reading value of 45. During the heavy rain simulation, it is carried out by flowing water continuously to the rain sensor surface. This experiment resulted in a rain sensor reading of 23.

The system test results during the simulation of light and heavy rain as a whole are shown in Table 2.

Table 2. Experiment and Simulation Result During Mid Rain and Heavy Rain

No	Input (Light Intensity)	Input (Rain)	Output (LED-Out)
1	71 (Bright)	52 (Mid)	0 (Low)
2	66 (Bright)	25 (Heavy)	0 (Low)
3	22 (Mid)	45 (Mid)	173,9 (Light Turns On Yellow)
4	20 (Mid)	25 (Heavy)	239,89 (Light Turns On Yellow)
5	8 (Low)	45 (Mid)	248,93 (Light Turns On Yellow)
6	8 (Low)	23 (Heavy)	248,93 (Light Turns On Yellow)

Based on Table 2, when conditions are bright the lights do not turn on even though they are exposed to medium or heavy rain. When conditions are dim when exposed to rain, the lights turn yellow with a lamp brightness level of 173.9 (PWM value), while during heavy rain the value is 239.89. When it is dark, the lights turn yellow with a light intensity of 248.93 even when it rains lightly or heavily.

IV. CONCLUSIONS

Based on the experiment result, it can be concluded that the proposed street light system was work well. The light intensity of the headlight success to change automatically based on the brightness of the environment and the rainy or non-rainy conditions. In rainy condition, the color of the lights turned yellow. At night time, the system ensure the lights stay on even though the light sensor is exposed to light. The Mamdani fuzzy method succsess in controlling the intensity of street light with the highest light intensity of 248.93 from the range 0-255 (PWM value). Average error between experiment results and simulation using Matlab about 0.05%.

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