한국항해항만학회지 제47권 제2호
J. Navig. Port Res. Vol. 47, No. 2 : 85-92, April 2023 (ISSN:1598-5725(Print)/ISSN:2093-8470(Online))
DOI : http://dx.doi.org/10.5394/KINPR.2023.47.2.85

Design and Implementation of Green Coastal Lighting System for Entrance to Coastal Pier

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Abstract : *The hardware of an LED lighting control system for coastal lighting at coastal pier entrance consists of a power supply unit, an AVR control unit, a CLCD output unit, an LED control unit, a scenario selection switch unit, and an operation speed display unit. It is made of an 8-channel. The CPU used ATmega128 and the FET was used to control the current signal. To operate the CPU, DC 12V was converted to DC 5V using a regulator 7805. A heat sink was used to remove heat generated in the FET. By connecting the load LED module to the manufactured 8-channel LED lighting control system, the operation was confirmed through various production scenarios. In addition, a control system was designed to show the most suitable color for the atmosphere of the coastal pier according to the input value of temperature and illumination using a fuzzy control system. Computer simulation was then conducted. Results confirmed that fuzzy control did not need to store many data inputs due to characteristics of artificial intelligence and that it could efficiently represent many output values with simple fuzzy rules.*

Key words : *illumination, membership, coastal lighting, coastal pier, controller, defuzzification*

1. Introduction

Since LEDs have been used as the main light source, the function of the light source has been expanded to provide aesthetic satisfaction or induce emotion beyond simply lighting up the darkness. It is expected that various emotional effects will be derived by dynamically changing the brightness, color, and purity of the lighting, which leads to opportunities for new product development and is recognized as a potential to create market demand. In other words, the area to use the color property of lighting as a design element is increasing. In this study, for the lighting atmosphere of the coastal pier entrance, the LED lighting control system for the coastal pier entrance was designed and implemented to represent the most appropriate scenario and color depending on temperature and illumination. As a configuration characteristic, it is possible to create various scenarios as an 8-channel. In addition, a control system was designed to show the most suitable color for the atmosphere of the coastal pier according to the input value of temperature and illumination using the fuzzy control system, and computer simulation was conducted[1-3]. And for the purpose of research, we used LEDs to contribute to the atmosphere of emotional lighting and the green environment to create a carbon-reducing environment at the entrance of the coastal pier.

2. LED Coastal Lighting Systems for Coastal Pier

2.1 LED Lighting Features

The main lighting characteristics of the LED light source are summarized as follows. Structurally, unlike conventional light sources, it is a small solid point light source that does not use glass electrodes, filaments, and mercury (Hg), making it very robust, long-lived, and environmentally friendly. Accordingly, unlike conventional lighting technologies, lighting technologies that use LEDs are called semiconductor lighting technologies that use solid-structured light sources. Light loss is very small and visibility is improved when applying lighting equipment that requires a specific color (or wavelength) while emitting optically clear monochromatic light, and light loss can be greatly reduced as a directional light source. In addition, it is easier to produce various colors because it has better

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dimming control ability than any existing light source. The DC driving light source electrically starts lighting at a voltage or higher, and after lighting, the current and intensity change sensitively even with a small voltage change. In addition, since the rated voltage changes according to the ambient temperature, the environmental adaptation characteristics become very poor when driving at a constant voltage, and in principle, it should be driven with a constant current source. Accordingly, in order to safely turn on the LED lighting device, a dedicated power supply device suitable for the LED lamp characteristics is required. Environmentally, when the temperature rises, the allowable current and light output decrease and a lot of heat is generated, and the dynamic characteristics change very sensitively to changes in the ambient temperature and operating temperature. If a current exceeding the allowable value flows, the life is greatly reduced and the performance is greatly reduced, so appropriate heat treatment technology is required in addition to the dedicated power supply device[4-5].

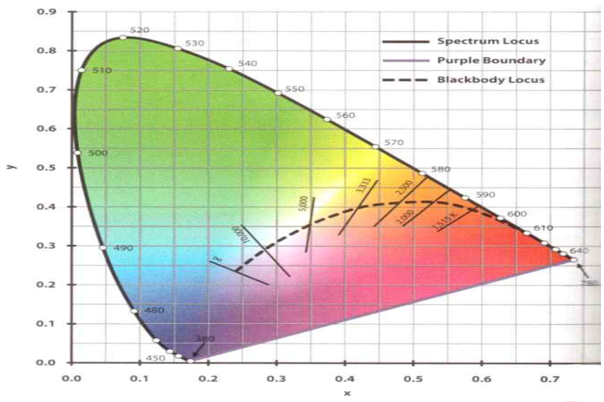

Fig. 1 CIE Chromaticity Diagram

An electrical dynamic characteristic LED is a light emitting diode, and its electrical polarity coincides with that of the diode, the current increases rapidly at a certain voltage or higher, and its brightness is directly proportional to the current size. The rated driving voltage of a single LED changes according to the light emission color and changes slightly in the ambient temperature. Unlike conventional light sources (incandescent lamps and fluorescent lamps), thermal dynamic LED light sources have characteristics that improve light output and light efficiency as the temperature of the junction is lower even if the current flowing is constant. This means that the higher the temperature, the lower the light output and light efficiency, and if necessary, in order to improve the lighting performance, the heat generated at the junction must be properly released. Since monochromatic light emission in a narrow wavelength band and high visibility LEDs emit monochromatic light in a narrow wavelength band determined by the semiconductor type, excellent lighting performance and effective light emission efficiency can be expected when applied to lighting equipment requiring specific colors[6].

2.2 Configuration of the Fuzzy Controller

In order to make fuzzy inference, an IF-THEN form of inference rule is required, which is called the "fuzzy IF-THEN rule".

Consider the case of two-input and one-output with two rules, such as Equation (1) and Equation (2).

$$R^1 = IF\ x\ is\ A_1\ AND\ y\ is\ B_1,\ THEN\ z\ is\ C_1 \quad (1)$$

$$R^2 = IF\ x\ is\ A_2\ AND\ y\ is\ B_2,\ THEN\ z\ is\ C_2 \quad (2)$$

Here, ,A_1 B_1, A_2, B_2, C_1, C_2 is a fuzzy set. Also, it is $A_1, A_2 \subset X$, $B_1, B_2 \subset Y$, $C_1, C_2 \subset Z$

In fuzzy rules such as Equations (1) and (2), if the connection strength α_1 of the first rule is defined as and the connection strength α_2 of the second rule is expressed as Equation (3) below.

$$\alpha_1 = \mu_{A_1}(x_0) \wedge \mu_{B_1}(y_0),\ \alpha_2 = \mu_{A_2}(x_0) \wedge \mu_{B_2}(y_0) \quad (3)$$

In Mamdani inference, the i-th fuzzy rule is defined by the following Equation (4).

$$\mu_{C_i}(W) = \alpha_i \wedge \mu_{C_i}(W) \quad (4)$$

As the final conclusion, $\mu_c(W)$ is shown in Equation (5).

$$\mu_c(W) = \mu_{c_1} \vee \mu_{c_2} = \left[\alpha_1 \wedge \mu_{c_1}(W)\right] \vee \left[\alpha_2 \wedge \mu_{c_2}(W)\right] \quad (5)$$

Here, in order to use this $\mu_c(W)$ as an actual control value, defuzzification must be performed as a real value. In this paper, the center of gravity method as in Equation (6) was used.

$$\mu = \frac{\sum_{j=1}^{n} \mu_c(z_j) z_j}{\sum_{j=1}^{n} \mu_c(z_j)} \qquad (6)$$

Fig. 2 illustrates this fuzzy inference process schematically.

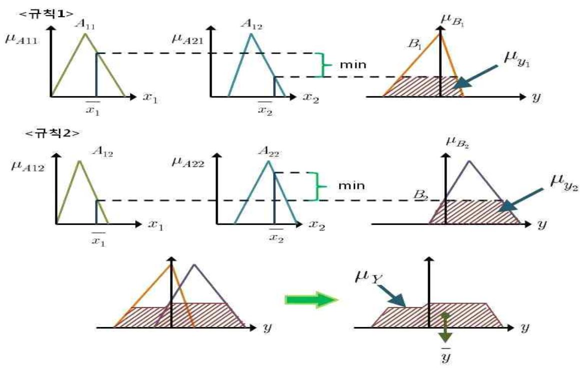

Fig. 2 Fuzzy inference process

And for the knowledge base design, the knowledge required for control can be expressed on a rule-based basis.

3. Design of LED Coastal Lighting Control Systems

The fuzzy algorithm is the part that converts quantified inputs into linguistic variables. Since the data measured in the control system is an actual value and the fuzzy controller is based on the fuzzy set theory, it is necessary to fuzzifier the quantified values. There are two methods of fuzzification: converting numerical values to fuzzy singletons and converting them to fuzzy numbers, where they are converted to fuzzy singletons. In this paper, the values input to the microprocessor are illumination, temperature, and two variables. And this variable derives the value of LED lighting color by fuzzy operation[7-8].

3.1 Fuzzy Control Rules Settings

What is important in fuzzy algorithms is to set rules, which are the most important in deriving results by input variables. Rules are prepared with expert advice or by generally accepted facts. In other words, since fuzzy logic control systems can be understood as mimicking expert judgment behavior, fuzzy logic control systems are practical applications of expert system control, and in order to implement fuzzy logic control systems, expert empirical knowledge must be described first. Experts who have sufficient learning and the knowledge necessary to control the system can describe their control rules in a qualitative and linguistic way rather than mathematical and quantitative way. In particular, this format was also used in this paper because the IF-Then format is convenient for expressing empirical knowledge. There are two input variables of the lighting system, five classes for each input, and one output variable and five classes. That is why the number of rules can also be made very large. The more rules there are, the more detailed and accurate calculations of fuzzy logic become, so adding all rules makes it the most ideal system, but it takes a long time to process and complicates the calculation, so the number of rules is limited in this paper[9].

The Fuzzy rules was converted to If-Then rules, which consisted of 25 items.

- Rule 1: If illumination = very dark and temperature = very low then Color = Purple

- Rule 2: If illumination = very dark and temperature = low then Color = Light Pink

- Rule 3: If illumination = Very dark and temperature = Moderate then color = Yellow

- Rule 4: If illumination = very dark and temperature = high then Color = Orange

- Rule 5: If light = very dark and temperature = very high then Color = Red

- Rule 6: If light = Dark and temperature = Very low then Color = Magenta

- Rule 7: If light = Dark and temperature = low then Color = Violet

- Rule 8: If illumination = Dark and temperature = Moderate then Color = Green Yellow

- Rule 9: If illumination = Dark and temperature = high then Color = Yellow

- Rule 10: If light = Dark and temperature = Very high then Color = Orange

- Rule 11: If illumination = Moderate and temperature =

Very low then Color = Cyan

– Rule 12: If illumination = Moderate and temperature = low then Color = Light Cyan

– Rule 13: If illumination = Moderate and temperature = Moderate then Color = Green

– Rule 14: If illumination = Moderate and temperature = high than Color = Green Yellow

– Rule 15 : If illumination = Moderate and temperature = very high then Color = Yellow

– Rule 16 : If light = bright and temperatur = very low then Color = Dodger Blue

– Rule 17 : If illumination = Bright and temperature = low then Color = Cyan

– Rule 18: If illumination = Brightness and temperature = Moderate then Color = Light Cyan

– Rule 19: If Light = Bright and temperature = high then Color = Violet

– Rule 20 : If light = bright and temperature = very high then Color = Light Pink

– Rule 21 : If light = Very bright and temperature = Very low then Color = Blue

– Rule 22 : If light = Very bright and temperature = low then Color = Dodger Blue

– Rule 23 : If light intensity = Very bright and temperature = Moderate then color = Cyan

– Rule 24 : If illumination = very bright and temperature = high then Color = Magenta

– Rule 25 : If illumination = very bright and temperature = very high then Color = Purple

The relationship function created based on the above rules can be expressed by Equations (7) and (8), respectively.

$$R_1 = \bigvee_{i=1}^{25} \{LX_{(i)} \wedge OUT_{(i)}\} \tag{7}$$

$$R_2 = \bigvee_{i=1}^{25} \{DS_{(i)} \wedge OUT_{(i)}\} \tag{8}$$

3.2 Defuzzification Process

The fuzzy figures calculated in the previous chapter cannot be used as direct outputs. Therefore, it must go through a defuzzifier process in order to convert it to a value that is actually available. There are various methods for non-fuzzy, but the Center of gravity method was mainly used as shown in Equation (9).

If the sensor measurements for the conditions A and B are a and b, the non-fuzzy result c is the actual output value that can operate the LED color using the center of gravity method.

$$c = \frac{\sum_{i=1}^{20} \min(\mu_{A_i}[a], \mu_{B_i}[b]) * C_i}{\sum_{i=1}^{20} \min(\mu_{A_i}[a], \mu_{B_i}[b])} \tag{9}$$

The output values are divided into RED, Yellow, Green, Cyan, Blue, Purple, Light Pink, Orange, Green Yellow, Light Cyan, Dodger Blue, Magenta, and Violet, each of which is the actual operating value of the LED output. The color values were arranged in order from very dark to very bright illumination, the color waves were assigned in order from long to short, blue, green, and red, and from very high to very low temperatures, the color waves were assigned in order from short to long, red, green, and blue.

3.3 Composition of landscape lighting scenario at coastal pier

In order to confirm the operation of the landscape lighting scenario of the coastal pier implemented in this paper, the scenarios in various cases below were constructed. For reference, the operation confirmation of various scenarios was actually produced and configured as shown in Fig. 8 and Fig. 9, and the operation was confirmed. The control system operation scenario was selected and configured to be outputable by 10 switches, and one of the configured scenarios is illustrated as follows.

Switch 1. 16 Color Panorama with Switching Method
Switch 2. 16 Color Change with One Step On
Switch 3. Dimming Color Moving to Front and Back with 16 Colors
Switch 4. Each On Moving with 16 Color Change
Switch 5. Color Storage with 16 Colors

Switch 6. 16 Color Panorama with Dimming Method
+
Dimming Color Moving to Front and Back with 16 Colors

Switch 7. All On and Switching with 16 Color Change
+
16 Color Change with One Step On

Switch 8. Color Moving to Front and Back with 16 Colors
+
16 Color Panorama with Switching Method

Switch 9. All Same Color Change with 16 Colors
+
Color Storage with 16 Colors

Switch 10. Each Dimming & Switching with 16 Colors
+
Each On Moving with 16 Color Change

4. Composition of Coastal Lighting System at Coastal Pier Entrance

4.1 Configuration of Coastal LED lighting system

4.1.1 Power supply

SMPS was used to apply power to the LED lighting control board. SMPS stands for Switching Mode Power Supply, and it is a device that converts DC voltage into a square wave voltage using IC devices such as power transistors, and outputs DC voltage after smoothing using a filter. The maximum voltage used in the control board is DC 12 V, so an AC/DC converter was used to convert AC 220V to DC 12V.

4.1.2 AVR Control Unit

The MCU of this system used ATmega128 model, an 8-bit RISC microcontroller from Atmel, and the circuit is shown in Fig. 3 below.

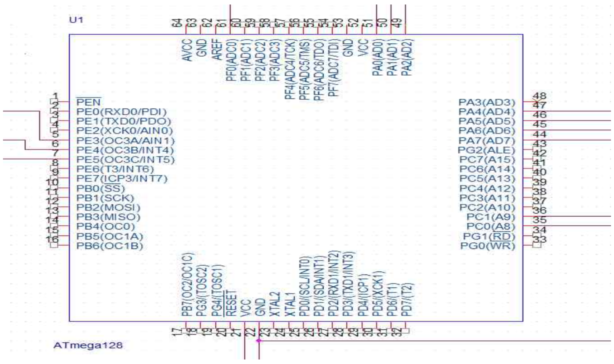

Fig. 3 Circuit of MCU of Control Board

The AVR control unit receives ADC values of the illuminance sensor and the temperature sensor and actually controls the color of each RGB LED module. The color control of the RGB LED DRIVE is basically performed through a timer/counter function. Utilizing this function, we create Pulse Width Modulation (PWM) output to adjust the luminance ratio of Red, Green, and Blue. Timer/counter, which is a 16-bit counter, is also used in timer/counter, and there are various modes such as FAST PWM and CTC mode, among which CTC mode is used. While counting, the CTC mode continuously compares the OCR value with the OCR value and outputs a matching signal when the counting value and the OCR value become the same, thereby outputting a pulse waveform to the waveform generator.

The timing diagram of the CTC mode is shown in Fig. 4.

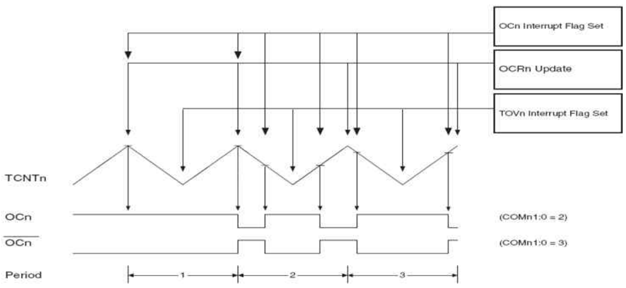

Fig. 4 Timing diagram of CTC mode

4.1.3 CLCD Output Section

The LCD used a typical 16x4 Line Character LCD (CLCD). It is implemented so that the PWM values of Red, Green, and Blue currently output through CLCD can be checked in real time.

The command for controlling the CLCD and the operation timing diagram for reading and writing are as shown in Fig. 5 and 6.

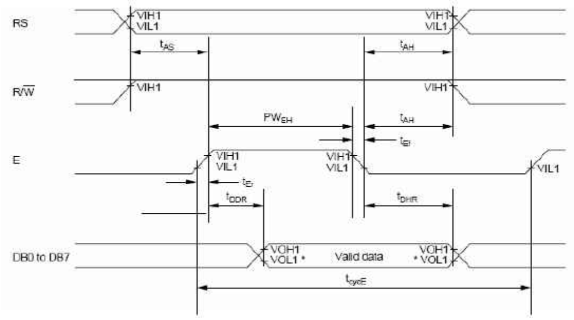

Fig. 5 Timing diagram of reading mode

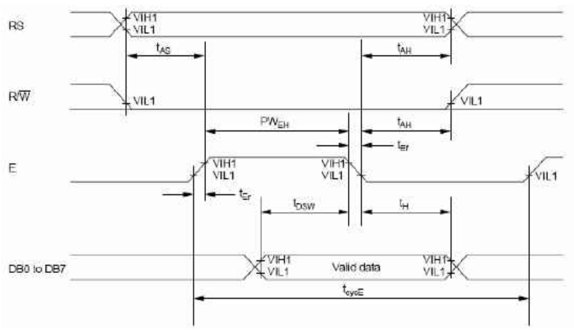

Fig. 6 Timing diagram of writing mode

4.1.4 LED control unit

An RGB LED module was used as an LED module that gives the calculation result value in RGB color. Since the value output from the MCU is DC 5V, which is the TTL voltage level, the RGB LED module cannot be driven. The driving voltage of the RGB LED module is DC 12V, which is applied directly by the SMPS unit, which is the power supply unit. The high and low outputs from the MCU are connected to the gate of the MOSFET and serve to switch the RGB LED module on-off. The color is expressed by applying power to the module according to the signal from the gate end.

The RGB LED module has four lines, R, G, B, and COM, and MOSFET is connected to the other three lines except Com to control the output color. The circuit of RGB LED drive is Fig. 7.

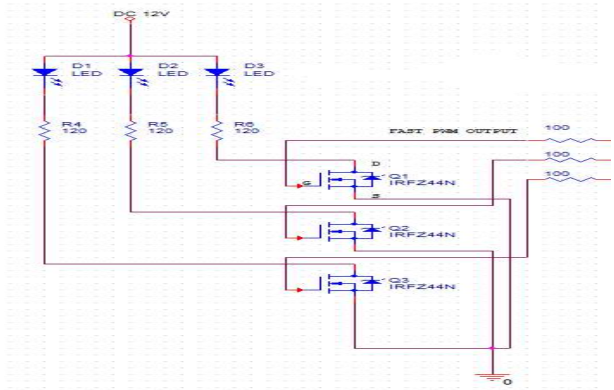

Fig. 7 Circuit of RGB LED drive

4.1.5 Hardware Configuration of Coastal Lighting LED Control System

The actual production board of the Coastal lighting LED control system is shown in Figure 8. ATmega128 was used as the CPU of the control board, and DC 12V was converted to DC 5V using a regulator 7805 to operate the CPU. FET was used to control the current signal.

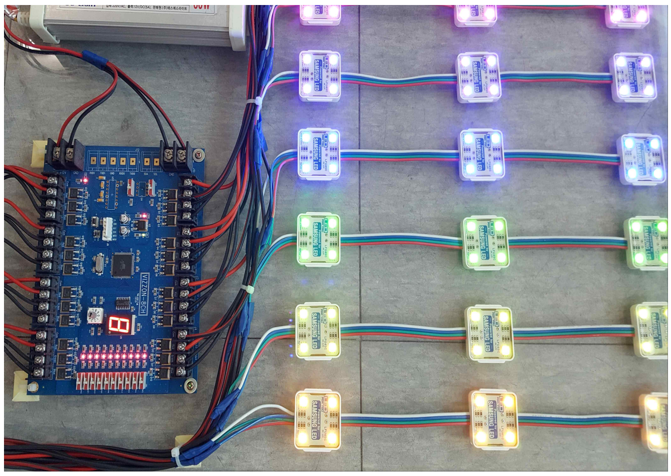

Fig. 8 Control Board of Coastal Lighting System

5. Experiments and Results

5.1 Construction and Experiment of Coastal Lighting System

The experiment of the coastal lighting system was created as Fig. 9 to see various scenarios such as "switching 16-color panorama program", "dimming 16-color program that changes color back and forth", "same color, blinking 3-color program", "16 color program that changes color as it builds up one by one", and so on.

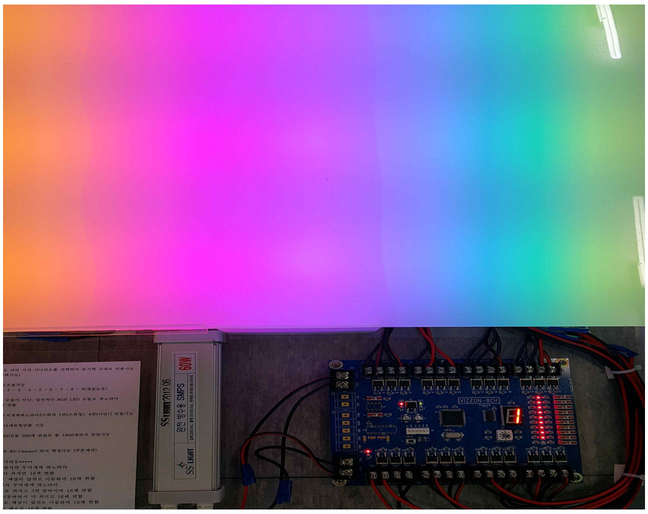

Fig. 9 Experiment of the Coastal Lighting System

5.2 Computer Simulation

An LED lighting control system was designed to represent the color of the fuzzy rule according to the input values of temperature and illumination, and computer simulation was also conducted with fuzzy control.

Table 1 is the result value derived through fuzzy control simulation based on fuzzy rules.

Table 1 RGB LED output result according to arbitrary illumination and temperature value

	illumination (Lux)	temperature (℃)	Color
No. 1	32	21	Light Cyan
No. 2	7	21	Yellow
No. 3	22	12	Green Yellow
No. 4	29	18	Green Yellow
No. 5	3	21	Yellow
No. 6	41	26	Violet
No. 7	26	11	Green Yellow
No. 8	33	19	Dodger Blue
No. 9	37	12	Green Yellow
No. 10	23	13	Green Yellow
No. 11	1	23	Green Yellow
No. 12	36	9	Light Pink
No. 13	44	22	Cyan
No. 14	31	23	Cyan
No. 15	22	14	Yellow
No. 16	47	27	Dodger Blue
No. 17	16	16	Yellow
No. 18	19	21	Light Pink
No. 19	21	21	Magenta
No. 20	4	22	Magenta
No. 21	27	30	Cyan
No. 22	49	29	Blue
No. 23	13	22	Magenta
No. 24	42	24	Light Cyan

The output of the fuzzy control is determined by various input variables and fuzzy rules. Even with the same input value, the output value can vary depending on how experts and designers in the area design the fuzzy rules and databases. This is because fuzzy logic has the characteristics of artificial intelligence. In addition, unlike crisp logic, there is no need to store the input value of many data, and it has the advantage of simply being composed of fuzzy rules. Due to these characteristics, it was confirmed that LED lighting control through the fuzzy control system becomes an organic and efficient system.

6. Conclusion

In order to create an emotional atmosphere of the coastal pier, an LED lighting control system for coastal lighting was designed and implemented. The hardware consists of a power supply unit, an AVR control unit, a CLCD output unit, an LED control unit, a scenario selection switch unit, and an operating speed display unit, and is produced as an 8-channel. The CPU used ATmega128, and FET was used to control the current signal. In addition, DC 12V was converted into DC 5V using a regulator 7805 to operate the CPU.

Various coastal lighting scenarios were confirmed by connecting the load RGB LED module to the manufactured 8-channel landscape lighting LED control system.

In addition, computer simulation was conducted by designing a control system so that the lighting showed the most appropriate color for the atmosphere according to the input value of temperature and illumination using the fuzzy control system. As a result, when looking at the result value and output color according to the fuzzy rule, it is not necessary to store the input value of many data, and it has the efficiency to represent many output values with a simple fuzzy rule.

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Received 26 December 2022
Revised 06 February 2023
Accepted 23 February 2023