Fuzzy Logic for Lighting System in Eco Airport Passenger Waiting Room

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Abstract. The lighting system is one of the great considerations in the eco airport buildings concept. The buildings are usually designed applying transparent-material-covered walls to get the advantages of natural and artificial lighting combinations to optimize and save the consumed energy. This research proposes the use of a fuzzy logic method to control the artificial lighting in the airport passenger waiting room to obtain effective and efficient lighting energy consumption. Using LEDs as lighting devices, the lighting areas are divided into several rectangle zones to simplify the adjustment. For every zone, LEDs are divided into 4 groups, 2 groups are on the upper side and the others are on the lower side. Each group consists of 2 sets of light lamps and placed between the diagonal-adjacent sensors line. Light sensors are placed on each side of the zone to obtain the optimal control result. The LEDs group will be only affected by the two adjacent sensors that flank them diagonally. The result showed that the LEDs current supply controlled by fuzzy that applied to one zone can give sufficient illumination as the IATA’s requirement which is between 200 – 300 lux on the floor level.

Keywords: fuzzy logic, LED, lighting, airport, eco, zonation area

1. Introduction

Air transport can be considered as the main transportation system for middle and long-distance travel nowadays. To perform the services, airports are needed as its supporting facilities. The airport can operate day and night due to the busy air traffic. According to its functions and workloads, airports are demanded to perform effective and efficient energy management. International Civil Aviation Organization (ICAO) as the world civil aviation organization has recommended the implementation of a modern environmental-friendly airport building concept, called eco airport, to all new airport buildings [1].

The eco airport building design concept presents an environmentally friendly airport that provides benefits in many aspects. It affects the economic side in reducing operational costs by saving energy. In addition, it can enhance the country’s image and help environmental policy and measures around the airport [2].

The elements to consider when planning an eco-design of airport buildings covers integrated systems, siting and access, building design and characteristics, power sources and energy conservation, heating and ventilation systems, emissions, waste management, water management and conservation, et cetera [3]. Building design and characteristics play the main role to accommodate the eco effects. By designing the building into a certain model, some optimal voluntary environmental
adjustments can be provided, including the lighting. The modern concept of eco airport buildings implements a see-through wall on a hallway-formed building to give a better combination of natural and artificial lighting to save energy. The see-through wall will permit the outdoor lighting to enter the building so there is no need for indoor artificial lighting when it is already bright enough. However, it is possible for additional lighting to be needed when the indoor illumination is insufficient or less than the required lighting intensity. Both external and internal factors such as the night atmosphere outside the building or the room arrangement itself can affect the lighting inside the building [4].

The airport consists of many rooms and facilities to deliver comfort for the passengers. The waiting room is usually arranged as the most comfortable one where many passengers spend their time before boarding the plane. In the eco concept, it is generally a long hallway to simplify the movement and maximize the eco effect. Alongside the seating features, the sufficient lighting intensity is also considered to provide the passengers ‘comfort. The usage of see-through wall and hallway-formed room concept for the room gives many advantages in saving lighting energy consumption.

To optimize and obtain an effective and efficient lighting energy consumption in the passenger waiting room, this research proposes an optimization lighting system using fuzzy logic to control the lights. The system only calculates lux for the light received on the floor level without considering the ceiling height. The output will be given as the voltage of the lamps. The room is presented in a zonation area shape taking the benefit of the hallway-formed room.

2. Research Modelling for The Room

2.1. Illumination Requirement of The Room

According to IATA standards [5][6], rooms related to passenger services require illumination of at least 200 – 300 lux available on the floor level, including in the passenger waiting room. The same interval value is applied in this study, considering the middle value of the recommended lux of 250 as the main considerations.

2.2. Zonation of The Room

The passenger waiting room is in a hallway shape, so it will be divided into several zones. Each zone is provided with several lamps and LDRs as light detector sensors which are arranged into certain configurations. Each zone is also given a specific zone code, as it is for the lamps and the sensors too. The code will be used to simplify the detection and control arrangement.

![Zonation Division of Room Area](image)

**Fig. 1. Zonation Division of Room Area**

Figure 1 shows the zonation division of the passenger waiting room proposed in the study. There are 2 zones of the zoned areas to be portrayed in the figure. The zones have an identical shape one to another, noted that there is a possibility to set some zones into a different shape regarding to the room space shape, and they are surrounded by see-through walls according to the eco building concept.

For each zone, there are 4 light detector sensors using LDR placed in the middle of each edge line. On the continuous edge side, the sensor is used together by the adjacent zones. Taking group 1 into consideration, the sensors are noted as S01 and S12 for the continuous sensors, and S1a and S1b for the upper and lower side sensors.
The light lamps are configured into 4 groups consists of 2 groups are in the upper side and 2 groups are in the lower side. Each group consists of 2 sets of light lamps and placed between the diagonal-adjacent sensors line. The lamps are noted as L01a and L11a for the upper side lights, and L01b and L11b for the lower side lights. The lamps used in the study here are LED lamp modelled having 24v in voltage.

The LEDs group will be only affected by the two adjacent sensors that flank them diagonally. For example, L01a will be affected by S01 and S1a, L11a will be affected by S11 and S1a, L11b will be affected by S01 and S1b, and L11b will be affected by S1b.

2.3. Measurement Parameters

The lamp radiates light in certain illumination level given in lumen (lm). One lux is equal to one lumen per square metre. The correlation between lux, lumen, and the lamps is given in formulas below.

\[ \Phi = P \times \eta \]  \hspace{1cm} (1)

\[ N = \frac{E \times A}{\Phi \times LLF \times Cu} \]  \hspace{1cm} (2)

\[ E = \frac{\Phi \times LLF \times Cu}{A} \]  \hspace{1cm} (3)

where

- \( \Phi \) : luminous flux (lumen),
- \( P \) : power (watt),
- \( \eta \) : luminous efficacy (lumen/watt),
- \( E \) : illumination intensity (lux),
- \( A \) : lighting space area (m²),
- \( LLF \) : Light Loss Factor (usually between 0.7 – 0.8),
- \( Cu \) : Coefficient of Utilization,

The typical luminous efficacy for LED is 80 – 100 lumens/watt. Thus, the illumination intensity can be calculated using equation (3), which is derived from equation (1) and (2).

3. Fuzzy Interference System

The fuzzy logic determination uses Mamdani type of fuzzy logic interferences system. Fuzzy logic is used to determine the suitable electrical current to supply the LED lamps. The current that flow through the dimmer will be calculated based on the input from the light detector sensors, giving the information about the illumination intensity received on the floor level. The determination neglects the room’s dimension [7][8][9].

Each of light sensor has fuzzy set that consists of dark, common, and bright. The mapping of its values is given in the membership function as shown Table 1 and the plot can be seen at Figure 2. The fuzzy set values are arranged from 0 to 400, comparing proportionally to the lux comparison from 0 – 400 lux. The higher intensity more than 400 lux will be neglected and considered as the maximum lux. According to the identical type of the light sensors, then the membership function is applied to all the input from the light sensors [10].

| LDR Fuzzy Set | Light Intensity Equivalent (lux) |
|---------------|---------------------------------|
| dark          | 0 – 200                         |
| common        | 200 – 300                       |
| bright        | 300 – 400                       |
The membership function for the output is shown in Table 2 and the plot can be seen at Figure 3. The fuzzy set consists of 3 statements, which are low, medium, and high. The output will be given as the LED’s dimmer current supply. This study used LEDs having specification 24v in voltage and voltage constant dimmer that has maximum current at 900mA.

Table 2. Membership Function of Output

| LED Fuzzy Set | Dimmer Current (mA) |
|---------------|---------------------|
| low           | 0 – 700             |
| medium        | 625 – 825           |
| high          | 800 – 900           |

The rules applied in fuzzy interference system is given in Table 3. It takes 1 zone into consideration, taking the zone 1 as the sample for the rule’s composition. The table delivered 4 sides compositions, figuring the 4 inputs by the light sensors and the 4 outputs for the LED’s dimmer current supply condition.

Table 3. The Fuzzy Rules for Lighting Control System

| Input S1a | Output L01a | Output L11a |
|-----------|-------------|-------------|
| dark      | dark        | dark        |
| common    | high        | high        |
| bright    | medium      | medium      |
| bright    | bright      | common      |
| common    | low         | low         |
| Input S01 | Output L01b | Output L11b |
| bright    | medium      | dark        |
| common    | high        | high        |
| low       | high        | medium      |
| low       | medium      | medium      |
| Input S1b | dark        | common      |
| common    | bright      | bright      |
| bright    | common      | dark        |
The inputs stated the sensor’s fuzzy set written in the edge side of the table, giving the S1a in the top, S1b in the bottom, S01 in the left, and S12 in the right side. The fuzzy sets accompanied to the sensors are written in columns or rows right next to the sensor’s name, printed in bolded words. The fuzzy set for each sensor is delivered twice to give information for both the adjacent outputs fuzzy set.

The outputs are written in the middle side of the table divided into 4 sections. The upper-left corner area gave the output for L01a, the upper-right corner area gave the output for L11a, the lower-left corner area gave the output for L01b, and the lower-left area gave the output for L11b. Each lamp’s dimmer current states are affected by the input condition that located right beside its section. The lamp’s output fuzzy sets give information about the current supplied to dimmer of certain lamp. The calculation of the current only affected by the detection output from the 2 sensors that clamp the lamp. Here from the table, the L01a is affected by the output from S1a and S01, the L11a is affected by the output from S1a and S01, the L11a is affected by the input from S1a and S12, and the L11b is affected by the input from S1b and S11b. Each composition for the output can be detected by the table colour.

The current calculation result then is used to power the LED’s dimmer, so that the LED will emit light in certain illumination level. The results of the light intensity calculation based on the current input flowing into the lamp will then be calculated and compared with the sensor detection results to be used as the feedback for the system. The light intensity calculation in this study neglected the real dimension of an airport, but it is replaced with the certain wide and length in proportional comparison values.

The illumination intensity is calculated using the suitable formula, then it is given in lux. The sensor point that get the higher level of illumination level than the calculated optimization result will give the input original value as well as the output due to the concept of eco airport and zone area setting. The eco airport concept implemented see-through wall material in certain way so that it will give the benefit of natural lighting especially in the day light, so the illumination intensity detected by the light sensor can reach higher number than the suggested value by IATA.

4. Result and Discussion

The obtained result for several input examples is presented in Table 4 below.

| Light Sensor Detection | Lamps Current Output (mA) | Final Light Intensity (Lux) |
|------------------------|----------------------------|----------------------------|
| S01 S12 S1a S1b L01a L01b L11a L11b S01 S12 S1a S1b |                             |
| 0 0 0 0 865 865 865 865 259,5 259,5 259,5 259,5 |
| 270 73 125 152 862 859 862 859 257,7 258,6 257,7 |
| 177 245 177 229 856 856 856 750 256,8 256,8 256,8 229 |
| 86 96 217 195 865 853 865 853 259,5 255,9 259,5 255,9 |
| 281 65 150 118 859 863 859 863 281 258,9 257,7 258,9 |
| 204 80 195 231 853 750 853 865 255,9 225 255,9 259,5 |
| 289 135 267 109 750 864 861 861 289 259,2 267 258,3 |
| 71 315 223 129 865 862 312 750 259,5 315 223 225 |
| 329 263 106 286 750 265 865 750 329 263 259,5 286 |
| 224 279 268 339 750 263 750 263 225 279 268 339 |
| 350 280 341 278 259 246 259 750 350 280 341 278 |
| 400 400 400 400 232 232 232 232 400 400 400 400 |

Table 4 showed the result of the illumination intensity detected by the light sensors in zone 1. The original inputs are given by the sensor’s detection results of S01, S12, S1a, and S1b. The outputs are stated in lamps current flowed through the LED’s dimmer. In the end, the artificial illumination resulted by the lamps optimization will affected the light sensors themselves.

The data results state that most of the achieved light intensity has value as in the range of the suggested lux values, which are between 200 lux and 300 lux. These conditions are achieved by
sensor’s light intensity detection output combination which values below 300. Meanwhile, some others have final light intensity result as the original input of sensor. In the final calculation of illumination intensity results, the illumination intensity in the sensor point that has greater value than the final calculation resulted by the lamp combination radiance will result the same light intensity value as the initial input. It is caused by the effect of the concept of eco airport building and the zonation arrangement. The other reason is that the higher light intensity is detected by the sensor, the less current will be transmitted to the LED’s dimmer. So, if the final calculated lux value is less than the initial lux input, the result will be neglected, and the initial lux value will be recorded as the instantaneous light intensity.

5. Conclusion

This study proposes fuzzy logic interference system method to provide the suitable electrical current amount to supply the LED lamps dimmer in the passenger waiting room of an eco-design airport. The result provides the suitable illumination level on the floor level for the room as the IATA’s requirement, which are between 200 – 300 lux, except for the points that already get illumination level more than the calculated result.

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