A new Approach for Intelligent Lighting System by Estimating Illuminance & Color Temperature

Providing Individual Illuminance & Color temperature for Workplace

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ABSTRACT

A new approach for intelligent lighting system has been proposed by estimating desired illuminance and proper color temperature to user in workplace. The approach has been developed by considering ergonomic setting for workers and energy efficiency for the environment.

The work has been expanded including more parameters and other constraint to reduce the power consumption of the environment, so the purpose of the research to provide individual illuminance with proper level of color temperature for user in workplace environment.

A proposed method based on an ordinary least square using hill climbing which based on an Adaptive Neighborhood Algorithm using Regression Coefficient (ANA/RC) to estimate the luminance.

As a conclusion for the research that is in general is no accurate intelligent lighting system can provide dedicated level to the individual illuminance and exact value of the color temperature for each user in the workplace without considering the parameters of the environment.

The rest of paper is structured as follows: the intelligent lighting control system has been discussed in details following with new approach for the system. Finally, simulation system and the performed experiment in verification has been conducted following with results are explained in details.

Keywords **–** Intelligent lighting system, Individual illuminance, Color temperature, Optimization method.

Introduction

Lighting systems have been widely applied in the daily life for firms, houses, and workplace. Nowadays, many efforts are becoming more prominent in emphasizing for green environment and energy saving. Smart lighting systems are an appealing of the new emerging technology practice [1].

Recently, using a smart technology in workplace or intelligent office lighting has been installed to increase the productivity of users, and improve the environment to be more comfortable for workers. Although the most advanced intelligent lighting system has an extraordinarily complex effectiveness for users, so the lighting control system is an important factor for the appropriate interaction of humans, technology and reciprocal information [2].

Towards ergonomic personal lighting system is become more compulsory for every workplace to provide a proper illuminance of workers or adequate level of color temperature in the office, so most of workplace environments are considering the design of lighting control system, and install a convenient ceiling lighting fixtures to provide a comfortable illuminance for users [3].

Intelligent lighting system is also known as automated lighting which use the optimization method to achieve the best solution of system in different situation, and estimate the best values of optimization elements which obtain the target of environment [4].

The problem statement of research is the inefficiency of using the energy to provide desired illuminance or color temperature for users in workplace due to traditional system especially in case providing tools to manage or control the lighting system is not ordinary available. The research intends to find the best state of lighting control system in providing favorable luminance for users in workplace environment, so the research is going to answer the next questions: (1) How to provide individual illuminance and desired color temperature for users in workplace, and (2) what is the optimum objective function to reduce the power consumption for the environment in case of previous question.

However, the research is going to improve lighting control system by providing proper illuminance, and comfortable color temperature for office in workplace by developing a smart system for intelligent lighting control to the workplace, and also providing the individual illuminance, and the adequate of color temperature by using a new approach in achieving the target of users.

A lot of related papers has found in the literature of intelligent and optimization area. The significance of work is becoming in using the adequate processing of lighting information in the workplace environments.

Lighting control system in workplace is based on ergonomic principles that have a positive influence on the motivation and performance, personal well health being, and the intellectual productivity of users. The lighting system does not only support the visual perception of workers, but also it has an impact to emotional and psychic biological of human [5]. Many related works have been done to improve the intelligent lighting systems.

Whatever, some of related works were demonstrated to perform well in Miki Laboratories for Doshisha University.

Automation & Configuration

Lighting control systems contain three components as indicated in Figure 1 linked by network, which is used to transmit signals to lights: Sensing Device for information; Network circuit to supply lighting; and Power Meter and Controller to change the output of lighting system [1]. However, illuminance sensors are connected in the network. All of them are connected in dimming controller to manage the network. Proper signal dimming has been set to all lights by controller and power meter via the network.

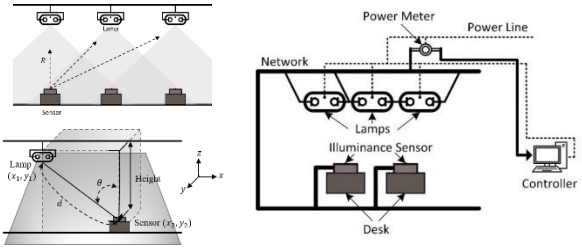

Fig. 1: Configuration of lighting control system.

LED Lighting fixture is created to use for providing luminance as required by user. Influence coefficient (R) is a basic factor which refer to the coupling stiffness between light and surface of office. This factor has affected to the level of luminance intensity which has been received by illuminance sensor in the office. It can be calculated depending on the method of calculation: theoretical (Eq.1) or empirical [7], as indicated below:

$$R = \cos\theta / d^2 \quad (1) \qquad R = I/L \quad (2)$$

Illuminance (I) is another parameter and feature of light [1]. It refers to amount of illuminance to surface of office. It is measured by Lux (lx), and can be calculated by (Eq.3):

$$I_j = \sum_{i=1}^{n} R_{ij} L_i \quad (3)$$

Color temperature or correlated color temperature (CCT) is a gauge of color light emitted from lamp appears [8]. It's measured in Kelvin (K) unit, and can be calculated by (Eq.4,5), and as indicated in Figure 2:

$$CCT = \beta_0 + \beta_1 . x \quad (4) \qquad x_{(cool)} = I_{(cool)} / I_{(cool+wam)} \quad (5)$$

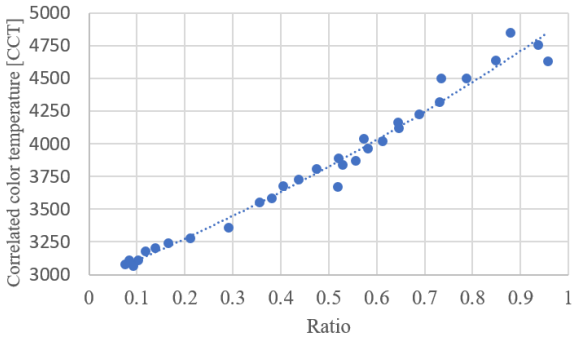

Fig 2: Color temperature for cool color light source.

Power consumption and saving energy has become one of the most important issues for smart systems [4]. In a simple way, total amount of luminance for lights are the main element for energy.

Proposal Method for Lighting Control System

Intelligent lighting system is a part of developed model for automated lighting control system, so the system could set a small amount of power consumption which required the lamps to satisfy the individual illuminance for all users [9].

The objective function (Eq.6) which has been used for the system based on regression coefficient to minimize power consumption.

$$\mathcal{F}_i = \min(p) + \min(\omega_{illu} . \sum_{j=1}^{n} g_{ij}) + \min(\omega_{cct} . \sum_{j=1}^{n} h_{ij}) \quad (6)$$

In general, the basic factor elements of objective function that have been used for intelligent lighting system are: illuminance constraint; color temperature constraint; and power consumption [10], as indicated in (Eq.7, and 8)"

$$g_{ij} = R_{ij} \times (Ic_j - It_j)^2 \quad (7)$$

$$h_{ij} = R_{ij} \times (Cc_j - Ct_j)^2 \quad (8)$$

However, ordinary least square has been used to estimate the optimal solution based on derivation of the values and using Hill Climbing method to change the values of luminance. Neighborhood had been generated based on the method of an Adaptive Neighborhood Algorithm using Regression Coefficient (ANA/RC). The distribution of luminance can be adjusted in the following approach: Initialize all luminance with the minimum values. Then calculate the illuminance and color temperature for each sensor, as well the constraint for each sensor. Check the convergence between current and target values, and change the amount of all luminance, and procced all lights. Minimize the objective function for each light to be optimized, and check the case of convergence for values. In case, values are not realized return back to previous state of luminance, and change again the values by applying neighborhood approach, and procced again till to realize the convergence, or the amount level of luminance can be used for the lighting system.

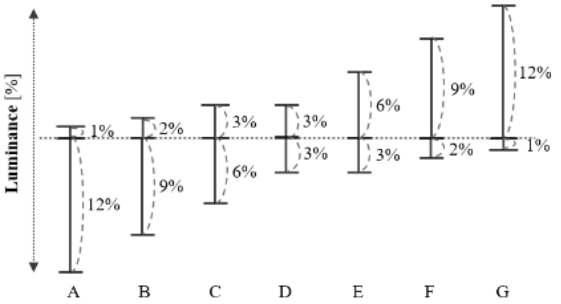

Fig 3: Neighborhood treatment.

The values of neighborhood have to be fixed for each observation of luminance, and based on environment. Neighborhood is a valuable to use in system as Figure 3. Table 1 shows the design.

Table 1: Neighborhood Design.

		Illuminance Constraint		
		High	Medium	Low
Influence Coefficient	High	E	F	G
	Medium	D	E	F
	Low	C	B	A

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Simulation & Verification

More details in the next section which some experiments are conducted for the research, and analyzing the data, as well verifying the data in real office of workplace. As indicated in Fig 4, 5, 6, and 7, experiments are conducted to study the system behavior to realize the target of workers.

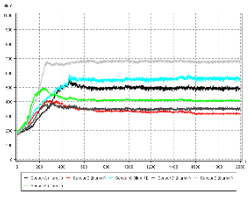

Fig 4: Illuminance history.

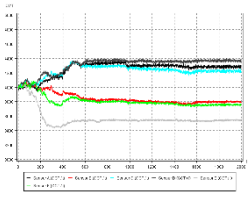

Fig 5: Color temperature history.

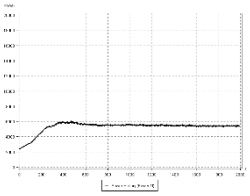

Fig 6: Power consumption history.

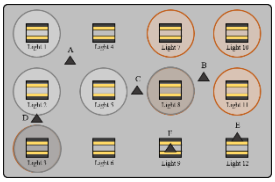

Fig 7: Experiment, Luminance result.

Conclusion

The new approach for intelligent lighting system could be able to satisfy the desire of user in different cases of required illuminance. The approach also is able to provide proper color temperature for users, as well to converge the target in a short time.

Therefore, the approach could minimize the power consumption of environment by using the minimum level of luminance to obtain the target, and accomplish the goal of the office environment, and this will help the global warming.

Bibliography

All references are available in the research.