Exploration on Illuminance Control of Daylight Perceptive Lighting by Fuzzy Logic

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***Abstract*—Basic concept of daylight perceptive lighting is that intensity of lamps are adjusted opposite to the trend of sun light intensity, so that constant illuminance on work surface is kept. The classic and compact arrangement of daylight perceptive lighting system were discussed, the compact was recommended from the view point of facilitating construction, although illuminance control by the classic is relative simpler than the compact. Considering visual character of human eyes, accurate illuminance control is not necessary; the key is how to use the character to realize a general policy. Through analysis and test, fuzzy logic is a good choice to illuminance control by the compact scheme. Based on fuzzy logic, elementary explore on illuminance equivalence fuzzifying control variable, was done and the possible membership function was given.**

Keywords-daylight perceptive lighting; illluminance control; fuzzy logic

I. INTRODUCTION

As we all know, solar energy is a clean and cheap resource, wide use of solar energy can obviously reduce consumption of traditional energy source, such as coal and petroleum etc. Considering 18% energy consumed by lighting every year, solar energy applied in lighting scenarios contributes very much to energy conservation. That benefits carbon emission reduction, which is more and more important to the living and sustainable development of human being. According to technology, daylight lighting can be classified into energy storage type, light guide type and photosensitive type. Energy storage type convert solar energy into electrical energy then store electrical energy in rechargeable battery during the hours of daytime. Lamps are powered through battery not mains in the night by means of storage type. Light guide type use fibre-optical or light pipe to introduce sunlight in room for lighting. Photosensitive type measure intensity of light to turn on or off lamps based on the measurement.

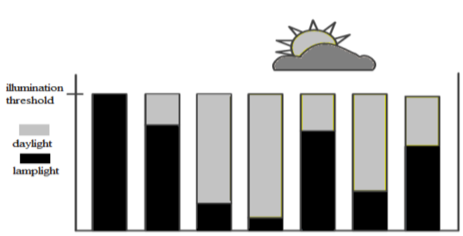

FIGURE I. BASIC PRINCIPLE OF DAYLIGHT PERCEPTIVE LIGHTING.

Basic concept of daylight perceptive lighting is that intensity of lamps are adjusted opposite to the trend of sun light intensity, so that constant illuminance on work surface is kept [1,2], as shown in figure 1. Applications of daylight perceptive lighting are very comprehensive, anywhere sunlight can reach. The key technology is how to keep constant illuminance on work surface, under any daylight circumstance where lamps are installed. In recent years, the control technology has been well developed and has become one of the most successful tools in the industry. Considering daylight is a dynamic source of lighting, .i.e. the illuminance from the sky is variable, and the variations in daylight can be quite large depending on season, location or latitude, and cloudiness, therefore traditional control systems, based on mathematical models, and often implemented as "proportional-integral-derivative (PID)" controller, have their limits as daylight perception lighting controller[3]. Taking into account the random pattern of potentially available daylight and rapid change of its characteristics, fuzzy control has proved to be a more convenient solution. Much research on lighting control has been done based on fuzzy logic [4-6].

II. PROPOSED DAYLIGHT PERCEPTIVE LIGHTING SYSTEM

Daylight perceptive lighting system consists of light source, such as LED, and smart driver used to regulate intensity of light source according to daylight condition, composed of sensing unit, processing unit and drive unit. Basic structure of the system is shown in Figure 2. From the viewpoint of being easy to apply, smart driver should be compact, all the three units mentioned above should be integrated in one little box. This put forward a serious challenge to realization of daylight perceptive lighting.

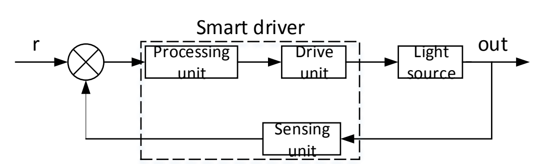

FIGURE II. BASIC STRUCTURE OF ILLUMINATION CONTROL.

Superficially, with the change of sunlight, keeping work surface illuminance constant is relatively simple when illuminance sensor is placed on desktop, according to the classic control technology. However, that does not completely

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fit for lighting scenarios, considering relative long distance, typical 2-2.5m from ceiling to work surface. As shown in Figure 3, if sensor unit is placed on desktop, long feedback line between sensor unit and lamp is required to send data to processing unit. Obviously, this cause big troubles to the construction of the system because of wiring.

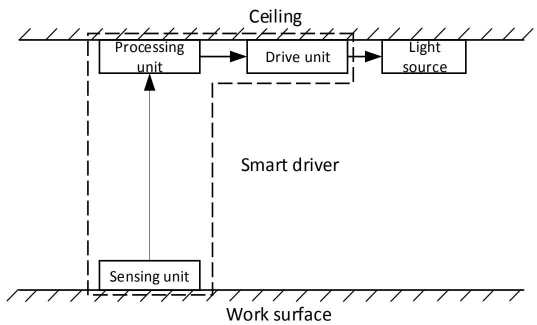

FIGURE III. CLASSIC ARRANGEMENT OF THE SYSTEM.

In order to avoid the trouble caused by wiring, smart driver should be more compact compared with classic arrangement, sensing unit, processing unit and drive unit should be placed together in a small box, shown in Figure 4. Because sensing unit is not placed on work surface, the measurements cannot be directly used as control variable to keep constant illuminance on work surface. So the measurements, illumination around lamp measured by sensor unit must be equivalent to illuminance on work surface through mapping relation L1=f(L2). Where L2 illuminance on work surface, L1 illuminance around lamp.

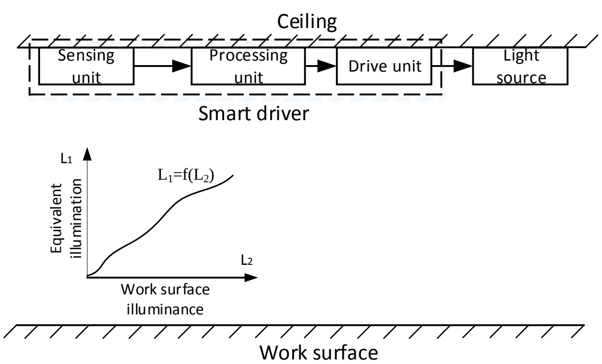

FIGURE IV. COMPACT ARRANGEMENT OF THE SYSTEM.

III. Discussion on Equivalent of Illuminance

A. Classic Equivalence Discussion

As mentioned above, compared with the classic the compact favour construction and improve usefulness of daylight perceptive lighting system. In order to control illuminance on work surface, equivalent of illumination is imperative so that L1 is transformed to L2. In fact, there are too many factors influence the transformation, such as indoor reflection capacity, windows orientation and dimension, lamps location and sensor optical structure etc. Therefore it is impossible to build the transformation fitting to all circumstance through classical mathematic, even in the same room because of the sunlight difference every day.

Given a room, illuminance corresponding to two different locations, desktop and floor respectively, were measured and 4 typical results were shown in figure 5 (A)-(D). All the measurements were done from Am 6 to Pm 6 in summer every 15 minutes. From figure 5, it could be concluded that there is no certain expression to illustrate the mapping between the two illuminance, although they have the same trend. So it is hardly possible to build the illuminance equivalence through classical mathematic.

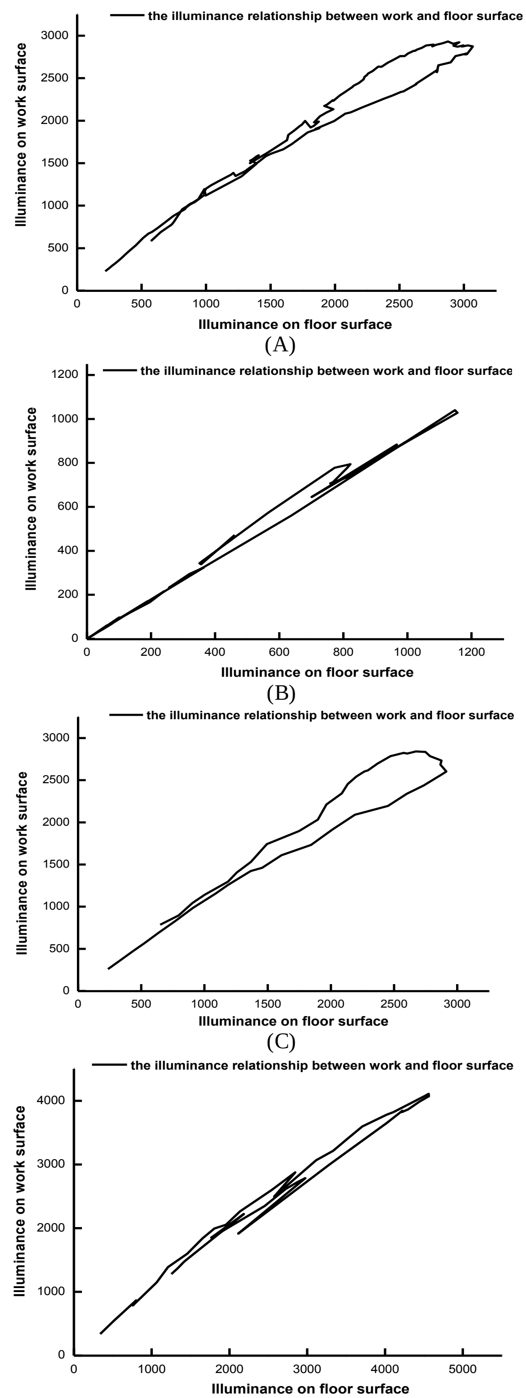

FIGURE V. MAPPING OF ILLUMINATION ON TWO DIFFERENT LOCATIONS.

B. *Fuzzy Equivalence Explore*

Given background illuminance, its small fluctuation might not be sensed by human eyes, and the fluctuation increase with the increase of background illuminance, according to the visual characteristics of human eyes. This is called fuzzy character of human eyes illuminance recognition in the paper. Due to the character, accurate control on illumination for lighting might not be necessary. Therefore limited illumination fluctuation on work surface is tolerated when the fluctuation cannot be perceived by human eyes. As shown in figure 6, the equivalent result should be stepped appearance, Li+1-Li (i=1,2,...n-1), range of fluctuation increase with the increase of illuminance on work surface.

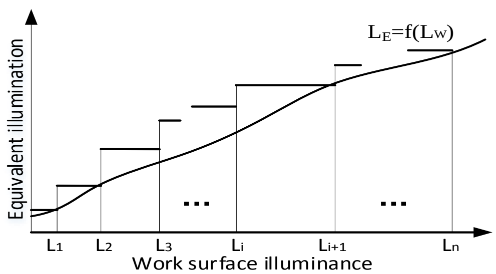

FIGURE VI. ILLUSTRATION OF ILLUMINATION EQUIVALENCE.

The difficulty is how to determine range of fluctuation based on human eyes visual character, daylight intensity and room condition, etc. As mentioned above, fuzzy logic is a good choice to resolve the problem. Membership function is basic ideology of fuzzy logic, decision of illuminance equivalence policy begin with building membership function. Membership function used to describe how illuminance measured by sensor unit close to reference illuminance on work surface might be illustrated as Figure 7 and equation 1.

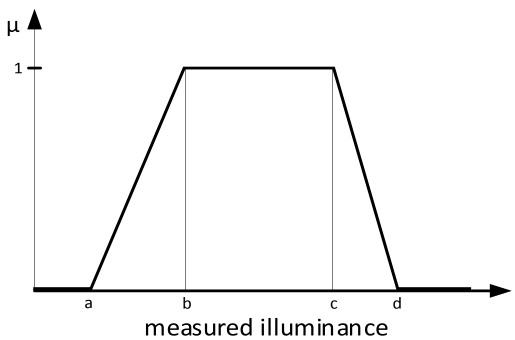

FIGURE VII. EXAMPLE OF MEMBERSHIP FUNCTION.

$$\mu(x)=\begin{cases}0, & x<a\\ \dfrac{x-a}{b-a}, & a\le x<b\\ 1, & b\le x<c\\ \dfrac{d-x}{d-c}, & c\le x<d\\ 0, & x\ge d\end{cases} \qquad (1)$$

As shown in figure 7, reference illuminance, used to keep constant illuminance on work surface, located in [a,b]. Obviously, with the increase of illuminance-measured by sensing unit a part of smart driver, from 0 to the reference, probability they equal to each other increase from 0 to 1. With the decrease of measured illuminance from the reference to 0, probability they equal to each other decrease from 1to 0.

IV. CONCLUSION

The classic and compact arrangement of daylight perceptive lighting system were discussed, the compact was recommended from the view point of facilitating construction, although illuminance control by the classic is relative simpler than the compact. Through analysis and test, fuzzy logic is a good choice to illuminance control by the compact scheme. Through fuzzy logic, elementary explore on illuminance equivalence fuzzifying control variable, was done and the possible membership function was given.

ACKNOWLEDGMENT

1. 2012 key supported project for undergraduate education by Education Dept. of Liaoning province “Light source and lighting”, (NO. [2012]108)

2. 2014 Education reform project for undergraduate by Education Dept. of Liaoning province “The study on education model of design and services major”, UPRP20140139

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