

An Energy-Saving Office Lighting Control System Linked to Employee's Entry/Exist

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Abstract— For conserving energy in the lighting of office buildings, we developed an lighting energy-saving control system by coordinating the access control system and the lighting control system. Our system controls the light dimming rate depending on the presence or absence of employee in a floor. By evaluating this system in an actual office building, we confirmed that it could reduce about 25% power consumption of lighting.

Keywords—office lighting control; energy-saving; BEMS;

I. INTRODUCTION

In Japan, regulations on energy consumption are enhanced. Nevertheless, energy consumption in office buildings is increasing tendency since the base year of the Kyoto Protocol [1]. Therefore, effective energy-saving methods are required.

Lighting and air-conditionings account for the majority of power consumption in the office [2]. Therefore, energy conservation methods of these equipments are important. To achieve energy-saving of the lighting without compromising comfort in the office, it is effective approach to turn off the lighting in the unnecessary area, and to keep appropriately illuminance. Therefore, in past studies, controls to automatically turn off the absence area using motion sensors, and controls to keep appropriately illuminance by illumination sensors has been performed [3],[4]. In recent years, studies to increase the energy-saving effect by controlling the brightness so as to provide the desired brightness each person has been performed [5]~[9]. Many of these studies utilize the lighting control system of individually controllable luminous intensity each equipment over the network.

In this paper, we propose an energy-saving lighting control system. Our system also provides the desired brightness to each person by cooperation of the lighting system and the access control system. Our system detects the employee's presence position in the office floor by using information obtained from the access control system, and provides the necessary and sufficient brightness for employees in the office by controlling dimming rates of lighting. In this study, we built a lighting control prototype system in an actual office building, applied the proposed lighting control method to the prototype system, and evaluated the energy-saving effect. In this evaluation result, we confirmed the energy-saving effect is

about 25% compared with a conventional method that is the wall light switch operation.

II. BACKGROUND

A. Features of Office Lighting

In office buildings, lighting power consumption accounts for 20 to 35% of the total, and its usage pattern remains almost constant throughout the year [2]. Therefore, it is possible to obtain the large energy-saving effect throughout the year by applying energy-saving methods for office lighting.

On the other hand, in office buildings, employees are constantly entering and leaving floors, so it is generally wasteful to control lighting in a fixed setting. So, it is an effective approach for reducing the waste to control lighting using the entering and leaving information such as the number of employee in a floor, and the presence or absence of a person at each desk.

Meanwhile, with the increase in company awareness about security, more access control systems are installed into office buildings. While the primary function of the access control system is to control the entry and exit of individuals, it can also be utilized as a means to grasp the entry or exit information such as the number of people on a floor, and the presence or absence of individuals in their rooms. In addition, if we can grasp seat position information of each individual, it is possible to roughly grasp whether there are customer presence in any position in the floor.

B. Power Consumption of Lighting

The power consumption of lighting (P_t) is expressed by the following formula (1) [10].

$$P_t = P * H * E * A / (F * U * M) \quad (1)$$

where P : Power consumption of equipment [W/unit], H : Used hours, E : Illuminance, A : Area, F : Luminous flux [lm/unit], U : Utilization factor, M : Maintenance rate.

As shown by formula (1), the power consumption can be reduced by controlling the lighting so that the required illuminance is ensured (minimization of E) only in the

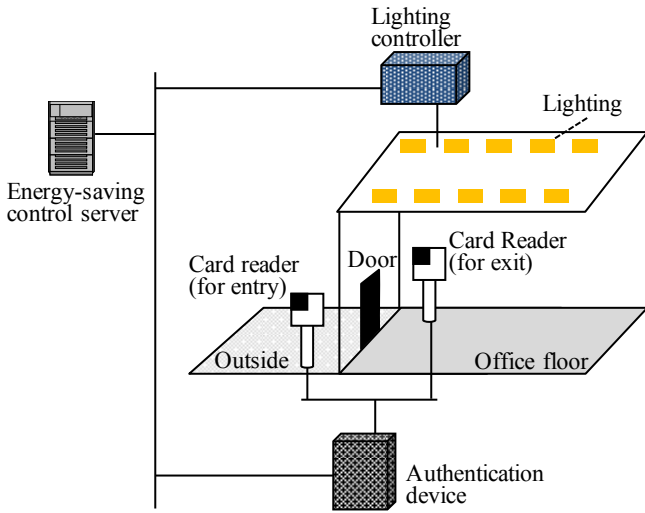


Fig.1 Structure of a proposed system.

required area (minimization of A) and for the required time (minimization of H).

Therefore, it is possible to achieve to save energy by controlling appropriately illuminance for the presence area, and turning off lighting for the absence area, so as to follow movement of the employee's entry and exit.

III. PROPOSED METHOD

This paper describes the “energy-saving office lighting control system linked to employee's entry/exit”, which uses entry and exit information obtained from the access control system and the seat position information of each individual. And, the system controls automatically lighting so that each lighting equipment are turned on only in the required area and for the required time ensuring a certain amount of illuminance only in the around of desks people are sitting.

A. Structure of a Proposed System

Fig.1 illustrates the structure of a proposed system. This system consists of the access control system (ACS), the lighting control system, and the energy-saving control server. Both systems and the server are linked over the network.

The ACS consist of an authentication device and card readers. The ACS is equipped with two types of card readers for entry and exit at each door on a floor. When employee is out of the office floor, he passes IC Card over the card reader for exit. As a result, the door opens. In a contrasting situation, when employee go into the office floor, he passes IC Card over the card reader for enter. By these actions of employees, the system is able to identify employees entering and leaving a room.

The lighting control system consist of a lighting controller and some lighting fixtures. These devices are linked by the wired network and the wireless network, and the lighting controller has BACnet Interface to receive other system's control request [11]. The lighting control system is able to control dimming rate for each lighting fixture. Dimming rate of lighting fixtures can be controlled in 1% increments.

The energy-saving control server has installed the energy-saving control program, linked to the ACS, and performs energy-saving control of lighting.

B. Lighting Control Algorithm

As shown in Figure 2, the lighting control algorithm controls lighting fixtures by the 1st phase and the 2nd phase. we describe these phases in detail below.

(1) 1st phase

The energy-saving control server detects employee within a floor, utilizing the information obtained from the ACS. And then, it specifies the zone that should be illuminated, using seat position information of employee that managed in advance. It then considers the location information between the individuals and the lighting fixtures in the room so that the lighting fixtures are turned on and the dimming rates are controlled only around the individuals present. As the distance

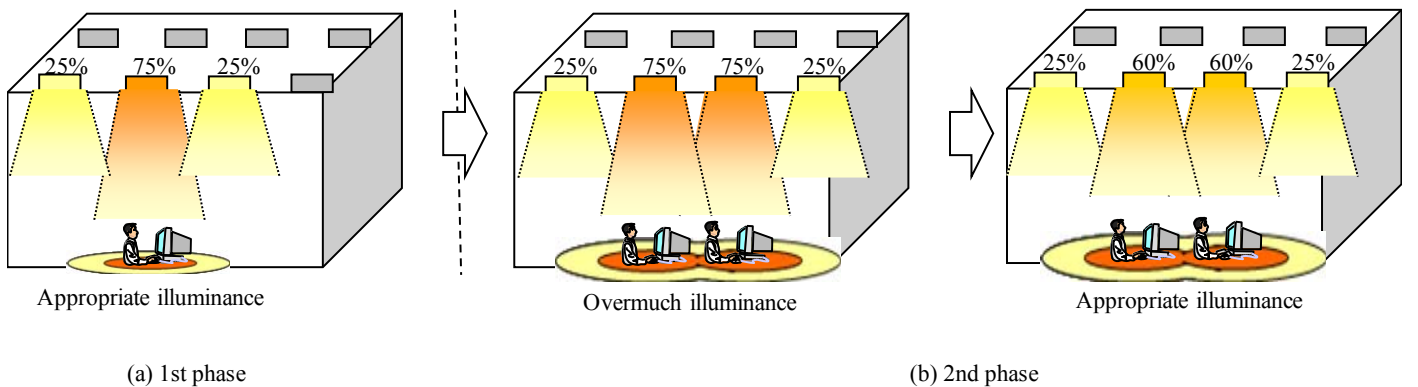


Fig.2 Overview of Lighting control method.

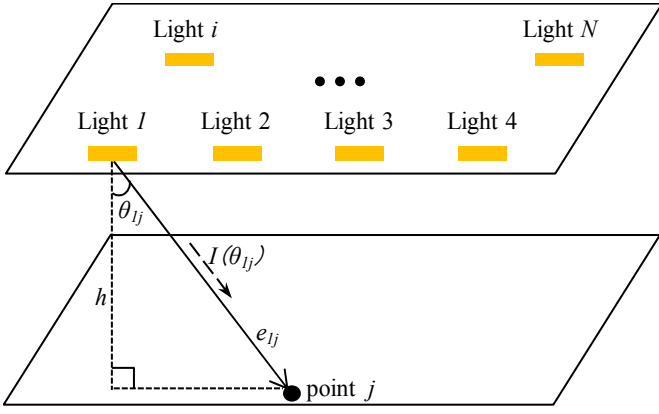


Fig.3. The point-by-point method

from the zone, brightness will decrease. For example, as shown in Fig. 2 (a), the dimming rate of a lighting fixture within one meter from each individual are set to 75%, and the lighting fixtures within two meters are set to 25%. Through this dimming control, areas near the individuals are kept bright, and a sharp decrease in brightness is prevented, mitigating the detection of any change in brightness. In addition, the lighting fixtures for individuals who have gone home or who are away from their desk for a meeting are automatically turned off.

Here, the value 75% and 25% are an example. In fact, these values are adjusted so as to satisfy the target illuminance of the person. Therefore, the proposed system calculates the illuminance for a presence person in the floor using the point-by-point method. As shown in Figure 3, the system calculates illuminance e_{ij} which lighting equipment i give the point j by Equation (2). Further, since point j is influenced from the several lighting fixtures, the illuminance E_j which is brightness of point j can be calculated by Equation (3).

$$e_{ij} = C_{ij} * r_i \quad (2)$$

$$C_{ij} = I(\theta_{ij}) * \cos^3(\theta_{ij}) * M / h^2$$

where r_i : Dimming rate of lighting fixture i ,

$I(\theta_{ij})$: Luminosity, M : Maintenance rate.

$$E_j = \sum_{i=1}^N C_{ij} * r_i \quad (3)$$

As Equation (2) shows, the illuminance of the person is changed by changing the dimming rate. Therefore, while changing gradually dimming rate, the proposed system controls dimming rate to satisfy the target illuminance.

(2) 2nd phase

When the 1st phase was executed, it assumed that there is only one sitting employee in a floor. Therefore, the illuminance of the sitting employee's area is optimized under the situation in which the influence of the lightings for neighbors is not received. But, as shown in left of Fig.2 (b), when its influence is received, it becomes the overmuch

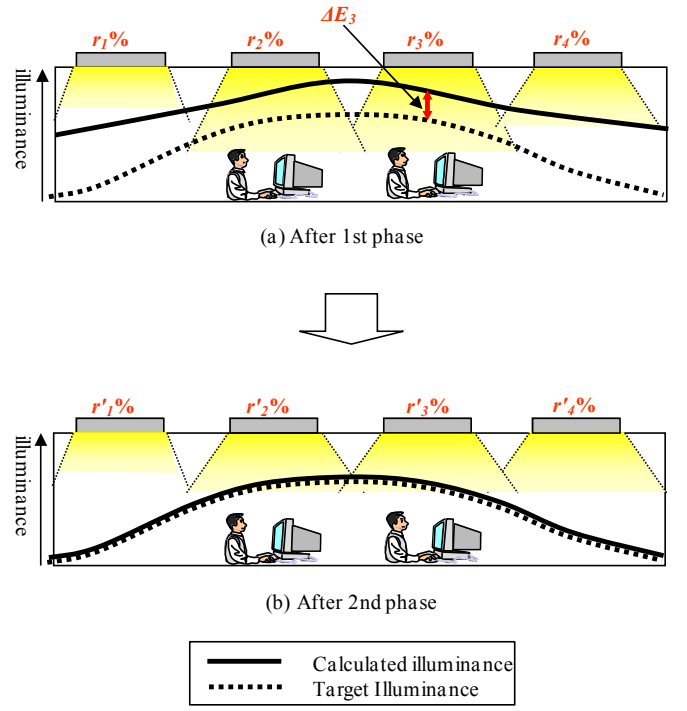


Fig.4. Illuminance correction control method

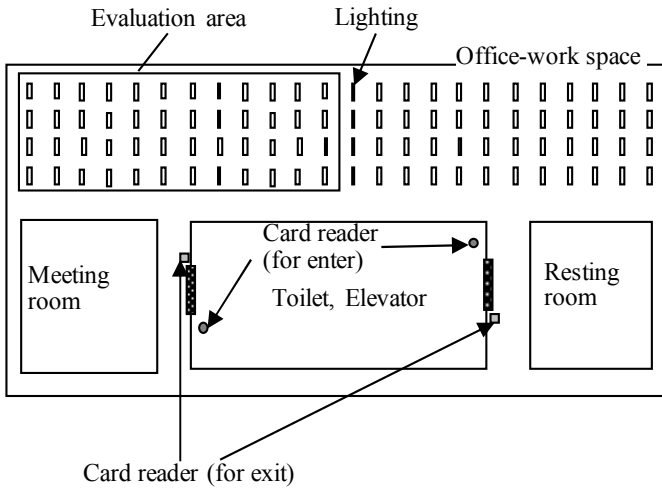
illuminance. To solve this problem, the proposed method corrects the dimming rates to negate the influence of the illuminance that received from the lighting fixtures for neighbors according to the following procedure. As a result, the system control the state shown in right of Fig.2 (b).

Fig.4 shows an image of illuminance correction control. In situations of Fig.4 (a) where the control of the 1st phase was finished, the dimming rate was controlled $r_1\%$, $r_2\%$, $r_3\%$, $r_4\%$, \dots , $r_N\%$. Here, calculated illuminance with the point-by-point method is as shown by the solid line. And the system corrects the dimming rate to be the target illuminance shown by the dotted line. The gap is defined ΔE . Here, when we defined dimming rates after correction as $r'_1\%$, $r'_2\%$, $r'_3\%$, $r'_4\%$, \dots , $r'_N\%$, this relationship is shown in Equation (4).

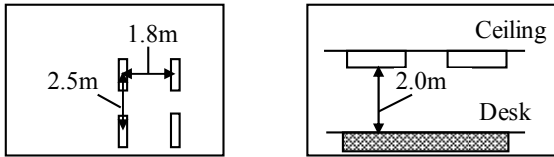
$$\begin{cases} \Delta E_1 = \sum_{i=1}^n C_{i1} * r_i - \sum_{i=1}^n C_{i1} * r'_i \\ \Delta E_2 = \sum_{i=1}^n C_{i2} * r_i - \sum_{i=1}^n C_{i2} * r'_i \\ \dots \\ \Delta E_n = \sum_{i=1}^n C_{in} * r_i - \sum_{i=1}^n C_{in} * r'_i \end{cases} \quad (4)$$

C. Lighting Equipment Configuration Management

The proposed system performs lighting control in the neighbor of presence person by using the location information on the lighting fixtures and seats; the equipment configuration management function manages this location data. Normally, the location data for installed lighting fixtures and employee



(a) Overview of evaluation area



(b) Arrangement of lights

Fig.5. Evaluation area

seating is set separately, and thus the location information between the seats and lighting fixtures needs to be predetermined in order to obtain the relationship. However, the seating position may change during the system operation by such personnel changes, and a running cost is required to maintain the definition data.

To resolve this issue, by using lighting equipment configuration management function, between lighting equipment and person's location information is retrieved by using separately defined lighting equipment's logical position data in the lighting system and the person's logical seat-location data in the seat management system. The lighting equipment configuration management function identifies the lights in the neighbor of a given seat by mapping the lighting fixtures onto the logical coordinate space for the seating, taking into consideration the difference in the logical coordinates, e.g., the difference in the position and spacing of the lighting fixtures and seats.

IV. EVALUATION OF DEVELOPED SYSTEM

A. Conditions of the evaluation area

In order to evaluate an effectiveness of the developed technology, we built a prototype system in an office building and have evaluated. Fig.5 shows the status of the evaluation

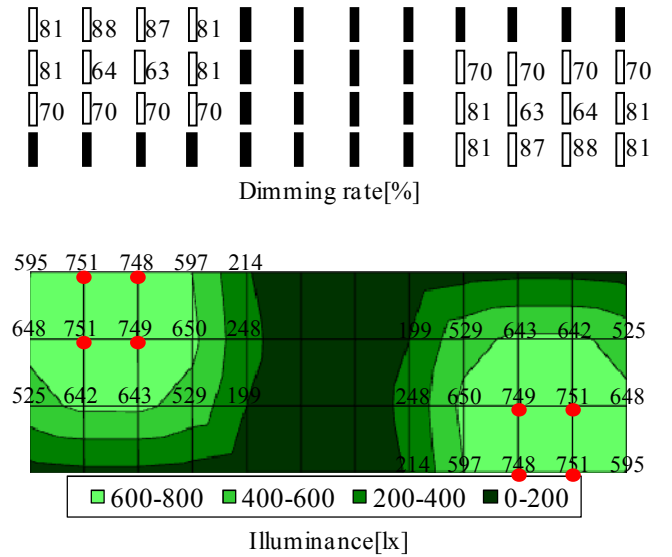


Fig.6. Control Result of proposed method

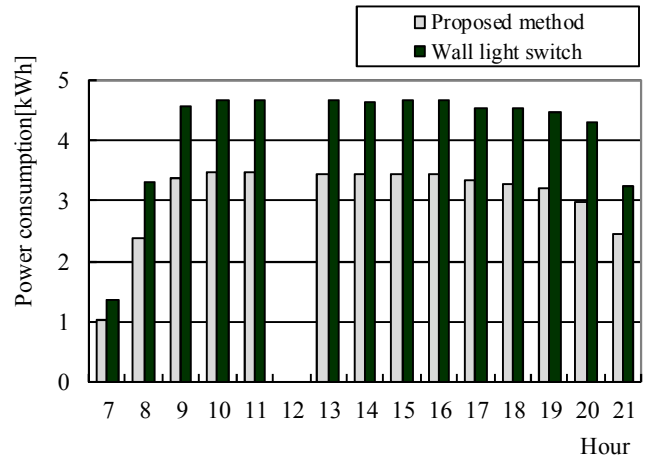


Fig.7. Result of energy-saving effect.

area. The experimental evaluation was conducted in one section on a floor (about 300 square meters, 48 lighting fixtures) where about 40 employees work at desks. In addition to the desks assigned to the employees, there is a meeting room, a resting room, toilet and elevator on the same floor. In the evaluation area, card readers for enter and leave are installed at the entrance of the room. The proposed method detects the presence of the office-work space by using information from the card readers. Further, the seat position of persons will be identified using the seat position information.

B. Control result of proposed method

Fig.6 shows dimming rates that the proposed method determined and the calculated illuminance on the desk surface by the point-by-point method. Here, the target illuminance of the presence zone is 750lx, and the presence zone are shown by red point in Fig.6. In addition, the illuminance level is expressed by gradation. In the case of Fig.6, the calculated

illuminance is 748lx ~ 751lx, we were confirmed that there was little error about the target illumination 750lx. Further, we were confirmed that the illuminance can be controlled so as to be lower with increasing distance from the presence person.

C. Result of energy-saving effect

Fig.7 illustrates a result of energy-saving effect. As a result of the experimental evaluation, which was evaluated for one month, it was confirmed that the power consumption for lighting was reduced by about 25% as compared to the wall light switch operation. The wall light switch is an operation that illuminates the block (one block is eight lightings) near presence person with 100% dimming rate. In order to control to pinpoint the lights around presence persons, the proposed method has made energy-saving effect higher than the wall lights switch operation. The power consumption for lighting accounts for about 30% of the total consumption on the floor including air conditioning and electrical outlets, and thus the developed technology reduces the power consumption of the entire office by about 7.5%. The developed technology determines the presence of an employee using only the access control information. Therefore, while employees are in the meeting room or resting room, electric power is wasted. Despite these conditions, it was confirmed that a sufficient energy-saving effect can be achieved.

The energy-saving effect measured in this evaluation represents only one example in a specific experimental environment. The energy-saving effect of this technology is expected to vary depending on the size of the office building, arrangement and model of lighting fixtures, entering and leaving frequency of employees (occupancy rate), etc. Therefore, in order to verify the effectiveness of this technology, it is essential to evaluate and demonstrate its performance in various actual environments.

V. CONCLUSION

We proposed a dimming control system of office lighting based on employee's entering/leaving information. In this system, the proposed lighting control algorithm determines the dimming rate that every presence employee's illuminance will satisfy enough required. Then, we built a lighting control system in a part of an office building that corresponds to about 300 square meters, and applied the proposed method to the system, and confirmed the energy-saving effect of 25 %.

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