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Lighting control based on worker's location information and illuminance preferences in a Smart Workplace

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1. Introduction

Smart workplace (SWP) is a concept implemented in an office that aims to simultaneously conserve energy and improve environmental amenities by controlling the building environment with information communication technology (ICT). SWP controls the workers' ambient surrounding according to personal preferences. That is, SWP uses ICT to restrict lighting and air-conditioning (AC) control to minimize energy consumption while simultaneously improving personal occupant comfort. These controls are automatically performed without a conscious effort on the part of the worker. Because the ambient controls directly affect the worker in an SWP, indirect lighting such as a task light is unnecessary. We developed the control system based on the concept of SWP, to examine the utility of SWP. This paper describes the control system, the results of energy conservation, and the degree of satisfaction, regarding lighting control, reported by the worker.

2. System model

We constructed an SWP in the Shimizu Corporation Institute of Technology in October 2011, and commenced the experiments that exemplify the effects [1]. Twenty-eight workers typically work in this office, which comprises 32 desks enclosed with panels (H = 1200) and 6 shared work tables. We installed AC outlets that open and close according to each individual's setting. Automatic monitoring of the AC is conducted within the

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legroom of each desk using wireless sensor nodes.

2.1 Detection of location infromation

Figure 1 shows the configuration of a system that acquires location information with semi-active radio-frequency identification (RFID). The coil antenna that sends the low-frequency (LF) wave (125 kHz) with location ID at regular intervals is installed between the floor and the carpet. The range within the LF wave can be received is termed as the detective area of a worker's location. The worker's tag sends an RFID wave (950 MHz) to an RFID reader during ingress to the area. The server that receives the information from the RFID reader manages location information for all workers, and controls equipment appropriately in cooperation with the equipment management system. The power conditioning of the LF transmitter is set to the size of the detection area, and the resolution capability of the LF antenna array is matched to the

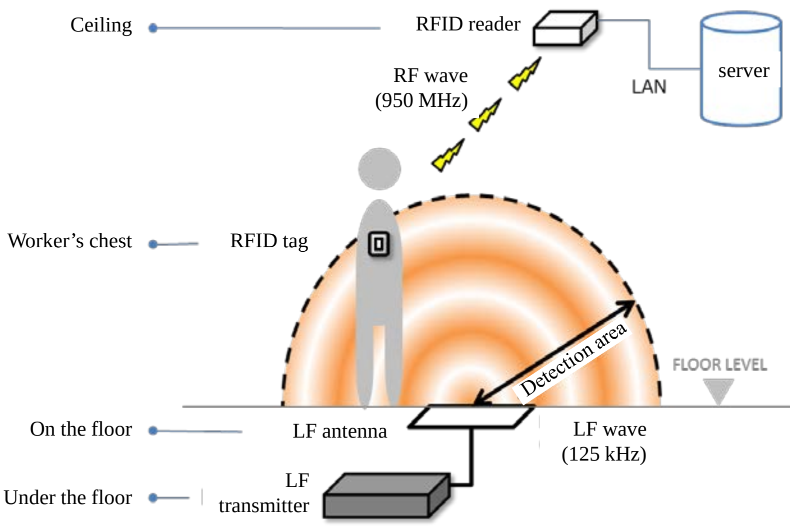

Figure 1 System of location information

office layout and the intended purpose. The antennas were closely arranged to achieve exact equipment control in personal workspaces (1.6 m × 1.6 m in size) and to detect the workers sitting on opposite sides of the desk on shared work tables.

2.2 Lighting control system

Seventy LED lightings capable of adjusting light intensity were installed in the ceiling grid of the SWP. Figure 2 shows the configuration diagram of the lighting control system. The location information server manages each person's location, the equipment control server calculates the best light intensity to illuminate each LED based on the location information and worker's preferences, and the lighting controller adjusts the light intensity of each LED. This system uses the database resulted from the simulation to calculate light intensity, whereas the standard system uses the illuminance sensor. We simulated the illumination distribution from LED lighting for the entire SWP utilizing the interactive ray tracing method and

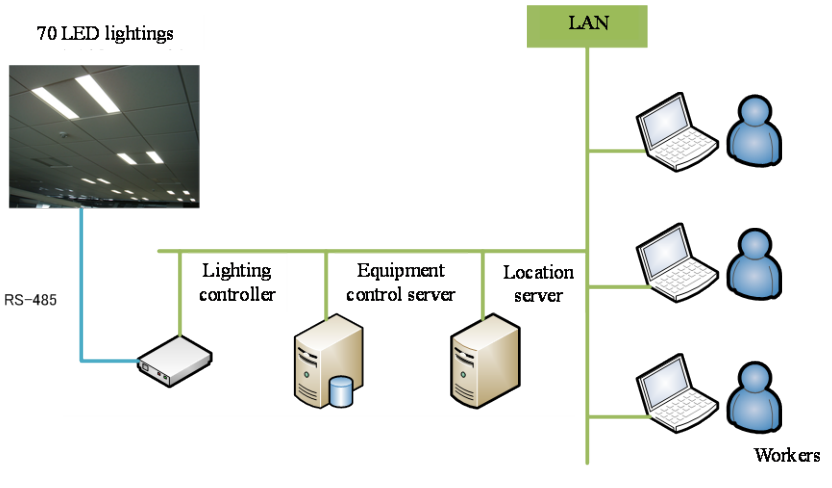

Figure 2 Lighting control system

Monte Carlo approach, and calculated the illuminance on each desk given by LEDs. Coefficients of determination (R^2) are 0.9932, and it can be said that the accuracy of the simulation is extremely sensitive. A database comprising desired light intensity on each desk ranging from 300 lux to 700 lux was compiled based on the illuminance data of the simulation. The controller illuminates 1–4 lights that are located around each desk based on database information at the request of the equipment server.

2.3 Energy conservation of the lighting

We compared lighting energy in the SWP and an office that had standard lighting and the same floor space to evaluate the energy-saving effect of the SWP. SWP had LED lightings that adjusted to the illuminance preferences of each individual worker, whereas the standard office (STD) had normal fluorescent tubes that switched ON/OFF in each zone. Figure 3 shows the number of people that were in the SWP or STD for one day and the amount of power consumed by the lighting during that time. Though fewer workers were in the SWP group after 15:00 hrs, the number of people in the SWP and STD from

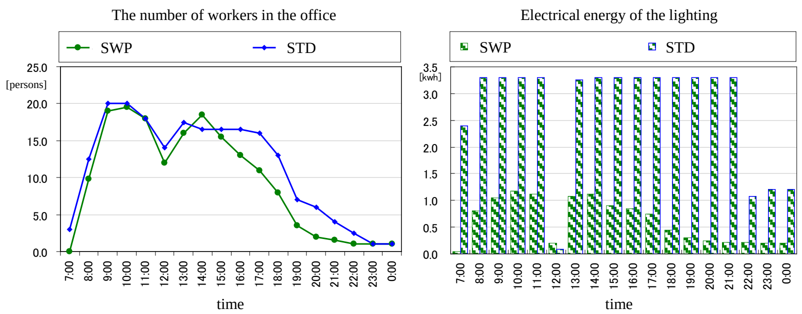

Figure 3 Number of people (left) and amount of power consumed by the lighting (right)

morning until night was nearly identical. Because both the SWP and STD had a control system that turned off lighting automatically at lunchtime, both workplaces showed a decrease in the amount of lighting electric energy at that time. In the SWP, the lighting electric energy increased or decreased in direct proportion to the number of workers present. Conversely, in the STD, energy consumption remained constant at the maximum value of all lightings exclusive of early morning or late-evening because an ON/OFF switch was located in each zone control. The lighting electric energy in the SWP decreased by approximately 69% compared with that in the STD during normal working hours (9:00–18:00). In addition, the energy consumption in the SWP decreased by approximately 78% compared with that in the STD over the timespan of one day; therefore, the lighting control had a particularly tremendous effect on energy conservation early in the morning and during overtime hours.

2.4 Worker's satisfaction in SWP

Figure 4 shows the result of the questionnaire used to assess worker satisfaction with regard to SWP implementation. With the questionnaire, we surveyed the workers and assessed their level of satisfaction with the light environment at their personal desks and in the entire SWP. The workers had to rate their level of satisfaction on a five degree range, from satisfaction (i.e., 5) to dissatisfaction (i.e., 1). The questionnaire was administered in April 2010 (before SWP) and November 2010 (after SWP). It was thought that this control was effective, because the satisfaction with the lighting both at the personal desk and in the entire SWP had improved as compared with the case before SWP. We thought that this was because workers in the SWP had an impact on their working environment by specifically adjusting illuminance on their desk.

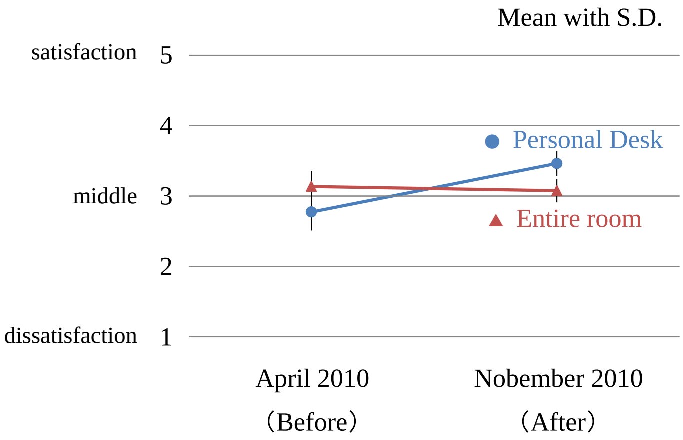

Figure 4 Worker's satisfaction of the lighting control in SWP

3. Conclusions

In this paper, the concept of SWP, the control system based on SWP, and the energy conservation performance and the satisfaction evaluation of the lighting control in SWP is described. The lighting control based on the location information and the worker's preferences was advantageous in terms of energy conservation and resulted in a higher degree of worker satisfaction compared with the standard control that only switched ON/OFF in each zone of the office. As previously described, we suggested a possible beneficial effect of the concept of SWP aimed at simultaneous pursuit of energy conservation and environmental amenity in the office. We will continue the research and development of this SWP technology with the goal of expanding the SWP domain of applicability.

4. References

1. Sadakiyo, K. and Igarashi, Y. A study on Smart Workplace, Summaries of Technical Papers of Annual Meeting of AIJ, AIJ. pp. 475-484 (2011)