Power saving parameter learning for light power control in public space

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Abstract: This paper describes a parameter learning system for light energy saving control. It is very important to control the light system efficiently because the large electric energy consumer is the light system. In the home light control, so far, the brightness sensor system which controls each light has been developed. However it controls each light independently, the multiple light control system doesn't work well. There are a lot of lights in even a single room of the office or the school. Furthermore, user requirements for lighting intensity are different according to user locations in the room. Therefore, in order to control each light properly, we must calculate optimal brightness pattern quickly. In this study, we propose the lighting system to determine the brightness of the lighting system using genetic algorithms in public spaces. This system solves the trade-off between the user satisfaction and the energy saving.

Keywords: lighting, energy conservation, usability, sensor network, genetic algorithm

1 INTRODUCTION

Recently, promotion of energy efficiency regulations for greenhouse gas emissions has become active to address global warming issues. Therefore, the saving energy is closely watched in the home and office. The targets of energy saving are the lighting, the air conditioning, and the consumer electronics etc. Among them, it is very important to control the light system efficiently because the large electric energy consumer is the light system [1]. So, the lighting energy saving is desirable. In the home light control, so far, the brightness sensor system which controls each light has been developed. However it controls each light independently, the multiple light control system doesn’t work well in the home. In the public space, such as the office and the school, the light control is achieved by more simple way which is switched on-off by detecting a human or comparing the brightness sensor with the fixed threshold value. Several works on the lighting control system providing a comfortable space for the end user and reducing power consumption in public space has been studied[2], [3]. There are a lot of lights in even a single room of the office or the school. Furthermore, user requirements for lighting intensity are different according to user locations in the room or the purpose. Therefore, in order to control each light properly, we must calculate optimal brightness pattern quickly. This problem is combinational optimization problem.

In this study, we propose the lighting system to determine the brightness of the lighting system using genetic algorithms (GA) in public spaces. This system solves the trade-off problem between the user satisfaction and the energy saving. Considering the sunlight, the total of power and the user requirement simultaneously, the lighting intensity must be controlled adequately. The genetic algorithm can solve this combinational optimization problem that decides the brightness of all lightings. To apply GA to control the light system, the genetic code is defined as the power level and brightness for each light. We considered the total electric power in a room and the amount of the differences between current and desired brightness of each light, to select good genes. In our method, fitness function is defined as the sum of these values, and gene is selected so that the function is minimized.

2 LIGHT POWER CONTROL SYSTEM

2.1 System configuration

Fig. 1 shows the lighting system configuration in this study. This system consists of the illuminance sensor, dimmable lighting and management PC. The end users have mobile device and can send the user preference information on brightness to management PC. Then, the desired brightness of each illumination is determined by gathering the user preference information. This system adjusts the brightness of each illumination near the desired brightness and uses the genetic algorithm to determine the optimal lighting pattern. If the environment changes, the desired brightness of each illumination is changed and the optimum lighting pattern of each illumination is determined again.

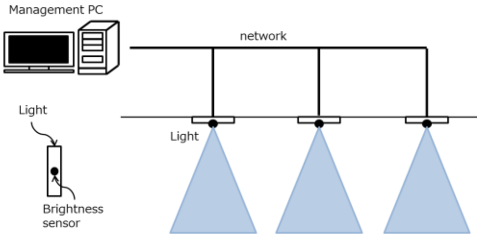

Fig. 1. Lighting system

2.2 Method to determine the optimal lighting pattern

This system uses the genetic algorithm to determine the optimal lighting pattern. The genetic algorithm is learning algorithm designed to model the biological mechanisms of genetic. This algorithm is superior to efficiently obtain the optimal solution. Therefore, the genetic algorithm has been shown to be effective systems for energy management plan [4], [5]. This section describes the flow of our system making use of genetic algorithm. Our system consists of the following 4 steps and repeats these steps to decide an adequate brightness. In the first step, we provide a plurality of individual. Fig. 2 shows the one example of an individual. The individual has a lot of gene. The gene has the value of power level and is prepared number of lighting in the room. The power level is divided by 8 intensities from level 1 to level 8 ,which is linked to the electric power and the brightness(in Table 1). In the second step, children's individuals are made with combination of the individuals. This process is called crossover. Then, in the third step, the outstanding individuals are selected from a collection of children's individuals. This process is called selection. The selection is used for the fitness function to evaluate whether the superior individual. This study used the following objective function,

$$F_n = W_{average} * Ld_{average} \quad (1)$$

$$W_{average} = \frac{\sum_{i=0}^{L_{number}} w_i + 1}{L_{number}} \quad (2)$$

$$Ld_{average} = \frac{\sum_{i=0}^{L_{number}} Ld_i}{L_{number}} \quad (3)$$

$$Ld_i = \begin{cases} 0 & (Lc_i - Lt_i \geq 0 \quad and \quad Llv = 1) \\ |Lc_i - Lt_i| & (otherwise) \end{cases} \quad (4)$$

where L_{number} is the number of lights. Fitness function F_n is defined as the multiplication of the total electric power in a room and the amount of the differences between current and desired brightness of each light, and the individual is selected so that the function is minimized. $W_{average}$ is the average of electric power to control all lighting(in eq.2). Ld_i represents the absolute value of the difference between current and desired brightness of each illumination. But, if the current brightness exceeds the desired brightness and the power level is level 1, this value is 0. In the final step, the selected individuals may mutate. This is mutation process.

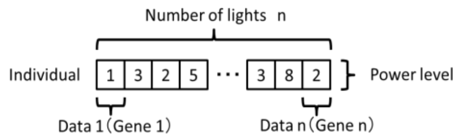

Fig. 2. One example of an individual

Table 1. Electric power and brightness

	Electric power	Brightness
Level 1	0 W	0 lx
Level 2	1 W	60 lx
Level 3	3 W	210 lx
Level 4	5 W	270 lx
Level 5	7 W	333 lx
Level 6	9 W	390 lx
Level 7	11 W	466 lx
Level 8	13 W	542 lx

3 PERFORMANCE EVALUATION

In order to verify the effectiveness of the proposed method in this study, we evaluated our system by computer simulation. This section shows our simulation environment and the results which is the brightness of each illumination and the number of generations created till the performance converges to the optimal solution.

3.1 Simulation Environment

Fig. 3 shows the simulation environment. The room of simulation environment has 12 lights which. Fig. 4 shows the coefficient representing the influence of the brightness from their neighbors. This coefficient is used to calculate the brightness considering indirect light. In this study, this coefficient calls the brightness coefficient. The brightness considering indirect light is calculated by summing up the multiplication of the brightness and the brightness coefficient. The specification of the PC performs simulation has a Core2Duo CPU, 3.0GHz memory and Windows7 OS. We evaluated our method in three environments where user requirement for lighting intensity are different. In the first environment, user requirements are uniformly distributed, in other words all requirements are equal. The second one is heterogeneous model, where the requirements are partially different. In the final environment, user requirement changes according to elapsed time.

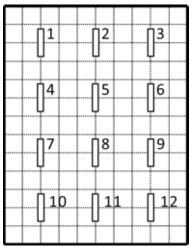

Fig. 3. Room of Simulation environment

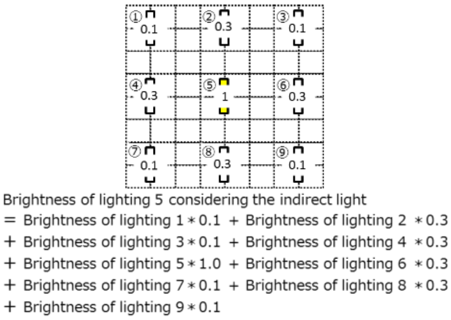

Fig. 4. Illuminance coefficient

Table 2. Parameters of Genetic Algorithm

	Number	Method
Initial individual	20	Random
Selection	10	Elitism
Crossover	20	Uniform crossover
Mutation probability	0.03	Random

3.2 SIMULATION RESULTS

3.2.1 Case 1: All requirements are equal

In the first environment, user requirement are uniformly distributed, in other words all requirements are equal. Table 3 shows the power level and brightness of each illumination. Table 4 shows the value of the optimal solution and the electric power. Fig. 5 shows the number of generations which is necessary to converge to the optimal solution. The simulation result shows that our method can satisfy the brightness of user requirements and reduce energy consumption. From table 3, the maximum difference among current brightness and desired brightness is about 37(lx). There is no problem because human eye cannot recognize such a difference. [6]. From Fig.5, the number of generations converges to the optimal solution in the first environment is the 158 generation and the convergence time is less than one second.

Table 3. Power level and brightness

Lighting Number	Power Level	Current Brightness	Desired Brightness
1	Level 4	402 lx	400 lx
2	Level 3	432 lx	400 lx
3	Level 4	402 lx	400 lx
4	Level 3	399 lx	400 lx
5	Level 2	363 lx	400 lx
6	Level 3	399 lx	400 lx
7	Level 3	399 lx	400 lx
8	Level 2	363 lx	400 lx
9	Level 3	399 lx	400 lx
10	Level 4	402 lx	400 lx
11	Level 3	432 lx	400 lx
12	Level 4	402 lx	400 lx

Table 4. Optimal solution and electric power

Optimal solution	Electric power
54.2	40 W

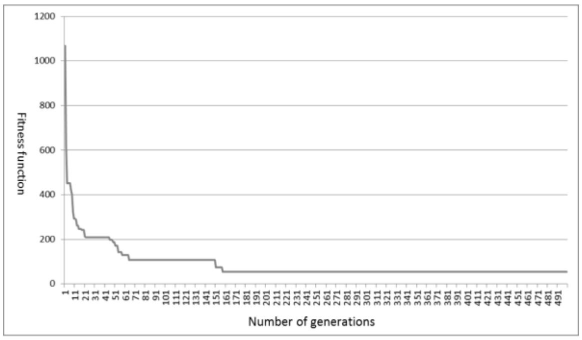

Fig. 5. Fitness function of generations

3.2.2 The requirements are partially different

The second environment is heterogeneous model, where the requirements are partially different. Table 5 shows the power level and brightness of each illumination. Table 6 shows the value of the optimal solution and the electric power. Fig. 6 shows the number of generations which is necessary to converge to the optimal solution. The simulation result also shows that our method can satisfy the brightness of user requirements and reduce energy consumption. But, there are great difference between current and desired brightness of lighting 9 and lighting 11. This is because the low desired brightness lighting is located next to the high desired brightness lighting. The number of generations converges to the optimal solution in the second environment is 3208 generation and the convergence time is less than one second, which is same as the case in the first environment.

Table 5. Power level and brightness

Lighting Number	Power Level	Current Brightness	Desired Brightness
1	Level 3	412 lx	400 lx
2	Level 3	427 lx	400 lx
3	Level 4	414 lx	400 lx
4	Level 7	595 lx	600 lx
5	Level 1	418 lx	400 lx
6	Level 4	399 lx	400 lx
7	Level 2	385 lx	400 lx
8	Level 4	445 lx	400 lx
9	Level 1	267 lx	200 lx
10	Level 5	396 lx	400 lx
11	Level 2	345 lx	400 lx
12	Level 5	378 lx	400 lx

Table 6. Optimal solution and electric power

Optimal solution	Electric power
111.2	44 W

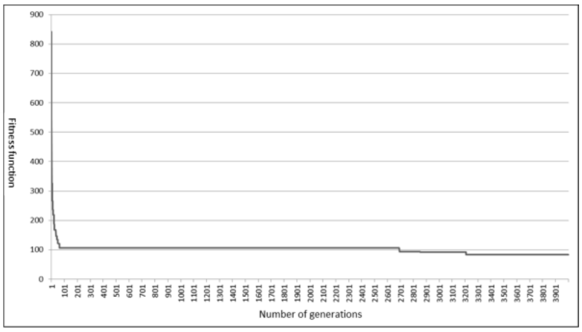

Fig. 6. Fitness function of generations

3.2.3 The end-user move in the room

In the third environment, user requirement changes according to elapsed time. One end-user moves as in Fig. 7 and requires 400[lx]. Fig. 8 shows the electric power of the user position. The simulation result shows that lighting intensities are adjusted adaptively according to varied demands.

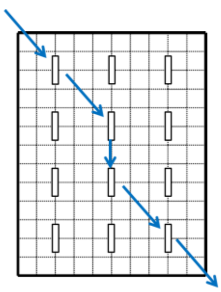

Fig. 7. Transfer pathway of the user in the room

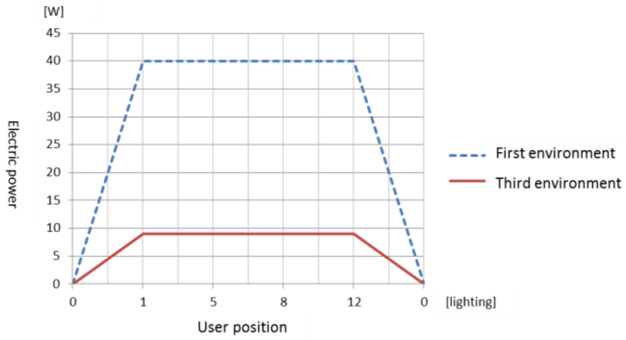

Fig. 8. Electric power of the user position

4 DISCUSSION

In summary, we propose the power saving control method for the lighting system to determine the brightness of the lighting system using genetic algorithms in public spaces. The simulation results in three environments show that the brightness provided by our method can satisfy the user requirements and reduce energy consumption. In the future, we would like to implement our method in a light power control system.

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