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Performance Evaluation of Lighting Control Applied with User Awareness Technology for Summer Solstice Lighting Energy Saving

Kihyun Choi

The Graduate School of Techno Design, Kookmin University, Jeongneung-dong Seongbuk-gu, Seoul, 136-702, Korea

Heangwoo Lee

The Graduate School of Techno Design, Kookmin University, Jeongneung-dong Seongbuk-gu, Seoul, 136-702, Korea

Yongseong Kim

The Graduate School of Techno Design, Kookmin University, Jeongneung-dong Seongbuk-gu, Seoul, 136-702, Korea

Abstract

Today, the energy consumption of buildings accounts for 38% of total energy consumption. Of the consumption, lighting energy accounts for high percentage at about 22% from the view of Korean criteria, requiring the necessity of effective technical research on lighting energy saving. energy consumption of buildings tends to frequent especially in the summer solstice among four seasons. With this in mind, the range of research should be focused on energy saving plans limited to the summer solstice. The study, therefore, carries out quantitative performance evaluation of lighting control applied with user awareness technology to reduce lighting energy consumed in the summer solstice. The range of time is based on the total of 8 hours between 8 a.m. to 4 p.m. when the most effective illuminance values are shown during daytime. As a result of comparative analysis of the electricity use of the lighting control, the energy saving performance of lighting control has been confirmed in the type 2 of user illumination requirement 400 lx and type 3 of 300 lx.

Keywords: Lighting Control System, User Awareness, Energy Saving

1 Introduction

Today, research on lighting control systems introduces a variety of techniques through active utilization of IT skills. However, there is a lack of research on performance verification for suggestions that demonstrate performance depending on changes in real environment. This paper conducts energy-saving performance based on the suggestions of lighting control system applied with user awareness technology. In preliminary research, performance evaluation was focused on a limited time period for a certain time zone, which makes it difficult to confirm overall performance[1][2]. The study, therefore, obtains electricity use during the summer solstice daytime using user awareness technology applied with lighting control and collects data of energy-saving performance. For the accuracy of the study, the research is carried out through quantitative performance on the actual test-bed, not simulation.

In the past, research is limited as it focused on between 12 p.m. to 1 p.m. when indoor illumination is at the highest level[1]. The research, therefore, setup the range of time between 8 a.m. to 4 p.m., which is the summer solstice daytime zone, to obtain the overall electricity use of summer solstice and carried out a comparative analysis on the electricity use of the On/Off lighting control.

2 Lighting Control System Applied with User Awareness Technology

2.1 User Awareness Technology

User awareness technology is applied to various fields as one of the elemental technologies of IT (Information Technology). The existing methods that based on an average value of user information are difficult to provide optimized services to various users. However, user awareness technology can provide the optimum service by actively using a variety of user information. Suppose services are used by one or more users simultaneously, an algorithm is required to determined optimization.

User awareness technology is distinguished according to the method of biometric data recognition and communications, and a suitable technique is applied depending on purposes. While biometric data recognition has the highest accuracy among the methods of user awareness, it also has downside in that it is difficult to use in various fields for it requires user behavior during the recognition process. On the contrary, the communication method does not require user's direct behavior. The study found that user awareness technology is suitable for lighting control systems as the technology helps energy saving of buildings based on communications[3][4].

2.2 Embodiment and Performance Evaluation of Lighting Control Systems Applied with User Awareness Technology

The lighting control systems applied with user awareness technology suggested in preliminary research basis on the fact that illumination requirement is different depending on age group of users[5]. The study embodies lighting control systems applied with user awareness technology according to the setting suggested in preliminary research[1]. The details are as follows: Setting of illumination requirement that is different from one another in UAT as requested by space users. User awareness within a space is transmitted through users' tags. Provide required illumination set through recognized user information to interior space. Effective energy saving can be realized; if inflow of illumination into indoor from outdoor is measured and applied to a lighting control system.

3 Setting of Experimental Environment for Performance Evaluation

3.1 Setting of Indoor Influx Illumination by the Summer Solstice Daytime Zone

For the experiment, solar illuminance values by the summer solstice daytime zone has been setup as shown in <Table 1>.The range of time is based on the total of 8 hours between 8 a.m. to 4 p.m. when the most effective illuminance values are shown during daytime . The result of lighting illuminance values measured by time using a test-bed chamber based on the solar illuminance value setting is as shown in <Table 2>.

Table 1. Setting of Solar Illuminance Values by the Mean Time of the Summer Solstice Daytime

Time(hr)	8 - 9 / 15 - 16	9 - 10 / 14 - 15	10 - 11 / 13 - 14	11 - 12 / 12 - 13
Illumination(lx)	50000	60000	70000	80000

Table 2. Results of the Measurement of Luminance Brought into the Indoors at Noon from Full South

Time	Illumination(lx)			
	Zone 1	Zone 2	Zone 3	Zone 4
8 - 9 / 15 - 16	208.63	812.76	243.66	1624.89
9 - 10 / 14 - 15	241.49	981.93	292.39	1949.87
10 - 11 / 13 - 14	284.80	1146.33	341.12	2274.84
11 - 12 / 12 - 13	329.92	1310.41	389.85	2599.82

3.2 Method of Experiment

The experiment of the On/Off lighting control uses the same illumination

requirement 500 lx for all users. This is the most used lighting control environment of which turns on the light of a zone that does not meet illumination requirement

The classification of the types of lighting control systems (a comparison target) applied with user awareness technology is as shown in < Table 3>. Space users are set as family member A, B and C, the space users are classified by age, and 600 lx, 400 lx and 300 lx are set respectively for the user illumination requirement of 60s, 40s and 20s. This setting is based on the fact that a higher age requires higher illumination requirement[3][4].

Table 3. Hierarchy of Illumination Requirement According to the User Configuration in the Space

	User	Illumination Requirement	Personnel Organization of Users		
Type 1	A (60age)	600 lx	A	A,B / A,C	A, B, C
Type 2	B (40age)	400 lx	B	B, C	-
Type 3	C (20age)	300 lx	C	-	-

The method of experiment is as follows: A user has a tag and enters inside a test bed; then the age of the user is recognized through the tag to control lighting according to illumination requirements. Lighting control is demined based on satisfactory of user illumination requirements for interior illumination according to the summer solstice daytime setting. The light will turn on in a zone that does not meet illumination requirements in accordance with four zones. If more than two users, lighting of user illumination requirements is controlled first. This is based on the fact that the higher the age group of users, the more illumination is required[3][4][5].

4 Performance Evaluation

4.1 The Measured Value of Experiment

The study conducted experiments on test-bed based on the setting of the previous paragraph in order to evaluate energy-saving performance. <Table 4> shows the experiment result of the On/Off lighting control. <Table 5> shows the result of lighting control applied with user awareness technology. Measured values are classified and arranged into time and type.

Table 4. Values of Experiment Measurement of the On/Off Lighting Control

Time	Type	User / Illumination Requirement	Zone 1	Zone 2	Zone 3	Zone 4	Electronic Consumption (kWh)	
			lx / Lighting	lx / Lighting	lx / Lighting	lx / Lighting		
8 - 9 / 15 - 16	Type 1	A / 500	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	0.8208
		AB / 500	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	
		AC / 500	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	
		ABC / 500	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	
	Type 2	B / 500	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	0.4104
		BC / 500	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	
	Type 3	C / 500	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	0.2052

Table 4. Values of Experiment Measurement of the On/Off Lighting Control (Continued)

9 - 10 / 14 - 15	Type 1	A / 500	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	0.8208
		AB / 500	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	
		AC / 500	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	
		ABC / 500	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	
	Type 2	B / 500	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	0.4104
		BC / 500	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	
	Type 3	C / 500	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	0.2052
10 - 11 / 13 - 14	Type 1	A / 500	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	0.4104
		AB / 500	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	
		AC / 500	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	
		ABC / 500	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	
	Type 2	B / 500	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	0.2052
		BC / 500	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	
	Type 3	C / 500	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	0.1026
11 - 12 / 12 - 13	Type 1	A / 500	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	0.4104
		AB / 500	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	
		AC / 500	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	
		ABC / 500	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	
	Type 2	B / 500	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	0.2052
		BC / 500	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	
	Type 3	C / 500	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	0.1026

Table 5. Values of Experiment Measurement of Lighting Control Applied with User Awareness Technology

Time	Type	User / Illumination Requirement	Zone 1	Zone 2	Zone 3	Zone 4	Electronic Consumption (kWh)	
			lx / Lighting	lx / Lighting	lx / Lighting	lx / Lighting		
8 - 9 / 15 - 16	Type 1	A / 600	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	0.8208
		AB / 600	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	
		AC / 600	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	
		ABC / 600	831.82 / On	867.99 / Off	937.07 / On	1713.07 / Off	0.2052	
	Type 2	B / 400	696.02 / On	843.44 / Off	415.25 / Off	1662.62 / Off	0.1026	0.2052
		BC / 400	696.02 / On	843.44 / Off	415.25 / Off	1662.62 / Off	0.1026	
	Type 3	C / 300	696.02 / On	843.44 / Off	415.25 / Off	1662.62 / Off	0.1026	0.1026
9 - 10 / 14 - 15	Type 1	A / 600	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	0.8208
		AB / 600	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	
		AC / 600	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	
		ABC / 600	864.68 / On	1037.16 / Off	985.80 / On	2038.05 / Off	0.2052	
	Type 2	B / 400	728.88 / On	1012.61 / Off	463.98 / Off	1987.60 / Off	0.1026	0.2052
		BC / 400	728.88 / On	1012.61 / Off	463.98 / Off	1987.60 / Off	0.1026	
	Type 3	C / 300	728.88 / On	1012.61 / Off	463.98 / Off	1987.60 / Off	0.1026	0.1026
10 - 11 / 13 - 14	Type 1	A / 600	907.99 / On	1201.56 / Off	1034.53 / On	1363.02 / Off	0.2052	0.8208
		AB / 600	907.99 / On	1201.56 / Off	1034.53 / On	1363.02 / Off	0.2052	
		AC / 600	907.99 / On	1201.56 / Off	1034.53 / On	1363.02 / Off	0.2052	
		ABC / 600	907.99 / On	1201.56 / Off	1034.53 / On	1363.02 / Off	0.2052	
	Type 2	B / 400	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	0.2052
		BC / 400	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	
	Type 3	C / 300	772.19 / On	1177.01 / Off	512.71 / Off	2312.57 / Off	0.1026	0.1026
11 - 12 / 12 - 13	Type 1	A / 600	953.11 / On	1365.64 / Off	1083.26 / On	2688.00 / Off	0.2052	0.8208
		AB / 600	953.11 / On	1365.64 / Off	1083.26 / On	2688.00 / Off	0.2052	
		AC / 600	953.11 / On	1365.64 / Off	1083.26 / On	2688.00 / Off	0.2052	
		ABC / 600	953.11 / On	1365.64 / Off	1083.26 / On	2688.00 / Off	0.2052	
	Type 2	B / 400	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	0.2052
		BC / 400	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	
	Type 3	C / 300	817.31 / On	1341.09 / Off	561.44 / Off	2637.55 / Off	0.1026	0.1026

4.2 The Measured Value of Experiment

The electricity use of the summer solstice obtained based on the experiment result is as shown in < Table 7> and < Table 8>. The summer solstice is presumed to be15 days. As a comparative result of electricity use, the energy-saving performance of lighting control applied with user awareness technology is confirmed in types 2 and 3. In type 1, the On/Off lighting control shows lower electricity use than that of lighting control applied with user awareness technology. That is because the lighting control requirement illumination applied with user awareness technology is set to 600 lx based on the user C (60s). In case of the On/Off lighting control, illumination requirement is set to 500 lx targeting all users; thus it uses relatively less power, but cannot provide sufficient illumination required by the user C (60s).

Table 7. Comparison of Electricity Use According to the Summer Solstice Daytime Zone

Time	Type / Illumination Requirement	Electronic Consumption (kWh)	
		On/Off	On/Off + User Awareness
9 / 16	Type 1 / 600 lx	0.8208*15(Day) = 12.312	0.8208*15(Day) = 12.312
	Type 2 / 400 lx	0.4104*15(Day) = 6.156	0.2052*15(Day) = 3.078
	Type 3 / 300 lx	0.2052*15(Day) = 3.078	0.1026*15(Day) = 1.539
10 / 15	Type 1 / 600 lx	0.8208*15(Day) = 12.312	0.8208*15(Day) = 12.312
	Type 2 / 400 lx	0.4104*15(Day) = 6.156	0.2052*15(Day) = 3.078
	Type 3 / 300 lx	0.2052*15(Day) = 3.078	0.1026*15(Day) = 1.539
11 / 14	Type 1 / 600 lx	0.4104*15(Day) = 6.156	0.8208*15(Day) = 12.312
	Type 2 / 400 lx	0.2052*15(Day) = 3.078	0.2052*15(Day) = 3.078
	Type 3 / 300 lx	0.1026*15(Day) = 1.539	0.1026*15(Day) = 1.539
12 / 13	Type 1 / 600 lx	0.4104*15(Day) = 6.156	0.8208*15(Day) = 12.312
	Type 2 / 400 lx	0.2052*15(Day) = 3.078	0.2052*15(Day) = 3.078
	Type 3 / 300 lx	0.1026*15(Day) = 1.539	0.1026*15(Day) = 1.539

Table 8. Comparison of Electricity Use of the Summer Solstice According to Time Classification

Type / Illumination Requirement	Electronic Consumption (kWh)	
	On/Off	On/Off + User Awareness
Type 1 / 600 lx	39.936	49.248
Type 2 / 400 lx	18.468	12.312
Type 3 / 300 lx	9.234	6.156
Total	67.638	67.716

5 Conclusion

The major result of the study is summarized as follows:

First, the existing method that based on the average value of user information cannot provide optimized services to various users. However, user awareness technology can provide the optimum service by actively using a variety of user information.

Second, UAT is classified into methods that use biometric data recognition and communications; for the energy-saving lighting control method, the communication is appropriate as it minimizes user inconveniences.

Third, effective energy saving can be realized if inflow of illumination into indoor from outdoor is measured and applied to a lighting control system.

Fourth, as a result of comparative analysis of the electricity use of the lighting control, the energy saving performance of lighting control has been confirmed in the type 2 of user illumination requirement 400lx and type 3 of 300lx.

Fifth, the experiment result shows that the electricity use of the method of lighting control applied with user awareness technology can be higher in accordance with user illumination requirement. Since the On/Off lighting control provides average illumination requirement only to users, it cannot provide sufficient illumination to the user C (60s).

The study evaluated the performance of the summer solstice daytime of the lighting control method applied with user awareness technology, and confirmed energy-saving performance by comparing the electricity use of the On/Off lighting control method. More research on the Smart Lighting Control System should follow henceforth to for higher energy-saving performance.

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