Lighting Energy-saving Optimization Model and Simulation of Living Space*

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Abstract

According to the idea of green building, an energy-saving optimization model is proposed. A kind of illumination system with scene control can achieved the energy-saving target of living space with health and comfort demand. The energy-saving model is simulated and confirmed by a living example. The result of simulation verified the energy-saving effection of the optimization model.

Keywords

green building, lighting, energy-saving, optimization model, living space

1 INTRODUCTION

With energy shortage increasingly serious, people try every means to search new energy and to achieve effective energy using. [1] By using technology to save energy other than changing people's habits and lifestyles is a kind of direction where we are headed.

Green building is a new building system which based positive cycle of ecological system, green economy, energy-saving society and green technology. [2] The pattern of green building is an important research of architecture style in the present society. The energy-saving in illumination system is an important pattern in energy-saving field and is of great significance. Illumination system is a traditional event, and a simple and controllable one, in electricity cost by building. Studies of illumination system contribute not only to energy using reduction in illumination system, but also to other electricity cost system. In the context of control theory, bringing study of illumination system into intelligent control system can achieve unified controllable and energy-saving.

Since it is the preliminary stage to apply control theory to energy conservation by building, simple building forms should be used for study, and complicated building forms can be used in the further study. Living space is structurally and functionally simple building space in various kinds, and therefore appropriate for theoretical research and initial simulation.

2 ENERGY-SAVING OPTIMIZING MODEL

In the traditional using of illumination system by building, health and comfort are major factor considered by people. Energy-saving in the demand of times should also be a major factor. Therefore the goals of the study subject---illumination system in living space should be: health, comfort and energy-saving.

Modeling thinking for illuminate energy-saving optimizing model

In the guidance of energy-saving and consideration of need for health and comfort, a multi-achievement should be got on the balance of them. According to requirements of traditional illumination system for health and comfort, we should find and definite reasonable expressing factors and patterns. The main indexes include: average illumination, uniformity of illuminance, glare, visual light and dark adaptation, key lighting coefficient, color rendering, etc, [3] showed as Figure 1. By indentifying illumination indexes of health and comfort, illuminate optimizing model is modeled bounding in energy-saving target.

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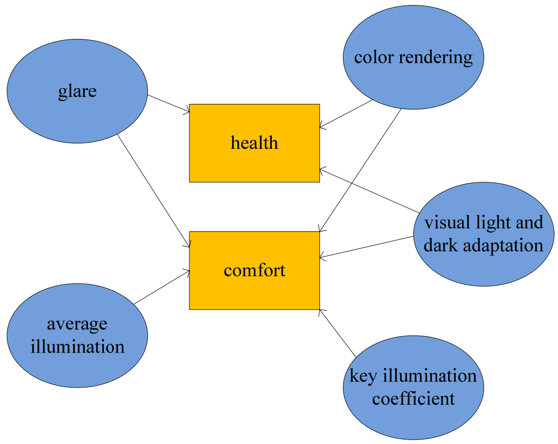


Fig. 1 mapping between illumination demand of living space and illumination indexes

Illumination energy-saving optimizing model of living space

According to the modeling thinking above-mentioned, modeling for illuminate energy-saving optimizing should consider in the following aspect:

Expression of architecture space and illumination

(1) Definition for key factors of illumination for building space

Space type, spatial function, subspace partition, subspace characteristics, subspace size and subspace hierarchical relations, etc. should be confirmed and expressed concretely. For example, the living space X is divided into many subspaces x1, x2, x3, etc. whose area are A1, A2, A3, etc. according to the function type, such as daily life, dinning, cooking, etc.

(2) Option on illumination mode

Options on luminaire and lamp based on space type and sub-spatial function to construct different luninious environments, such as kind, color temperature, power, quantity and location. On the energy-saving demand, the power of luminaire optioned in the subspaces is W1, W2, W3, etc.

Modeling of illumination control system

(1) The evaluation of health and comfort target

Make sure whether the defined illumination indexes coincidence the target of health and comfort or not with national standard or all kinds of experiment methods.

(2) Find out the ratios of subspaces

State variable of spatial function and its range should be determined in terms of building subspace partition. The ratios of subspaces should be determined on the basis of application of building space in different occasion, which shows α, β, γ ,etc.

Spatial function should be determined in the sense mode such as application of space under different circumstances and subspace cooperation. For instance, in a residential building, dweller will turn on most of lamps in building when he has a reception, turn off most of them when he enjoy his home theatre, and merely turn on the lamp above the mess table or a few of other lamps to assist.

(3) Operation mode of control strategy

Operation mode and control strategy including continuous light tuning, fractionation dimming and scene control, individual control, should be chosen in terms of illumination mode. [4] The control strategy should be expressed quantified in term of control method. The restrained conditions should be found to achieve the target of health and comfort.

The energy model of illumination system of living space

Among the indexes of energy consumption, more commonly used LPD (Lighting Power Density) and actual potency value are chosen. The power of the living space is W,

$$W=\alpha W1+\beta W2+\gamma W3+\cdots \quad (1)$$

And the LPD,

$$T=\frac{W}{A}=\frac{\alpha W1+\beta W2+\gamma W3+\ldots\ldots}{A1+A2+A3+\ldots\ldots} \quad (2)$$

The actual potency value,

$$S=\frac{T}{h}=\frac{\alpha W1+\beta W2+\gamma W3+\ldots\ldots}{h(A1+A2+A3+\ldots\ldots)} \quad (3)$$

h is the corresponding illuminance value (lx).

For some scene mode, the ratios of luminaries in subspace can be determined by empirical value. The LPD and actual potency value can be obtained by the ratios.

The perception, calculation and control of illumination system of living space

Sensors settled in the living space can get information about all kinds of complex status real time. Sensors may control the users of energy optimized real time. Establishment of energy-saving optimizing may be confirmed by a kind of intelligent control algorithm, such as swarm intelligence, neural network, fuzzy theory.

3 MODELING AND SIMULATION EXAMPLE OF SINGLE BUILDING

In order to facilitate research, modeling and simulation examples of home building space, which consists of three subspaces of a living room area, a dining area and a kitchen, are considered under the single building model. Location elements of the building space room is shown in Figure 2, calculated surface diagram shown in Figure 3. As is clearly shown in the figures, ②is living room, ①is dining area, ③is kitchen area, x1 represents for the living area, x2 for the dining area, and x3 for the kitchen area.

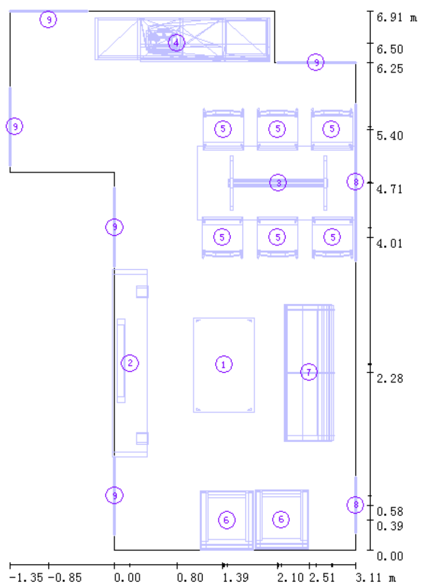


Fig. 2 location elements of the building space room

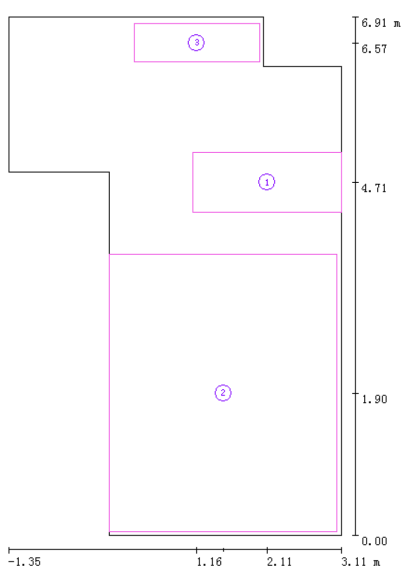


Fig. 3 calculated surface of building space

In order to facility control, LED lamps are used in every area in accordance with the lighting requirements. Traditional light sources, which mainly include heat radiation light source and gas discharge source, are all based on the luminous mechanism using current to light up material. Because of its unique light-emitting mechanism, LED light source has low power consumption, high luminous efficiency, dimmable, long life and many other advantages. In particular, its tunable optical property is especially suitable in the intelligent lighting control system.

The lamp powers of three areas are W1, W2, W3 respectively. The luminaire location is shown in Figure 4.

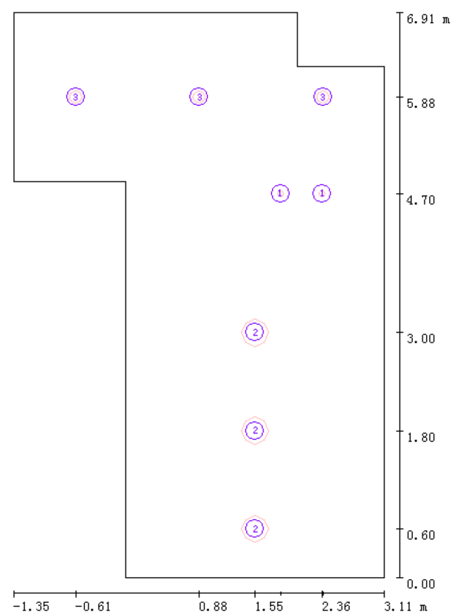


Fig. 4 luminaire location

As the structure of this home building is simple, the requirements of visual light and dark adaptation, key lighting coefficient and color rendering among the indexes can be ignored. The considerations of illuminance level and glare will be the references in the simulation and design.

Neglecting the little impact indicators, with the realizations of illuminance level and glare indicators requirements and energy-saving goals of lighting system, three typical scenarios are set: welcoming scene, dining scene and party scene. In these scenes, closing some lamps or dimming down the brightness to realize energy-saving goal without influencing the health and comfort in corresponding scene of building space. With experiences and the calculation area A1, A2, A3 of the subspaces, corresponding calculated brightness values is of the three models is shown in Table 1.

Table 1 brightness values under the lighting control scenes

Object	lighting control scenes		
	welcoming	dining	party
living room lamp	100%	30%	100%
kitchen lamp	50%	50%	80%
dining room lamp	0%	100%	100%

With the prevailing bus control in current electrical market, continuos controllable of loop illumination can be easily achieved. KNX/EIB product of Schneider Electric is applied in this building space. EIB (Europe Installation Bus) is a two-wire, bus type fully distributed intelligent control system. It is mainly used to control lighting system, blind system, HVAC system (shown in Figure 5), also applied in the fire, security and other systems linkage control. [5]

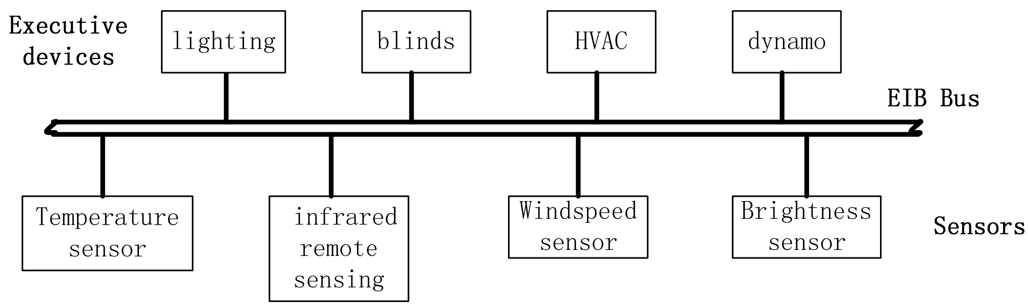


Fig. 5 KNX/EIB intelligent control system

KNX/EIB bus for the lighting system can function to facilitate the setting and control of the scene, and to facilitate the determination of light brightness of various scenes. Simulate with DIALux, the popular software in the lighting field. After the calculation of the DIALux, simulation of pseudo-isochromaticdiagram and gray scale illumination of three models are shown in Figure 6 to Figure 11.

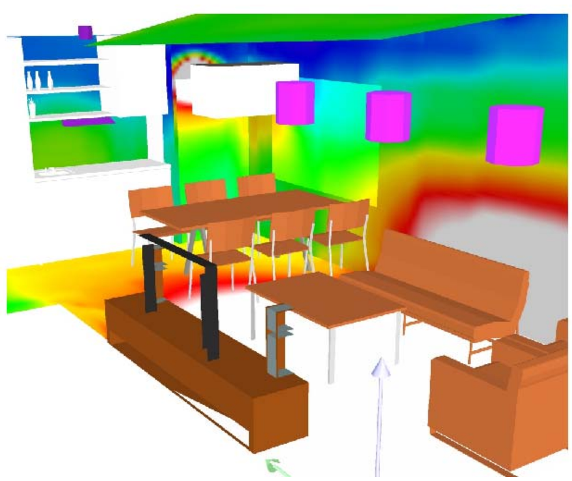


Fig. 6 pseudo-isochromaticdiagram of welcoming scene

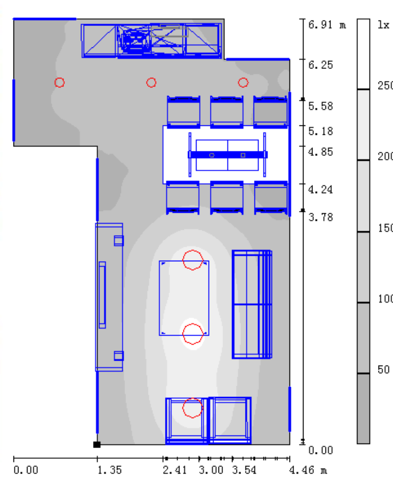
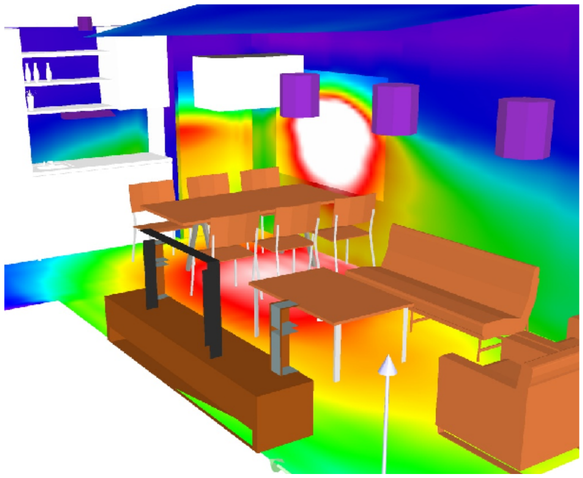


Fig. 7 gray scale illumination of welcoming scene



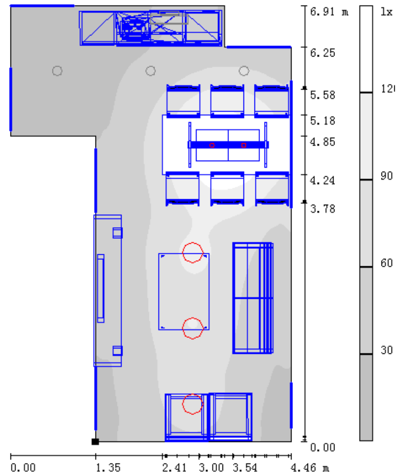
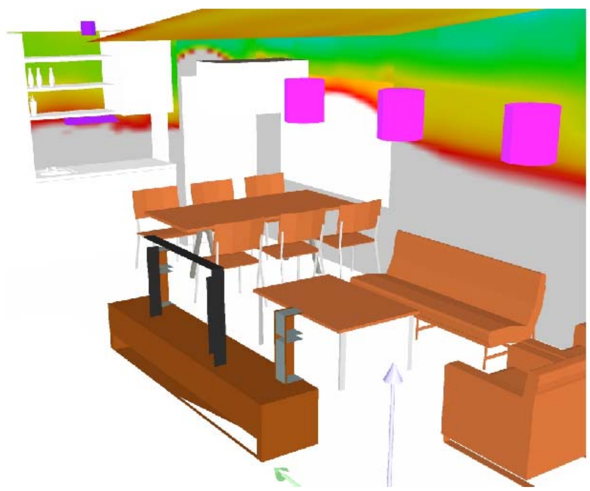


Fig. 8 pseudo-isochromaticdiagram of dinning scene **Fig. 9 gray scale illumination of dinning scene**



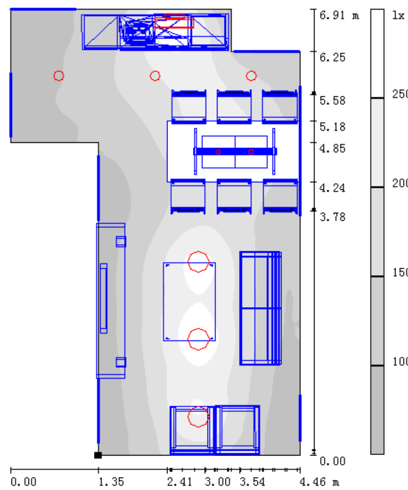


Fig. 10 pseudo-isochromaticdiagram of party scene **Fig. 11 gray scale illumination of party scene**

4 ANALYSIS BASED ON SIMULATION AND IMPLEMENT OF THE PROPOSAL

Compare experimental data with national standard to judge the index of illumination comfort and energy conservation.

The national architectural standard

Table 2 and table 3 show the national standard of average illuminance and LPD. [6]

Table 2 dwelling illumination criterion

Rooms or arenas		reference surface and height	Criterion value of illuminance（lx）
living room	general activities	0.75m ground	100
	Reading & writing		300*
dining room		0.75m table surface	150
kitchen	general activities	0.75m ground	100
	operating table	ground	150*
Ps.*better for complex lighting			

Table 3 illumination power density of each dwelling household

Rooms or arenas	illumination power density（W/m^2）		Corresponding illuminance value（lx）
	Current value	Target value	
living room	7	6	100
dining room			150
kitchen			100

Simulation data analysis

Table 4 shows mainly illuminance calculation value of the architecture space

Table 4 corresponding data of architecture space based on each model

control scene	average illuminance（lx）	power density（W/m^2）
welcoming	100	3.12
dining	79	4.24
party	166	4.81

The actual potency values (W/m2/100lx) of the welcoming and party scene are 3.11 and 2.90 respectively.

It should be fulfill with the requirement of average illuminance, because welcoming mode in architecture space is general activities. Compared with table 2 and table 4, average illuminance value and LPD are suitable.

Illuminance level on the dining table should be inspected in the dining mode. Average illuminance on the dining table from calculation is 245lx, which is fulfilled with national criterion, as well as power density value.

Illuminance requirement in party mode is stricter, but still fulfilled with criterion from calculation, as well as power density value.

Compared simulation data with national criterion, we can deem the design is fulfilled with the requirement, and is valuable for actual building project. Meanwhile, the intelligent control system is valuable in practice.

5 CONCLUSION

Intelligent control algorithm is used to model energy-saving optimizing model of illumination system in living space. With scene control mode, targets of green building, energy-saving, health, comfort are achieved. An example is simulated, and the result of the simulation verifies that the energy-saving optimized model accords with the corresponding national standard and can be applied as illumination mode of living space.

Because of the complexity of living environment and the multiformity of the living space users, there are still many problems in the modeling of illumination energy-saving optimizing of living space.

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