Auto-layout of Lighting Objects to Support Lighting Design in the Early Phase of Design

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Abstract

This paper aims to propose an approach to automated lighting layout system in indoor space in the perspective of auto-generation of design alternatives. Lighting environment is one of the most important factors in the domain of interior design. Well-designed lighting environment enables occupants to perform their actions safely. Furthermore, it supports occupants' psychological stability. In existing lighting design process, difficultness is that the process is usually depended on experts' experience and it is performed manually based on 2D CAD drawings. Thus, it tends to be time-consuming to create alternatives and error-prone to meet standards in the early phase of design. In this regards, as the way to create alternatives of lighting environment based on quantitative data, this paper suggests an approach to auto-layout system of lighting objects in indoor space in BIM plug-in form. The entire system consists of three major parts: 1) derivation of properties from BIM object and user parameter, 2) calculation of illuminance and the number of lighting fixture according to derived properties for creating alternative which meet standards and 3) suggestion of automatically generated alternative, reports on result value associated with created alternative and visualization of created alternative. In short, this paper proposes a way to create design alternatives of lighting design intuitively using properties included in BIM model by auto-layout of lightings. And it also includes provision of output data associated with result reports from performance analysis.

Keywords –

Automated lighting arrangement system; Building information modeling(BIM); Parametric design; Alternative creation;

1 Introduction

1.1 Research Background and Objectives

The demand for Building information modeling(BIM) is increasing in the domain of Architecture, Engineering, Construction, Facility Management(AEC-FM)[1]. BIM supports efficient utilization of various information within the lifecycle of building based on 3D model[10,18]. And one of applications of BIM, powerful parametric modeling has become possible by taking advantage of object's various properties and its relation with the other object in 3D computational environment[11]. It enables to produce various alternatives intuitively with parameters which are derivable and controllable properties in BIM model.

On the other hand, in the early phase of design, repetition of alternative production, alternative analysis, alternative assessment, alternative selection, decision-making has been existed[12]. Its process tends to be time-consuming and error-prone because it is usually performed based on experts' knowledge by manual. Thus, it is still vulnerable to design changes. And dynamic decision making process which is based on information from performance analysis is still insufficient[3]. Thus, new approach which is flexible to design change and minimizes effort and time consumption that occurs when to find suitable alternative. And it also should meet complex design requirements in the perspective of utilizing information[21].

With this background, this paper aims to suggest an approach that utilizes BIM properties as parameters for creating design alternatives in the domain of lighting design. As one of supportive tools to lighting design, the approach is achieved by auto arrangement of lighting objects in indoor space. The approach is for minimization of trial and error and immediate alternative production, analysis and assessment.

1.2 Research Approach and Scope

This paper suggests automated lighting arrangement system which lays out lighting fixtures in indoor space to meet specific standard by utilizing BIM object's various properties. To design lightings in indoor space to meet standards, various variables associated with lighting fixture and particular space are needed to be considered such as luminous flux, the number of lighting, space area, space height, purpose of space, etc. For the research, we studied preceding researches associated with existing lighting design process. In terms of supplementation and extension of existing mechanism, this paper aims to suggest auto-layout of lighting objects system using BIM object's properties and user input parameter as variables for meeting recommended levels of illuminance according to facility type and space type based on illuminance calculation. And database is also applied in the system for additional parameter according to collected properties. The suggested system is implemented in actual BIM plug-in form. As shown in figure 1, its system is composed of three major parts; 1) Input data part: derives variables related to space and lighting which are selected by user from BIM object's properties and user parameters, 2) Calculation part: using collected information, calculates intensity of illumination to judge whether space's illuminance meets standards or not. In addition, it calculates the number of lighting fixtures according to properties of space object and lighting object and 3) Output data parts: arranges lightings in space according to calculation automatically and provides outputs such as reports associated with designed lighting environment and visualizations of created alternative.

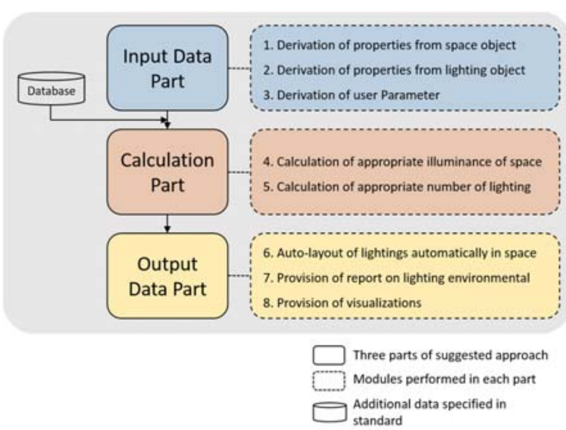

Figure 1. Composition and flow of the approach

After dealing with the three parts of automated lighting layout system, this paper will conduct a demonstration on an actual space. The target space is designed automatically through the implemented BIM plug-in. This paper is based on recommended levels of illumination specified in Korean Industrial Standards(KS) which is similar to USA's American National Standard Institute(ANSI) or Japan's Japanese Industrial Standards. The research progresses according to numeric data and actual standard quantitatively based on lumen method which is general method that calculates illuminance in indoor space and the number of lighting. And esthetic or qualitative factors of lighting environment which affects mentally are excluded in this paper.

2 Lighting Design Process

Lighting design is for providing visually suitable environment which enables occupants to perform their activities safely[22]. Furthermore, it should provide psychological stability[2]. To design suitable lighting environment, accurate illuminance calculation of each space according to its purpose is important. Because it is hard to change lighting design after installation of lighting equipments[4].

The standard associated with recommended levels of illuminance is specified in Korean Industrial Standards(KS)[5]. It specifies recommended standard according to type of facilities such as hospital, public institution as a higher level classification and type of spaces according to actions which performed in space as a lower level classification[6]. To design lighting environment which meets recommended levels of illuminance specified in KS, variables such as lighting system, type of lighting fixtures, luminous flux, space area, purpose of space, reflexibility of space's finishing materials, etc. must be considered[13]. These have been analyzed and derived through reviewing architectural drafting such as 2D-CAD manually[13,14]. Existing lighting design process and various variables for illuminance calculation are shown in fig.2. According to result value of illuminance calculation, appropriate number of lighting fixtures and their arrangement are decided. Thus, consideration of variables for energy-efficient and appropriate lighting environment is essential[21].

On the other hand, 2D-CAD based design process usually has been performed manually and often depended on experts' experience and knowledge in terms of architectural and interior design. Thus, it has been time-consuming and somewhat ad-hoc to make alternatives which meet standards in the design developing process[15]. In 2D-CAD based process, it has general design errors due to error of information, omission of information, etc[16]. In addition, those are connected to static decision-making due to lack of information[17]. Thus, new kinds of design process which enables dynamic decision-making through utilizing rich information in BIM-model is needed[7,9].

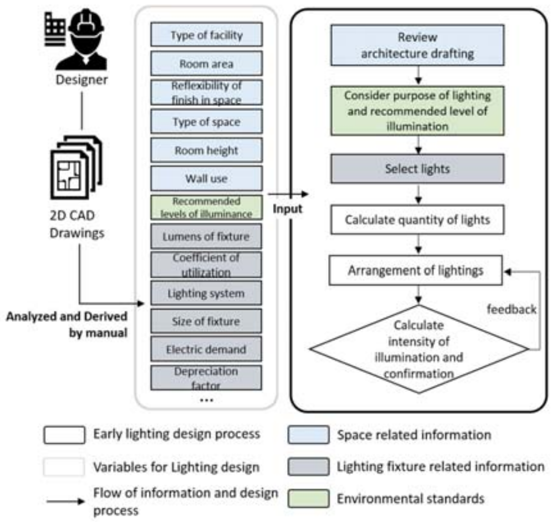

Figure 2. Existing lighting design process and variables for each phase

3 Lighting Design Process

3.1 Parametric Design

Parametric design has become possible though the development of computer operation. It can maximize creativity and economical benefits[8]. It was developed for 'reuse of existing design'. And it sets parameters on variables which define shape and it produces appropriate shapes by controlling relations between parameters[9]. Furthermore, generative parametric design which is mixed concept of mass production and parametric design enables BIM to increase its capability as a creative design tool. Based on the object's properties and relations with other objects, process that producing infinite instances which specific type can support analysis of performance and tracking flow of changes[3]. In the perspective of early phase of design, parametric design is meaningful that idea and intention can be easily realization[23].

3.2 Compatibility of Parametric Design and BIM in the Early Phase of Design

In the early phase of design, various alternatives are created and analyzed. There is repetition of creation, analysis, assessment, selection, decision-making. Thus, design changes frequently exist and this phase has a big impact on decision-making and design quality improvement[12]. In other words, design process without comparison among alternatives based on performance analysis is usually directly connected to static design-making[3,17]. In case of parametric design, it is important that grasp result value of analysis and find superior alternative simultaneously through repetitive process. In this perspective, utilizing properties in BIM model is important for meaningful performance analysis.

4 Lighting Design Process

The automated lighting design system is based on characteristics of BIM and parametric design. In other words, it utilizes information in BIM model as the parameters for producing possible alternatives which meet limited condition. In BIM environment, the system uses properties of space object and lighting object in model for automated lighting design which meets standards. It arranges lighting fixtures automatically in space based on calculation of illuminance and the number of lighting under suitable condition that is specified in Korea Industrial Standard. Figure3 gives an overview of process and information flow in the system.

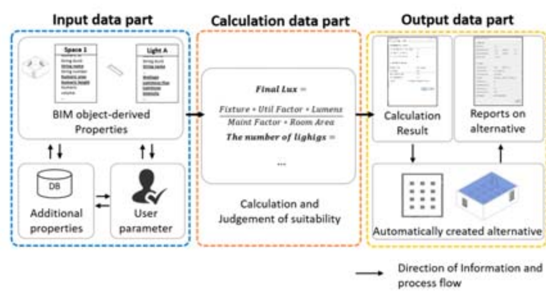

Figure 3. Flow of process and information in auto-layout of lighting objects system

4.1 Input Data Part

4.1.1 Derivation of Space Related Properties

In existing lighting design process, information for designing lighting environment is derived by reviewing architecture drafting, 2D CAD drawings and field survey[19].

In this paper, we suggest to derive this information automatically. In illuminance calculation for auto lighting arrangement, various space related properties are required as shown in Table 1. Type of facility, type of space, area of space, height of space, condition that some object is adjacent to wall or not, reflexibility of finishing in space are fundamental requisites for illuminance calculation[13]. They are properties which are included in BIM model and they can be derived directly from BIM objects. And additional data according to derived BIM properties is able to be collected from database which we designed. For example, recommended range of illumination is collected from database according to facility type and type of space as specified in KS. Table 1 shows this classification of properties.

Table 1 Space related properties for auto lighting arrangement system and classification

	Properties	
BIM properties derived directly from BIM object	Space name	Area of space
	Facility type	Space type
	Height of space	Condition that something is adjacent to wall or not
	Reflexibility of finishing in space	
Additional property	Recommended levels of illumination	

4.1.2 Derivation of Lighting Fixture Related Properties

Lighting fixture related data is also classified into directly BIM-derived properties and additional properties. Information for illuminance calculation, luminous flux of lighting, electric demand can be derived. And additional properties according to derived BIM properties are able to be set default value or collected from database such as depreciation factor, coefficient of utilization. Depreciation factor is property which exists due to expectation illuminance decrease[13]. Thus, it is set to default value because we have no data associated with factors that cause illuminance decrease in the research scope. And coefficient of utilization is the factor that occurs because of expectation of illuminance decrease. Coefficient of utilization is the factor which means incident light of luminous flux on working surface. It is affected by type of lighting system, room ratio and reflexibility of finishing materials in indoor space. Thus, information associated with coefficient of utilization is served as chart so that designer can find appropriate value in actual lighting design process[14]. We mapped this chart into database.

Table 2 Lighting properties for illumination calculation

	Properties	
BIM properties derived directly from BIM object	Lighting name	Electric demand
	Luminous flux	.
Additional properties	Depreciation factor	Coefficient of utilization

4.1.3 Gathering of User Paratemer

After deriving properties from BIM model, additional parameters for illuminance calculation are required. Type of lighting system is needed to be selected for automated lighting design. Because it affects to variables such as distance between lighting fixtures and distance between lighting fixtures and wall[19].

4.2 Calculation Part

4.2.1 Calculation of the Number of Lighting

This module calculates maximum distance between walls and lightings and maximum distance between lightings. When maximum distance between walls and lightings is decided, minimum area in ceiling where lightings can be arranged is decided. It is affected by condition that whether some objects is adjacent to wall or not[13]. On the other hand, maximum distance between lightings is affected by type of lighting system. And both distances are affected by height of space. Consequently, two types of data affect to the number of lighting fixture[19].

4.2.2 Calculation of Illuminance of Space

In this module, illuminance calculation is conducted using parameter which were collected in before parts. For calculate overall illuminance, lumen method is applied in the system. Equation (1) shows formula for calculating illuminance according to lumen method[19]. It is implemented in the system.

$$Final\ illuminance = \frac{Luminous\ flux * The\ number\ of\ lighting * Coefficient\ of\ utilzation}{Space\ area * Depreciation\ factor} \quad (1)$$

4.3 Output Data Part

4.3.1 Suggestion of Result Value

Result value associated with properties of space, lighting fixture and lighting environmental factors of the created alternative are suggested in this module. It can be used as the basis for comparison among alternatives in performance-oriented design process. In addition, it informs whether current state of lighting environment is suitable to standards or not so that feedback can be performed quickly. Table 5 shows providable information in the perspective of performance analysis.

Table 5 Providable information based on performance analysis of created alternative

Properties		
Properties derived directly from BIM model	Space name	Area (ceiling, wall, floor)
	Reflexibility of finishing (ceiling, wall, floor)	Facility type
	Space purpose	Condition that something is adjacent to wall or not
	Recommended illuminance	Recommended range of illuminance
	Lighting fixture name	Electric demand
	Depreciation factor	Luminous flux
Calculated properties of alternative	The number of lighting fixture	Final illuminance
	Maximum distance between lightings	Maximum distance between lighting and wall

4.3.2 Visualization

One of BIM application, visualization based on objects' properties is possible. This module suggests visualization of indoor space which is designed by the system based on actual value of BIM object. Addition to report of result value associated with created alternative, it is meaningful that visualization such as 3D renderings is enable for intuitive comparison among alternatives. In addition, it enables to provide indirect experience that how space going to be changed after lighting design.

5 Demonstration

We implemented the suggested system in BIM plug-in form based on Revit2015 for demonstration. The demonstration was conducted with one of lecture rooms in college of human ecology in Hanyang University as a target space. Figure 4 shows target space which is on fifth floor in college of human ecology. And we choose two different types of lighting objects for auto arrangement in the target space. Two scenarios was conducted for demonstration according to difference between lightings.

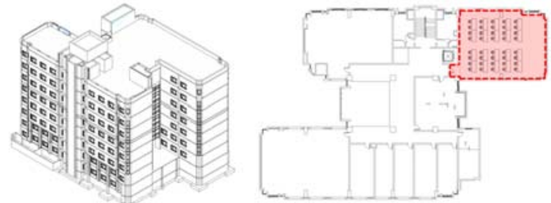

Figure 4. BIM model of college of human ecology building and one target lecture room for the demonstration

5.1.1 Derivation of variables

Figure 5 shows GUI(Graphical user interface) of BIM plug-in when space object of target space and target lighting fixture were selected. As shown in figure 5, properties associated with target space and lighting can be classified in three types of property: 1) properties derived from BIM model automatically, 2) properties derived from predefined database and 3) properties which are additional user parameters. We could derive those properties from two scenarios as shown in Table 6.

Table 6 Derived properties in input part of the system

Property type	Property name	Scenario A	Scenario B
Properties derived directly from BIM model	Space name	Lecture room 507	Lecture room 507
	Area (ceiling)	163.34m^2	163.34m^2
	Area (wall)	194.92m^2	194.92m^2
	Area (floor)	163.34m^2	163.34m^2
	Reflexibility of finishing (ceiling)	75%	75%
	Reflexibility of finishing (wall)	50%	50%
	Reflexibility of finishing (floor)	20%	20%
	Facility type	Universit y	Universit y
	Space type	Lecture room	Lecture room
	Condition of wall	No	No
	Type of lighting	M_Ceilin g light-Linear box (3 lamps)	M_Ceilin g light-Linear box (2 lamps)
	Electric demand	66W	80W
	Luminous flux	9450lm	6300lm

Properties derived from predefined database	Recommended illuminance	400	400
	Recommended range of illuminance	300~600	300~600
	Depreciation factor	140	140
Properties as user parameter	Type of lighting system	Direct (recessed)	Direct (recessed)

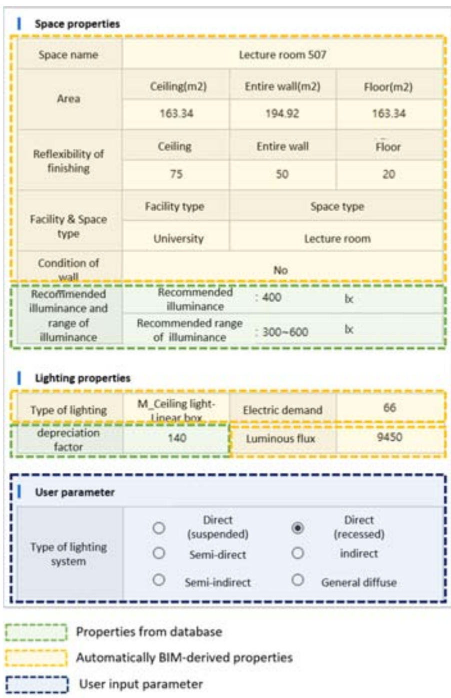

Figure 5 GUI of data input part and its components implemented in BIM plug-in form

According to scenarios which are based on difference of lighting objects, entire properties except lighting related properties are same. And one direct type of lighting system was selected as additional user parameter identically. And then, several calculations implemented in the system could be conducted.

5.1.2 Calculation and provision of data outputs

Figure 6 shows next step of BIM plug-in GUI which informs simple pre-plan of layout and suitability of lighting fixture after calculation as one of data outputs. In other words, it informs properties associated with arrangement of lighting fixture and lighting environmental factors. They could be classified into three types: 1) calculated properties, 2) properties derived from database according to case of formerly derived properties and 3) final suitability decision of alternative whether it meets standards or not. Table 7 shows derived properties from two scenarios based on properties shown in Table 6.

Table 7 Properties in Pre-plan of auto-layout

Property type	Property name	Scenario A	Scenario B
Calculated properties	Minimum number of lighting	30	30
	Maximum distance between lighting and wall	1.33m	1.33m^2
	Maximum distance between lightings	2.38m	2.84m^2
	Final illuminance	520lx	132 lx
	Optimal luminous flux of a lighting	7260lm	7260lm
	Luminous flux of selected lighting	9450lm	2400lm
Properties derived from predefined database	Recommen -ded illuminance	400lx	400lx
	Recommen -ded range of illuminance	300~600lx	300~600lx
Suitability judgement	Suitability (calculation result)	YES	No

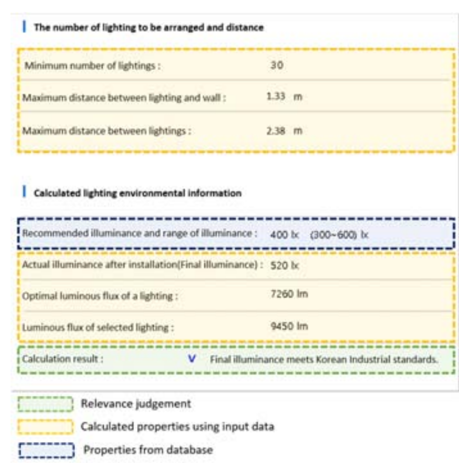

Figure 6. GUI of BIM plug-in as one of data output parts which suggests information related to auto-layout

As shown in Table 7, partly different values were derived from two scenarios. According to the calculation result, it was analyzed that selected lighting fixture's luminous flux is too low to meet standards when arranged in scenario B. When alternative is created, final illuminance of target space is too low to meet standards. On the other hand, in scenario A, it is analyzed that selected lighting's luminous flux is suitable to arrange. When it arranged automatically as many as calculated before, final illuminance of target space is able to be included in recommended range of illuminance. As a result, it was analyzed that only scenario A is allowed to create suitable alternative.

As next phase, the system arranged lighting objects in indoor space and created alternatives were provided as shown in Figure 7. According to properties and calculated values from two scenarios, two different alternatives were created.

And final reports was suggested as shown in Figure 8. It is comprehensive list of properties which was suggest in derivation properties and their calculation phase. Thus, it suggests overall information associated with created alternative. And information could be classified into three parts: 1) properties from calculation, 2) properties from database and 3) properties from created alternative.

Lastly, visualization through 3D rendering images was provided. Figure 9 shows 3D rendering images from two scenarios. It was on fundamental level because we used BIM model with simple material to just observe difference between two lighting environment for demonstration. We found that 3D rendering image of scenario B is visually darker then scenario A as the system analyzed before.

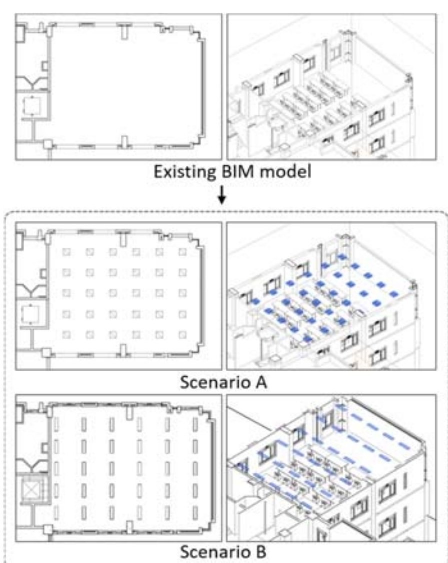

Figure 7. Ceiling plan and 3D view of target space and created alternatives based on scenario through auto layout system

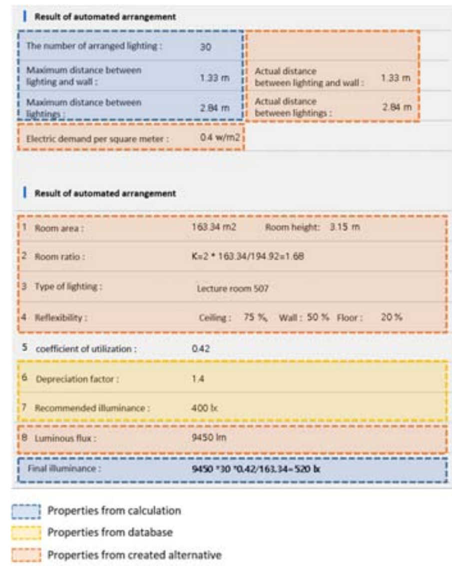

Figure 8. GUI of final report in the system as one of results of data output part.

Figure 9. Suggested 3D rendering images based on two scenarios through the system(left: scenario A, right: scenario B).

6 Conclusion

This paper introduces and demonstrates an approach to auto-arrangement of lighting fixture in indoor space under the condition of recommended levels of illuminance specified in KS. As one of supportive tools to lighting design process, the approach is implemented in BIM plug-in form. The entire system consists of three major parts according to type of data processing. As shown in section 5.Demonstration, arrangement mechanism suggested in this paper enables to create design alternative using various properties in BIM model parametrically to meet recommended standards. Lighting design based on BIM and parametric design has the merit of being updated immediately when design changes occur. And comparison among design alternatives are possible because each alternative is based on performance analysis with quantitative data. To include qualitative and esthetic factors as parameters in auto lighting arrangement system as a supportive tool, we need to develop further study.

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