Plea2004 - The 21th Conference on Passive and Low Energy Architecture. Eindhoven, The Netherlands, 19 - 22 September 2004

Daylight planning by simulation in practise - Simple, fast and convincing -

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ABSTRACT: Daylight planning by simulation in practise is presented on the basis of typical examples. The conditions for an easy and fast processing are termed and convincing results, which the planners can rely on, are shown.

Conference Topic: 2 Design strategies and tools
Keywords: daylight planning, lighting simulation, economy

INTRODUCTION

For architects and engineers it is a customary task to do the lighting planning in the design phase of a building. It may be the task formulation of planning the daylighting and artificial lighting of a complex offices building which is several storeys high and consists of different building parts with an atrium between. Sun protection shall be provided by blinds and louvres on the sloped atrium roof.

Planning the lighting via the method of lighting simulation in this particular case will be a complicated venture. The lighting planner has to face a difficult task determined by wasteful and time-consuming changes and revisions of the according CAD model - if it exists at all in this early phase of design - which is to be used for performing a lighting simulation. This preliminary work of preparing the geometric CAD data does truly not decrease the expenses of a building project.

A solution for the trouble with long-winded lighting simulation preparations would be an easy and flexible input of 3D geometries optimally adjusted to the ray tracer program the lighting calculation is done with.

2. OVERVIEW: LIGHTING PLANNING

Lighting planning by simulation is a process which should contain certain items to allow a development of the project during the design and planning phase if the planning shall be serious and deliver the best possible results. The desirable procedure of lighting planning by simulation includes following steps:

First of all, a task formulation communicated by certain requirements concerning the lighting has to be given. This is a question that shall be examined via the lighting simulation.

In order to perform the lighting simulation a virtual model of the particular room or building (including the surroundings if of any importance) has to be constructed. This is the input for the simulation program.

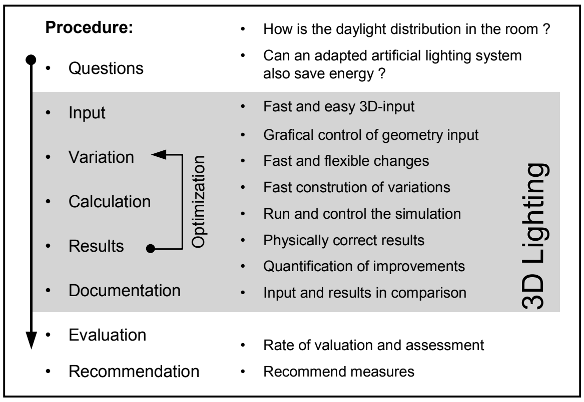

Figure 1: Lighting planning consulting procedure

For optimization it is very useful to create variations of the basis model. These variations are several geometric modifications. A sufficient number of possible changes of the building geometry should be examined for adjusting daylight inlets according to the requirements. Often also variations concerning the lighting properties are required for examining the effects of using other materials in the particular room.

After variations of the topical room have been built the lighting simulation (calculation) is performed. This is done by reproducing the real lighting situation mathematically according to the settings of the variations. Different scenarios of lighting can be calculated for the project: only daylighting, daylighting and artificial lighting combined, and only artificial lighting. Serious lighting planning by simulation makes only sense when the calculation engine works properly. Therefore, internationally acknowledged calculation engines which work on a physical basis should be used. Radiance [Ward, 1998] is such a calculation engine. It uses the backward raytracing system and generates accurate values of illuminance and luminance. This software was developed by Lawrence Berkeley Laboratory, USA, and allows a mathematical evaluation of light density images according to the human perception.

The physically correct results provided by the calculation can be luminance images for chosen views, illuminance values, or daylight factor courses. Also the daylight autonomy and the related energy savings for artificial lighting are often calculated.

Daylighting planning by lighting simulation is an optimization process. By running through the steps variation - calculation - results several times a successive improvement of the room properties according to the task formulation is achieved.

After necessary variations have undergone a lighting simulation it is very useful and working-time saving to obtain a documentation of the work done by mouse-click. The following evaluation of the calculation results can easily be done on the basis of a documentation with all inputs and results in comparison of the variations. Also the achieved improvements can be quantified.

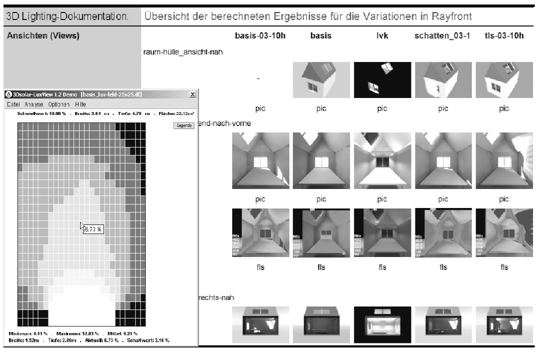

Figure 2: Documentation of input and results in comparison of variations

The results have to be evaluated to answer the task formulation from the beginning. The evaluation is based on certain evaluation criteria. This rate of valuation contains calculated values in relation to the room and daylight supply (daylight factor, equability, daylight autonomy, contrasts, unified glare rating, reference to the outside). Further, the rate of assessment allows a classification of the calculated values by a grading scale. Such an evaluation, based on valid norms and regulations is the basis on which recommendations for suitable lighting planning measures are made.

After the evaluation is done recommendations of suitable measures are given. According to the results of the lighting simulation encompassing the successive optimization process and a careful evaluation on the basis of specific evaluation criteria, the effects of recommended lighting planning measures are guaranteed.

This optimization process via simulation - meaning comparison of different variations to find out the best improvement of the former building design and to recommend measures to achieve the goals for daylighting - is only feasible with swift modifications of the geometric building model. Thus for a fast and economic lighting planning the easy geometry input and a flexible change of geometry for the lighting simulation program is the deciding factor.

2. EASY 3D INPUT FOR SIMULATION PURPOSE

The design phase of a building is determined by a vast amount of geometry changes. The building closure is revised again and again, the facade changes several times, the ground plan is modified moreover... the list of anticipated changes in the geometrical structure of the building in the design phase is long. Thus, the lighting planning procedure demands a fast input and flexible changing of the geometry into the simulation program as the lighting planner has not only to follow design-dependent changes but also should examine possible modifications in advance in order to regard only the best solutions for further planning as described above. Besides, it should not be underestimated that the geometric conditions of a building have a very big impact on the lighting, especially daylighting. Taking into account the shading effect of the surroundings is the main item to plan passive buildings due to daylighting and air-conditioning. This also shows how important an easy input phase of lighting simulation is.

For the lighting simulation three-dimensional geometry models are required. Therefore, for example, two-dimensional CAD files which often still are the only CAD data available are quite useless for the lighting simulation.

On the other hand it makes sense to apply Occam’s razor to reduce the geometry model to the necessary features. Costly details may be of important significance for visualization of a building design at presentations but they have actually no effect for statements concerning the daylight situation (e.g. expressed as daylight factors). Further, geometric properties of the building without any influence on the lighting can completely be ignored for the simulation (e.g. the thickness of a windowless rear wall of a room illuminated through the window in the front wall etc.). It can be highly time saving if such reduced geometric models are input into the simulation software.

Since three-dimensional geometry models are needed as input for the simulation software it is useful to simply enter complete 3D objects. It is much faster and easier to input predefined complete objects and to adapt their properties afterwards than to construct each object out of nothing. So, a step to a fast and simple input of 3D geometry is to select objects from different groups. These groups of objects can be solids, holes, variations, luminaires, views, and lux-points. Actually, these are all types of objects required for 3D geometry input into a lighting simulation program.

The group solid contains all conventional building parts divided into according subgroups as room (objects as room shape, wall, posts, louvres, ceiling etc.), roof (includes objects as saddle roof, sloped roof, shed roof, etc.), window, shading, furniture, surroundings, human, usage and others.

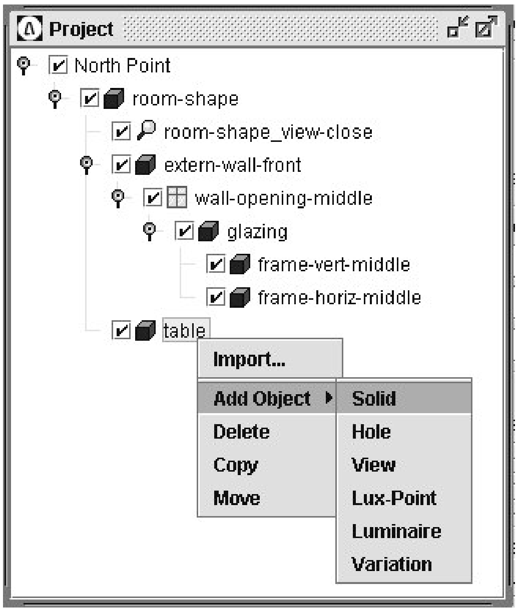

Figure 3: Adding 3D objects to the project

The group holes contains, also divided into subgroups, objects that perform Boolean operations of subtraction onto the solid objects.

With those two groups of 3D objects, solids and holes, the whole geometry of the building can be defined. In order to enable comfortable construction of geometric variations of the building it is very useful to have such an object as variation which simply takes over 100% of the geometric properties of the basic version. The variation object including the whole structure of the geometric model it is added to provide the basis for a new, complete version of the according building (or building part) where modifications and revisions can be carried out.

After the geometry of the simulation model is completed it is necessary to add luminaire objects which shall be chosen from the group luminaires.

From the perspective of later evaluation of the simulation results it is helpful to be able to add chosen views as further objects to the simulation model. Furthermore, for the calculation of the illuminance level or daylight factors the object lux point would offer a simple and fast method of adding predefined fields with points on which illumination values can be calculated in the lighting simulation.

A further step towards fast and easy 3D input to the simulation program is the use of templates. Therefore, libraries should not only contain predefined 3D objects as described above, they also should additionally contain whole subsystems of buildings and building parts. A wonderful subsystem template would be a classification of standard room types. There are 8 different types of inner rooms according to [Sick, 2003].

These standard rooms are in particular the single-sided lit room without external buildings as room type 1, the two-sided cross-directional lit room without external buildings as room type 2, and the two-sided opposite-directional lit room without external buildings as room type 3. Room type 4 stands for the single-sided lit room with fornent placed external buildings and room type 5 shows the single-sided lit room within an atrium situation. Room type 6 is represented by a room being illuminated from above via single skylights, as room type 7 it is lighted via roof sheds instead and as room type 8 it is lit through roof laterns.

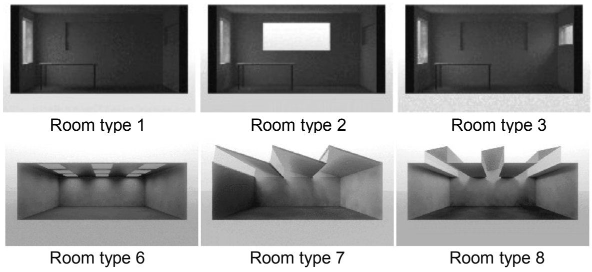

Figure 4: Standard room types according to [Sick, 2003]

These types of rooms provide useful templates for the models used in lighting simulations since they can be parametrized by modification of their specific values (dimensions, window openings) and thus allow very fast adaption to the properties given in the actual project. Such it is possible for example to derive an office room from room type 1, a classroom or shop with shop windows from room type 2 in the twinkling of an eye. An example for room type 3 may be an office room with glazing above the entrance door. Room type 4 can be the basis for a living room with external building arrangement on the other side of the street and room type 5 for an office connected with and lighted by an atrium. Room types 6, 7 and 8 provide the templates e.g. for coliseums and industry halls.

Moreover, it is time-saving if these modified rooms can arbitrarily be copied and moved within a bigger over-all geometry. For example, think of the use if the three kinds of existing office types in a big office building can easily be put to any desired location within the building where the daylight situation shall be examined.

Also other kinds of templates to take advantage of in quickly inputting 3D geometries are imaginable such as building extensions and attachments, as well as different types of facades.

To speed-up the 3D input for the lighting simulation the modification methods can be made easy by minimizing the input effort. This can be done by a concept of transmitting geometric properties of objects to other objects comparable to heredity. There are three kinds of possibilities conceivable for passing on geometric properties from one object to another: One the idea of a unit editor for easy parametrization, two is the conception of parent-child relation implying methods of placement, rotation, and multiplication of objects and three is to derive new objects from planes of objects.

The unit editor would offer the opportunity to describe geometric connections between 3D objects. Thereby a central fast modification of geometry as well as a compact documentation of the input can be achieved. There are three types of units which have to be definable: length [m], angles [°], and number [x] can be assigned to any numerical value. By the unit editor the geometry of the project can be changed very fast at a central point. Given the possibility to create (edit) suitable units modification of certain 3D objects within the model can be done quickly and readily. Typical unit names targeted on are floor-to-floor-height, ceiling thickness, louvres slope, or wall thickness etc.

Besides the mentioned units there is the special unit [%] which would originate parent-child relations. Often it is very useful that the geometric properties of 3D objects are dependent on those of other objects which are kind of superordinated. By input of a numerical value with the unit [%] geometric properties should be passed on from the parent-object to the child-object. For example, a bounding wall of a room shall be 100 % as wide as the room width. Furthermore, modifications of such a parent-object should be followed by automatical adaption of the child-objects. For example, if the room width is enlarged the bounding wall has to adapt itself to the new width. Every object in the tree of figure 3 has its own coordinate system in which the next object can be described.

Also an option for deriving new 3D objects out of planes of other objects can be an interesting feature assisting fast and trouble-free geometry input for the lighting simulation. This is also a case of parent-child relation. If the form of the parent object is changed the connected child-objects adapt themselves automatically to the new geometric properties.

Especially for the placement of objects the parent-child relation is very helpful because the position of a child-object is based on the coordinate system of the parent-object. This means, for example that a window opening is easily placed in the middle of the wall and stays exactly in this central position even if the wall or the window is enlarged or shrunken. The existence of a local inserting and fulcrum point which can be located in dependence of the according object would perfect the placement of 3D objects. An offset percentage of 50 % in the directions of width and depth would set the inserting point in the middle of its basic plane. For example, this would make easy the placement of columns onto a grid where they shall stand concentrically on the points. In its function as a fulcrum this offers excellent help for rotating blinds.

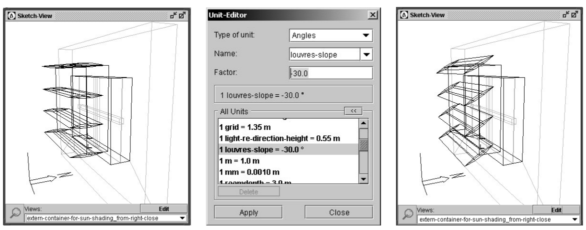

Figure 5: Easy rotation of blinds by changing the louvres-slope angle

The parent-child relation of objects also possesses significance for the multiplication of 3D objects. Any object that is needed in a large number could get multiple child-objects with exactly the same geometric properties. For example, a system of louvres with the same rotation angle could easily be constructed.

Easy and therefore fast geometry input for the simulation program also serves to minimize the source of errors. For further assisting of avoiding input errors it is important to provide a visual control of the entered geometry model. The lighting planner should be enabled to examine and verify his model from any desired view. Thereby any 3D object in his project should be singly selectable for visual checking.

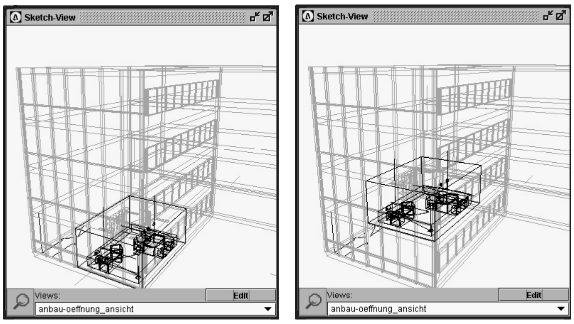

Figure 6: Easy and fast change of geometry - A room with all contained objects can be shifted in a building one floor higher.

All these supposed options for a fast and easy 3D geometry input for a lighting simulation represent a new concept for preparing a simulation model that is the basis of lighting planning. By all the described advantages the planner would be able to construct his model more quickly and fuss-free and thus to perform proper lighting planning as described above. For, as already mentioned, only a fast input with easy modification possibilities can secure the examination of a sufficient number of variations that are necessary for lighting simulation as an optimization process.

3. CONVINCING RESULTS OF THE LIGHTING SIMULATION

Before starting the lighting simulation lighting properties such as colour, roughness, transmission, reflection etc. have to be assigned to the objects of the geometric model. Also luminaires including specific light distribution curves and daylight redirection systems can be inserted if necessary. For our example - the office - a shading device of horizontal louvres is added to the south facade of the building (figure 7).

For optimization it is very useful to create variations of the basis model. These variations can be several geometric modifications. As mentioned above a sufficient number of possible changes of the building geometry should be examined for adjusting daylight inlets according to the requirements. Often also variations concerning the lighting properties are required for examining the effects of using other materials in the particular room. Investigation of special conditions of solar radiation is another reason for using variations. The daylight situation in the room depending on certain daytimes are a matter of interest as well as the daylight supply in reliance on the season and simply the influence of a cloudy or a sunny sky. Variations enable the simulation program to calculate different scenarios of lighting for one project: only daylighting (e.g. in times with enough daylight available), daylighting and artificial lighting combined (e.g. workstation in an office with single-position lighting), and only artificial lighting (e.g. by night).

After variations of the topical room have been built the lighting simulation is performed. This is done by reproducing the real lighting situation mathematically according to the settings of the variations. Serious lighting planning by simulation makes only sense when the calculation engine works properly. Therefore, internationally acknowledged calculation engines such as Radiance [Ward, 1998] which work on a scientific basis and the front-end Rayfront [Mischler, 1999] are used. These physically correct results can be luminance images for chosen views, illuminance values, or daylight factor courses. Also the daylight autonomy can be calculated.

Figure 6: Results of luminance images, according to human perception of the eye with solar irradiation. The cross section of the office room and the view from a sitting person at the working place shows how the room looks like when there are louvres in front of the southern facade and a down-to-top roller blind at the windows of the eastern facade. The sun position is scheduled to the 21st March at 10:00 o'clock in Braunschweig Germany (Latitude 52,1° N).

Also the daylight factors in the ground plane, calculated by an overcast sky, can be used to determine the daylight autonomy [Hennings, 2002] for the office.

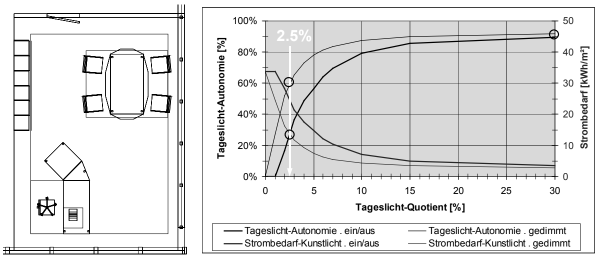

Figure 7: Results - daylight factor and daylight autonomy for the office room for the lighting zone of the working area in the lower left of the ground plane

It can be seen that a daylight autonomy of 27% during the occupied time can be achieved when a daylight factor of 2.5% is reached in the lighting zone. The artificial lighting is switched on when absolute illuminance level is reached. The calculation based on an hourly basis of the horizontal diffuse solar irradiation.

After necessary variations have undergone a lighting simulation it is very useful and working-time saving to obtain a documentation of the work done by mouse-click (Figure 2) to see all inputs and results in comparison of the variations. Also the achieved improvements can be quantified.

CONCLUSION

After the input of the geometric 3D model into the simulation software the lighting simulation is performed. As we have seen above it is important to calculate variations if an optimization in regard to the lighting of the building design shall be achieved. Using a scientifically acknowledged calculation engine physically correct and convincing results are delivered which provide the basis on which recommendations for measures with guaranteed effects can be made.

So, as we have seen the advantages of daylighting planning by simulation are manifold. By use of a fitting software program including fast geometry input which provides simple, fast, and convincing daylight simulation the economic efficiency is secured. For the specialist planner and consulting engineer daylighting planning by simulation provides planning security. Economic workflow through working time saving processing minimizes the costs for lighting planning. By the way, carefully planned artificial lighting is a guarantor of environment friendliness and economy related to the artificial lighting device.

All in all, daylighting planning by simulation means quality assurance for the building owner. And - most important - for the user of the rooms a lighting planning optimized by simulation does not only procure the daylight optimized for his tasks of seeing but also an increase of visual comfort which is an improvement of the aspect of health, vitality and productivity. Further the user gains from a upgrading of architectural quality since a proper lighting planning serves atmosphere and aesthetics. In other words, easy, fast, and convincing lighting planning by simulation means optimization and contributes to the development of better buildings.

Economic lighting planning by the use of lighting simulation is monumentally dependent on simple and fast input of the virtual geometric model into the simulation software. Thus, a planning tool with very easy-to-use 3D input is one key to simple, fast, and convincing daylight planning in practise.

ACKNOWLEDGEMENT

This document is meant to be a summary of the oral presentation from PLEA 2004 Conference in Eindhoven, Netherlands.

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