Application of the Lightsolve methodology for the pre-design of the new Belgian VELUX headquarters

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Through the example of the VELUX*Belgium* building, this paper presents a real case application of a new methodology that is being developed to favor an interactive and intuitive approach of daylighting in buildings in the schematic design phase. The Lightsolve method, under development, is based on an interactive goal-oriented approach, and provides visual representations of annual, climate-based data that rely on a combination of sky distributions using the ASRC-CIE model. This paper focuses on the use of graphical representation of climate-based daylight performance metrics (illuminance and glare metrics) combined with luminance renderings for evaluating the design options occurring during the pre-design stage of the building.

1. INTRODUCTION

VELUX*Belgium*, which is part of the VKR group, decided to build a new head office. The company, through an architectural competition, gathered together a multidisciplinary team leaded by the architect association "EVR-Architecten and Atelier 229", around a common will to realize a building in a sustainable approach. The main objective of the VELUX*Belgium* management was to provide to their employees high indoor comfort while reducing energy consumption and the environmental impact of the building. Extended use of daylight is one of the strategies applied in order to reach this objective. The 1500 m^2 built-up area building is located in Louvain-la-Neuve and is oriented along a NorthWest-SouthEast axis. This three-level building is divided in: a training center for seminar or workshop, a showroom to present VELUX products and offices for employees. The building construction follows a sequence of 90 cm wide modules. The main façades differ from each other by louver type (horizontal for the SW façade and vertical for NE façade). Its multi-sloped roof is North-West and South-East oriented and integrates several VELUX products.

Fig. 1 : Axonometric view of the building (North-East façade, pre-design status)

2. LIGHTSOLVE : AN INTERACTIVE GOAL-ORIENTED DAYLIGHT DESIGN APPROACH

Lightsolve, a work in progress[1], aims at supporting the design process using a goal-oriented approach that is based on suggesting design improvements iteratively. The main objective of the method is to analyze interactively quantitative daylight metrics and qualitative daylight criteria. The quantitative metrics all rely on the annual weather variation at the considered location. Their graphical representation over a year is based on the "Spatio-Temporal Irradiation Maps" representation proposed by Mardaljevic[2] and explained in details in [3]. The qualitative criterion is based on the visual rendering of the space, following the same year-division principle as the one developed for quantitative metrics. A more elaborated qualitative metric is under development.

2.1 Time-varied performance metrics

In Lightsolve, the daylight performance is assessed using climate-based metrics evaluating the dynamics of daylight over the year. Data are represented graphically as temporal maps so as to offer a condensed yet informative visualization of performance to a designer over the entire year, to facilitate the decision making process in the early stage of design. This representation is based on a time-segmentation method of the year into 56 periods and on the probability of occurrence of certain sky conditions within each of these periods[3]. Weather data files (TMY2) of the considered location are used to determine the latter in combination with the ASRC-CIE sky model developed by Perez[4], which proposes four sky types (clear, clear turbid, intermediate and overcast). The method is described in detail and validated in Kleindienst et al[3].

2.2 Temporal map representation and goal-oriented metrics

Temporal maps[2] are a powerful and intuitive way to represent the evolution of metrics over the entire year. The days of the year are plotted along the x-axis and the time of the day, along the y-axis (see Figure 2).

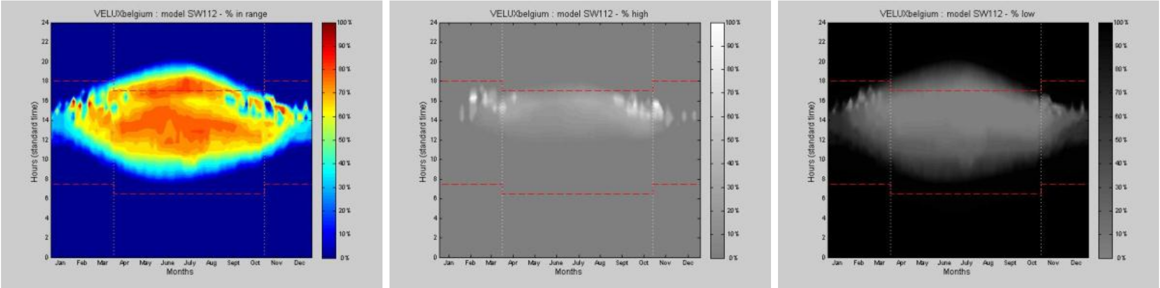

Fig. 2 : Temporal map for a south-west façade, 2a: % of area within target illuminance; 2b: % of area having too high illuminances; 2c: % of area with too low illuminances.

To incorporate spatial information in these graphical representations without having too many temporal maps or losing too much information through averaging, it was decided to choose a goal-oriented rather than an absolute metrics approach[3]. In the case of the VELUX building, the minimal illuminance value was set to 500 lux (with partial credits up to 300 lux) and the maximal illuminance value was set to 1000 lux (with partial credits up to 2000 lux). The metric represented on temporal maps in Figure 2a corresponds to the percent of area within this target illuminance (500-1000 lux). Moreover, additional information is given in Figure 2b and 2c which represent the percent of area having illuminance higher than 2000 lux and lower than 300 lux, respectively. All the calculations were done with RADIANCE although a new interactive global illumination system is actually in development and should replace RADIANCE in order to speed up the calculation procedure in Lightsolve[5]. In order to assess the risks of glare, the Daylight Glare Probability (DGP) index proposed by Wienold and Christoffersen[6], based on and validated with daylighting, was evaluated for one position and one view direction in the room. In this specific case, the DGP temporal maps represent either the DGP for the predominant sky type (Figure 3a) or the maximal DGP, namely, the DGP at the considered time, for the most glaring sky type, whatever its occurrence probability (DGP MAX in Figure 3b).

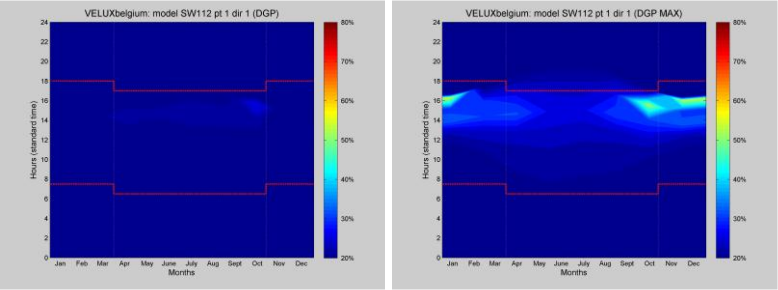

Fig. 3: Temporal map for a south-west façade: 3a: average DGP for a seated person (looking in the direction of the wall); 3b: maximal DGP for a seated person looking in the same direction – for the most glaring sky type.

2.3 Spatial visual renderings

Accurate visual renderings of the space are connected to the temporal maps in order to connect quantitative daylight performance to qualitative aspect of daylight. So, for each chosen period in the temporal map representation, a luminance view was produced. In this specific case, the option was to color the luminance views in order to extract the whole range of information held in these pictures. High Dynamic Range luminance views were also provided to the designers.

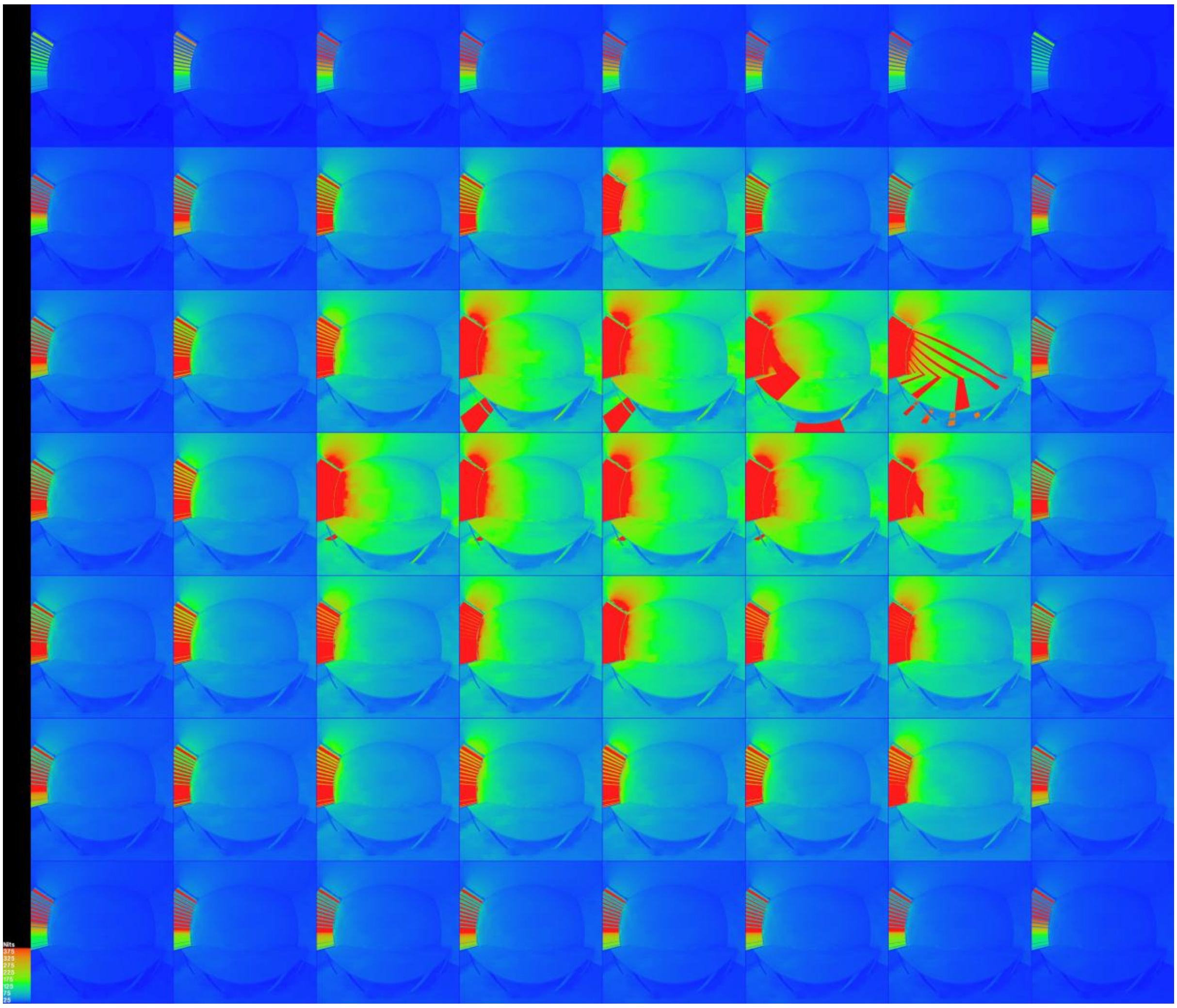

Fig. 3: Luminance views (false color in cd/m²) for 56 period of the year – day along x-axis and hours along y-axis.

2.4 Benefits of the Lightsolve methodology application in case of the VELUX project

Following the architect's demand, the Lightsolve method was applied to study the window width, height and position, the external louvers position, dimensions and slope as well as wall colors and the influence of an overhang. Beveled edges were considered too, as well as the position of the window in the wall. South-west and north-east façades as well as the roof windows were studied.

For both façades, the analysis emphasized the main parameters influencing the daylight quantity and quality in the building. This result is very important for the designers as a part of the global optimization process of their design, considering that daylight is only one parameter of this process. One particularly interesting conclusion is that some windows were too small. Indeed, sky conditions in Belgium are mainly overcast and intermediate and thus, too small window area should be avoided. As another consequence of the Belgian climate and the building geometry, the calculated glare probability was rather low, with the occupant view direction being perpendicular to the window and focusing on the work task, even without any shading device. It appears then that the louvers, originally designed by the architects using a traditional method based on the solstice sun position combined with a clear sky, were oversized. However, these conclusions are only based on daylight considerations and should be confirmed with thermal simulations.

3. CONCLUSION AND FUTURE WORK

Based on the feedback and discussions with the designers, we can conclude that the chosen metrics seem to be well accepted. The year segmentation method is well understood and the goal-oriented approach is efficient. In the case of the VELUX project, the benefit of the climate-based approach as opposed to the traditional Daylight Factor method is obvious as it shown that the daylight penetration in the building was too low. This observation was unexpected as in most cases the DF method leads to over-sizing of windows.

Even though DGP is a new metric, it was well understood and, in this case, demonstrated that the multiplication of sun protection devices was useless, from a daylighting standpoint. This observation also shows that it is essential to be able to link daylight metrics to a thermal metric in order to deal with the thermal aspect as soon as possible in the design process.

The temporal map representation of the metrics needed a little time to be well understood. Afterwards, it allowed architects to evaluate the lighting quantity and quality in the rooms, for a whole year, in one glance and, mostly, to compare the results to each others.

This work is the first application of the Lightsolve methodology on a real design case. It should be compared with other projects, if possible for a different location and climate type.

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