USER ASSESSMENT OF A NEW INTERACTIVE GRAPHICAL VISUALIZATION FOR ANNUAL DAYLIGHTING ANALYSIS

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ABSTRACT

Despite the abundance of daylighting design software, there are few tools which focus on annually comprehensive and climate-realistic data, and fewer which give performance as a function of time. Lightsolve, a tool under development, emphasizes the importance of full year, climate specific data in early stage daylight design. It performs a representative group of annual simulations based on TMY2 data and graphically displays the results using both temporal maps and spatial renderings.

With any new method, it is critical to determine if the intended audience finds it more useful than existing methods. Therefore, two user surveys were given. The first was given to practitioners and students attending a daylighting design workshop at MIT in January of 2009. Participants were taught to use both Lightsolve and Ecotect (with exports to Radiance and Daysim). The aim of this survey was to help validate the usefulness of Lightsolve's temporal approach and the intuitive nature of the temporal maps, and to observe architects' interaction with the software. Because of the limited number of responses, a different stand-alone survey comparing spatial and temporal daylighting data was given, mostly to student architects, in May of 2009. The aim was to judge how intuitive temporal data was to the inexperienced architect. This paper presents the findings of both surveys.

INTRODUCTION

There are many daylighting analysis tools, but few are both graphically intuitive and analytically comprehensive. Most available tools produce either renderings or numerical data for a single moment in time, a situation which is too specific to be of use to the designer and too time-costly to apply to annual analysis. Of those few which take annual data into account, none show the user how daylighting performance varies over time.

Programs like SketchUp and Ecotect have the ability to display time-lapsed shadows, and AGI32 can arrange sequences of the same image over multiple days or hours, but while interesting, these animated explorations don't give any indication of performance. The most useful time-based outputs available in tools today are Daylight Autonomy (DA) [1,2], and Useful Daylight Illuminance (UDI) [3,4]. Both metrics, which indicate the percent of occupied hours when a sensor point is above or between certain lux thresholds, are displayed in a spatial grid, as is often done with Daylight Factor or illuminance measurements. S.P.O.T. [5], Daysim [2], and Daylight1-2-3 [6], are three programs which provide calculations of DA.

Unfortunately, one cannot fit every desirable piece of information on a single clear graph. In order to show the variation of performance over space, Daysim condenses temporal information to a single number. The user may set occupancy hours (although not seasonal occupancy), which ensures the relevance of all daily data points, but the user does not know if the design fails in the morning, afternoon, summer, or winter. Unfortunately, many practical daylighting problems are caused by not anticipating the effects of sun angles and weather conditions – variables which are largely dependant on time of year and day. To fully understand these factors and to best judge the nature of a design's success or failure requires lighting data in a fourth dimension.

A very efficient way to solve this problem is by using temporal maps – color-scaled surface graphs with the year on the x- and the day on the y-axis. However, only a few explorations into their use with daylighting data have been done, and they remain largely unknown in the world of architecture. Two studies of note include those by Daniel Glaser and John Mardaljevic [7,8]. Both suggested that temporal data be displayed along side spatial data, and Glaser's work included "brushing and linking" (changing one data type as you scroll over the other) and one attempt to integrate the two into a single two dimensional graph [9]. As applied in existing tools, Glaser's Lightsketch (not widely available) [10] employs some of his data graphics research, and the tool Spot! displays direct sunlight data in a time-variant chart [11]. Most other examples do not involve lighting data.

LIGHTSOLVE

To answer the need for a new balance between spatial and temporal outputs in early design stages, a temporal-spatial pairing is being used in Lightsolve, a design tool under development at MIT that specifically focuses on exploratory, early-stage of design. Using CAD inputs from SketchUp, it performs a representative group of annual simulations based on TMY2 weather files and graphically displays the results as temporal maps and spatial renderings. The ASRC-CIE weather model [12] is used ensuring that, while all renderings are done under realistic skies, a block of transient data can be reduced to a single number [13]. Figure 1 shows the main features of the Lightsolve interface, in which the renderings update when the user scrolls over the temporal maps. In this way, the user can connect the time-based performance of the space with a realistic depiction of sun penetration and light distribution for a single weather type, or for the dominant conditions at that particular time of day and year.

The temporal maps themselves feature two goal-based metrics: one based on illuminance on workplane estimations, and one on glare risks. The authors are currently investigating the inclusion of solar gains data as a third metric. Specifically, for the first one, Lightsolve requires the user to enter a lux-level goal range for each illuminance sensor plane in the model, and the corresponding temporal map uses a color scale to show how much of that sensor plane is within the desired range. Instead of having to set a changing color scale to represent illuminance, the user is shown yellow if the sensor plane is within the given goal

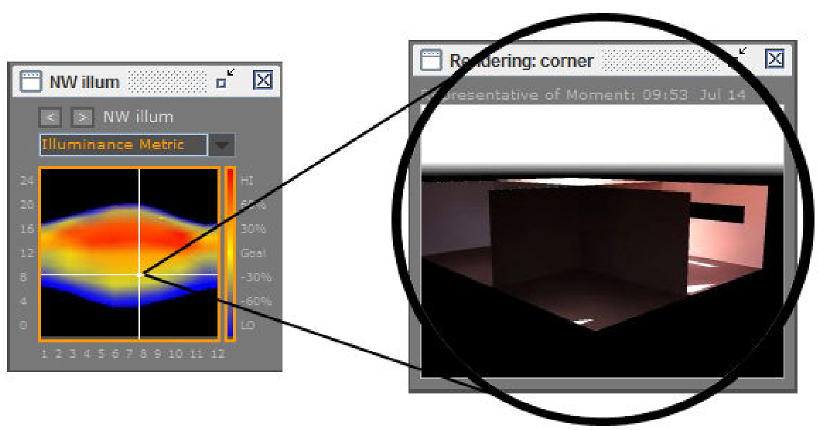

Figure 1: A piece of the main Lightsolve interface. The crosshairs in the temporal maps determine the time and date of the renderings shown below them. For color pictures, visit: http://daylighting.mit.edu/publications/Kleindienst09_UserAssessVisualLightsolve_Cisbat09.

range, red if it is too high, and blue if it is too low. The second ones, which are still being improved and are displayed as glare risk temporal maps, show the percent of vertical planes that perceive glare, as defined by Wienold's Daylight Glare Probability [14].

DESCRIPTION OF SURVEYS

Since one purpose of Lightsolve is to find more intuitive ways of presenting daylighting data to architects, it was essential to get feedback from the intended audience. Therefore, two formal surveys were given to complement informal feedback already received. The first was a comprehensive survey given in January 2009 to a small number of workshop participants. Held at MIT, the 3-day workshop taught participants to use both Lightsolve and Ecotect (with Radiance and Daysim), and assigned them a daylight design problem with which to practice using both programs. The Ecotect/Radiance/Daysim control group was selected as the most advanced set of daylighting analysis tools available. The survey given at the end of the workshop focused on software usability as well as data presentation, although only the latter is relevant to this paper. The goal of this survey was to determine whether participants created more successful solutions using Lightsolve's analysis format than with existing software. Regrettably, time was too short for the participants to go through enough design iterations of their project to enable such conclusions to be drawn, but the results regarding use of temporal data were still valuable. As a further exploration, another survey about data presentation was given which did not depend on learning or using Lightsolve.

In May 2009, a survey comparing data formats was given mainly to student architects at MIT. Given a basic model, daylighting goals, and resulting data in spatial format (as a control) and temporal maps, participants were asked to assess how well the model had achieved the desired goals. The model consisted of two 34 ft by 22 ft by 8 ft classrooms on a double-loaded corridor with punch windows facing either Southeast or Northwest. A second iteration of this model included an indirect skylight which gave some bilateral lighting to both classrooms. The given goal was to keep the workplanes of both classrooms between 400 and 2000 lux from 8am to 4pm between September 1st and June 30th in Boston. Spatial data was given as an array of falsecolor illuminance graphs for CIE clear skies at 9am, 12pm, and 3pm on December 21st, March 21st, and June 21st, for one 10,000 lux CIE overcast sky, and for daylight autonomy (with occupancy hours set as 8am-4pm and the illuminance threshold at 400 lux). Temporal data was given in the form of one temporal map for each classroom's workplane, showing the percent of the workplane which achieved the given goals (see figure

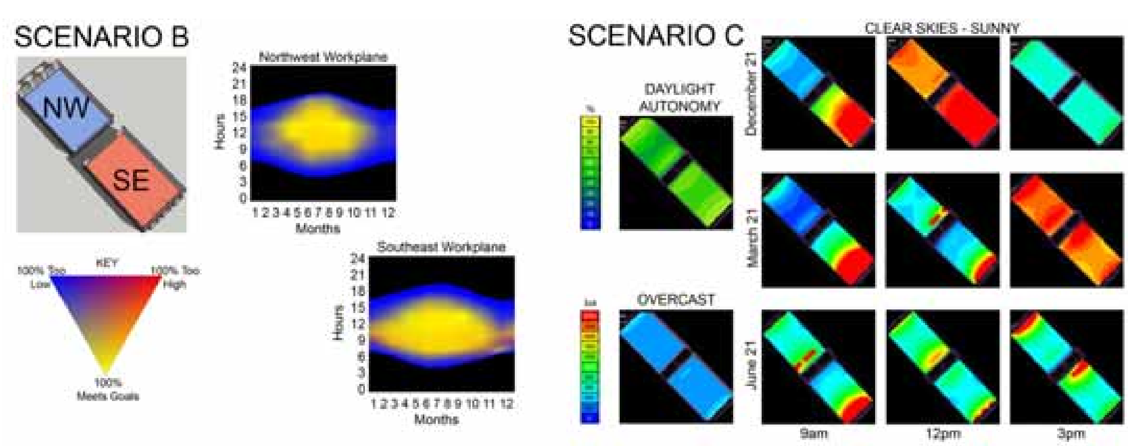

Figure 2: This figure is an example of the data used to compare available temporal and spatial data. Both scenarios represent the better of the two models (the original model very obviously did not let in enough daylight).

2). Before the survey, a very brief introduction to workplane illuminance, daylight autonomy, and temporal maps was given by the survey administrator. Photorealistic renderings were not given for either data format. Participants were not told which model they were assessing, and neither were they informed that there were only two iterations of the basic model. Finally, the survey was strictly timed – participants were given 3 minutes to answer questions about the first scenario and 2 minutes 15 seconds to answer the same questions for each following scenario. The restrictive time limits forced participants to rely on intuition and put a special emphasis on the speed of the analysis.

RESULTS

Lightsolve User Survey

Of the 13 people who took the LightSolve user survey, 9 were student or practicing architects, 3 were lighting specialists and one was an engineer. When asked how intuitive each program set was, they gave Ecotect an average of 2.86 out of 5, and Lightsolve an average of 3.55 out of 5. Although 3 people thought these graphs were sufficient to judge daylighting performance, 6 thought they were not, but nearly all agreed that adding daylight autonomy data really improved the analysis. Five of those who used the Lightsolve interface (which included both temporal maps and renderings) thought it gave sufficient information to judge performance, and all others skipped the question. When asked which program was more useful in early stage design, 10 of 13 chose Lightsolve, but when asked which was quicker to use, 8 of 13 chose Ecotect. This may have been influenced by Lightsolve's usability issues.

Data Formats Survey

Through queries about software experience, and familiarity with a number of daylighting terms, the 58 participants (mostly student or practicing architects) were shown to have little daylighting experience in general. However, one third was familiar with the term "temporal maps" and 22% said they could explain it. This is unusual, but unsurprising given that some students were familiar with the authors, and that a few lighting specialists were also surveyed.

The main body of the survey asked 6 questions about each of four scenarios (see figure 2). Paraphrasing, these questions were 1) did the scenario meet the goals during occupied hours, 2) if not, what was the biggest problem, 3) when do problems occur, 4) where in the room do problems occur, 5) how confident are you in your analysis, and 6) what other information do you want? The tallied responses to all scenario and follow-up questions are given in figure 3.

DISCUSSION

The consistency in responses to the temporal data (scenarios B and D) – especially questions 2 and 3 regarding what the problem was and when it happened – and the first follow-up question show that temporal maps are both readable to the untrained eye and quick, intuitive methods for displaying comprehensive daylighting data. Also, several participants commented on the "at-a-glance" nature of temporal data and the intuitive nature of the "goal-range" color scheme, although another comment unfavorably mistook the temporal maps as a collection of average illuminances. Both surveys, interestingly, revealed the architects' attachment to spatial graphics. Renderings and illuminance maps were the most requested pieces of "extra information" in question 6, and a surprising number of people revealed – through comments and confidence levels – an abiding faith in traditional single-moment illuminance graphs. The spatial data was also considered more complete, as the discrete illuminance graphs gave an illusion of temporal information. This can also be seen in the fact that nearly no one considered the spatial data "not enough information" to answer the time-dependent question 3

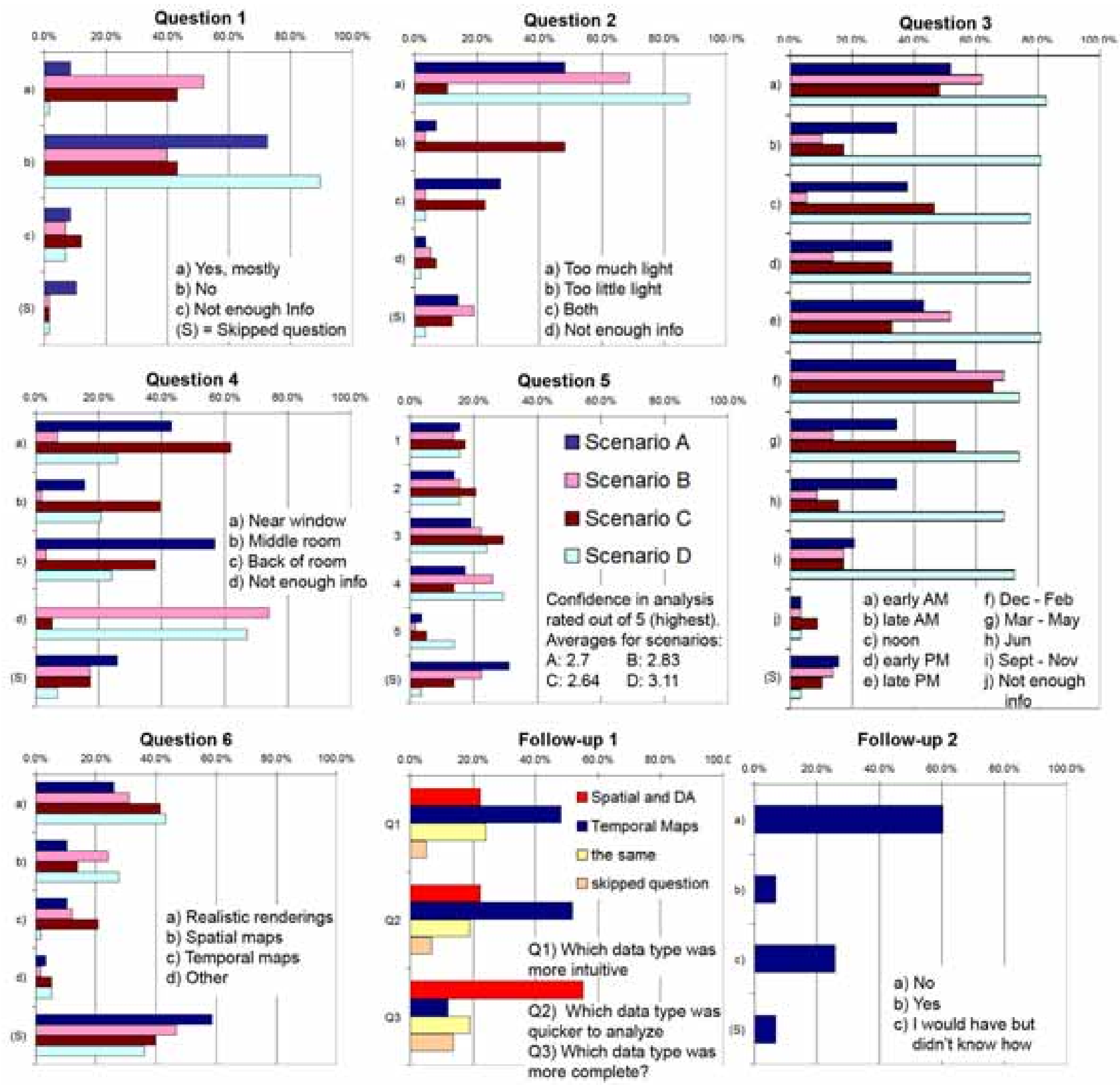

Figure 3: The results from the bulk of the data formats survey. Scenario A is the original model spatial data, B is the improved model temporal data, C is the improved model spatial data, and D is the original model temporal data.

(and the answers were highly inconsistent with each other), but the vast majority recognized there was not enough information in temporal maps to answer the spatial-dependant question 4. Finally, for the improved model, participants decided that the biggest problem was "too much light" when given spatial data, and either no problem or "not enough light" when given temporal data. This is most likely because too much attention was paid to the clear-skies illuminance data over the climate-specific daylight autonomy, while the temporal maps took Boston weather (which is often overcast) into account. The majority of participants admitted that they did not take weather into account when using spatial data.

Since there's a slight redundancy between renderings and spatial graphs, temporal maps could give daylighting data new depth. However, the choice should not be spatial versus temporal data – both should be used to create the greatest understanding of daylight performance.

There were a couple complaints that the time designations in question three were somewhat ambiguous (see figure 3) and that the spatial data page was found to be a little 'crowded' and ‘confusing’. It is also the authors’ suspicion that most participants ignored the daylight autonomy data in favor of the 3x3 clear sky illuminance graphs, despite the fact that the daylight autonomy graphs should have been the focus. However, it was not the authors’ intention to show that either data format was superior, rather to show the weaknesses of either without the other and to prove that temporal maps are intuitive enough for non-experts to use.

CONCLUSION

The goal of the surveys described above was to prove the usability and usefulness of temporal daylighting data and to show that, in combination with spatial data, they improve an architect’s understanding of daylighting performance. While the former claim is well supported by the results above, there is still some work to be done in demonstrating the latter. The authors plan to readdress the issue by administering a new survey in the coming month.

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