Helping architects to design their personal daylight

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Abstract: - This communication is based on a seven years experience of teaching day lighting to graduate architects coming from very different latitudes and climates. We first created didactic software to help them controlling sun paths. Later, we developed it gradually to support the common part of the problem: the geometrical one. With the same knowledge and tool, the students imagined very different projects, which reflected their different sensitivities and ideas about light, especially in its chromatic aspect. Their works confirmed us the evidence that the justified preoccupation about ecology and sustainability must not obviate the fact that good architecture is, first of all, an art. Our software, “Heliodon” (authors: Benoit Beckers & Luc Masset) [1] offers synthetic and original representations that allow the architect to develop its design freely, but controlling simultaneously space and time aspects. It complements commercial rendering software and is a fundamental component of a personal theory about light ambiances and color. The results are very original projects that blend aesthetic expression, geometrical control and environmental conscience. With this teaching, every architect is expected to discover his personal daylight.

Key-Words: - architecture project – daylight - solar radiation – geometry – projections - simulation

1 Introduction
In the last few years, the rendering techniques have known a spectacular progression, and it is now possible to produce very realistic images of an architectural project in a small number of hours, with the correct and detailed illumination of an edifice that does not exist yet.

However, many architects continue using manual methods in the elaboration of their ideas, and only few of them produce final renderings of their projects for a public presentation. The main reason lies in the fundamental difference between design and analysis. Although interactive rendering software are announced for several years [2], for practical use, the available commercial programs are still far too slow to be considered as design tools and their results lack of the necessary limpidity for a secure interpretation.

The sun moves throughout the day and year; a double sequence of renderized pictures, or a sequence of animations can show such a variety of paths. But they deliver so dilute information that these representations are impracticable in the design process, when the forms and orientations are still to be modified. It should be necessary to use a much more synthetic representation of the sun paths and of their effects. The render programs do not offer it because their main goal is photographic realism.

A software dedicated to design must offer computations and representations that should be fast (allowing interactive handling), synthetic (allowing the visualization of all the useful information) and limpid (with unambiguous interpretation).

However, regarding solar radiation, the energetic approach is not enough for architecture. Firstly, architecture is not only concerned by the thermal balance, but by the perception of the energies, as well. In second place, this perception does not depend only on the physical data, but also on their cultural and aesthetical evaluation.

2 The colors when Sun enters
The first example is a project by Dalia González [3], at Chilpancingo (Mexico), where the protagonists are colors.

Fig. 1: Project of a loft and sun-paths control
The chromatic proposal (only visible, obviously, in the color version of figure 1) is the result of a long and sensitive work realized on a mock-up illuminated by sun and sky light. A particularly beautiful effect is obtained on the reflecting hall ground, where sky meets with the high blue door, forming a blue continue reflection (on the left). Sun-path diagrams allowed the author to control the periods of the day and year when the light appearance shown on the images is really effective (on the right).

This is giving us the opportunity to propose some important comments.
1. The author preferred to use manual techniques (with painting and colored papers) to elaborate the chromatic project. Rendering simulation was considered too slow, and computer colors insecure.
2. However, she used the software “Heliodon” to control daylight along the day and the year. She accepted to study the abstract sun path diagram, because she needed the synthetic information it offers.
3. She neglected any thermal optimization, because she considered aesthetical perfection much more important.
4. She spent a lot of time in the mock-up, not only to obtain good pictures, but also because she knew that this student project would not be realized. So, the mock-up was the realization, the final result.

This work and these comments are representative of the difficulties and demands of the architect with respect to daylight. The question is: how digital simulation can help without changing the project, as energetic optimization software would conduct? The architects always have to deal with various criteria and any optimization has to be manual, with an interactive process allowing the designer to blend aesthetic and scientific notion.

3 Geometry and latitude
In the past centuries, every architect was working for his city, his region or, with a bit of luck, for different places of his country. All his projects were located at the same latitude. He had a practical and intuitive knowledge of sun paths in winter and in summer. He did not need to think a lot about that.

Nowadays, the architects travel and, what is more important, they study projects in reviews, which correspond to very different latitudes. So, they need imperatively to become sensitive to the differences of sun paths due to geographical location. The other components of climate are easy to describe with parameters (altitude, hygrometry) or general notions (maritime or continental location, dominant winds), but latitude is more surprising, because it has significant geometrical consequences on the architectural design.

For example, we can observe in Fig. 2 that London and Rio Gallegos (Argentina) are nearly at the same latitude, as Barcelona and Puerto Montt (Chile) or Moscow and Ushuaia. Diversity of climate is easily explained by the oceanic streams (Gulf Stream vs. Humboldt Stream), but it is curious – and not without incidence on architecture – that sun paths are equal in Buenos Aires and Fez. Despite very different climatic conditions, solar protection will impose the same geometric arrangements in these two cities.

So, it is very important to have the ability to perform the climatic simulations sustaining the project, in any living place, at any latitude. However, the actual knowledge of the atmosphere allows getting the relevant information about the sky characteristics only in the few places where complete measures are available since at least 10 years. Sky models exist to overcome the lack of data or their poor quality due to measurements performed too far from the analyzed site [5]. But their utilization is too difficult if the goal is helping the architect who has to take decisions in the evolution of his project.

However and despite the expected advances in this field, we will show that in numerous situations the architecture doesn’t need these data if the geometrical parameters (sun paths and sky opening) are fully available and easy to manage. Indeed, the quality of an architectural project depends more on the extreme conditions (sunny solstices, overcast day) than on the averages. The seasonal or annual energetic balance is important for the engineer but has no direct impact on the formal choices of the architect.
4 Design and simulation

Since the year 2003, we are developing the software “Heliodon” with the intention to realize a proper tool for aided design with natural light. We started with the direct sun light, using the classical stereographic representation.

The stereography gives all the information about sunlight for every hour of the year, but only at a point. In order to interpret it correctly, it is very useful to relate it with a shadowed top view, that shows all the space, but in an instantaneous graphic (the shadows correspond to a precise instant of the day and of the year). Heliodon presents three simultaneous views, completing the information with a 3D view, so that any change in one of them has instantaneous effects on the two others: moving the sun in the stereography, the shadows move in the two spatial views, while any movement of the sensor in the 2D view modifies the masks in the stereography.

This original and simple idea really enhances the tool, allowing the user to control the consequences of his modifications in the geometric model simultaneously in time and space, each representation balancing the limits of the two others. In this first step, we achieve the three requirements for a user-friendly design tool: speed, synthesis and limpidity.

The second version of “Heliodon” (2006) pretends to allow more computations without loosing the qualities of the previous one. We reached this goal using the particular properties of different projections [6].

Considering the stereography in its spatial aspect, we observe that it does not allow comparing the hidden portion with the visible part of the vault of heaven, since this projection does not respect the proportions between surfaces; so the solution was to implement an equivalent projection.

This is the second azimuthal projection we are using. If we examine the different azimuthal projections we will also observe after Nusselt [7] that the so called orthographic one will help us to compute the view factors necessary to solve the radiosity equations [8].

Today more attention is paid to these projections that share the characteristic of being able to provide larger field of view, e.g. to approximate omnidirectional shadow maps [9].

Considering the temporal aspect, again it is not possible to compare the hidden part of the sun paths with the visible one, because neither the hours nor the months are equidistant. Consequently, we had to invent a new projection, which we called isochronal, because in this graphics hours (horizontal axis) and months (vertical axis) are equidistant, property which allows integrating the sunlight duration in intervals defined by the user.

In Fig.3, a sensor located in a very simple building (at bottom right) defines a stereography (on top left) that can be transformed in an equivalent projection (at bottom left) or in an isochronal one (on top right). In the isochronal graphics, a grayscale indicates the variation of solar flux, depending on latitude, altitude and sun elevation (with a maximum when sun reaches the zenith).

The equivalent and isochronal projections can be evaluated on arbitrary plane sections, yielding, respectively, to sky factors or sunlight maps. We have observed, at this stage of the application that the user is accepting to loose interactivity because he is gaining more synthetic representations. This will give him a better control of his work and the opportunity to present some consequences of his advanced design.

Fig. 3: Stereographic, isochronal and equivalent projection of a simple configuration, with “Heliodon”.

In Fig. 4, two horizontal maps are calculated at ground level in the same example of Fig. 3: sky factor and sun flux. Sun flux is a daily average along the year, and it offers to the designer a global energetic balance of its project. The values are not realistic, because they assume a totally clear sky all along the year. However, such an approximation is already interesting for simple comparisons between different geometric configurations.

Fig. 4: Sky factors and Sun flux maps, with “Heliodon”
5 Daylight control in the project

The next projects are examples of the results obtained after an intensive lecture on daylight (three weeks), which led graduating architects to learn “Heliodon” and commercial rendering software, in order to dominate daylighting in the urban and architectural projects. They had to project a pavilion whose geometry had to be determined by sun paths. The site was “Plaza Cataluña”, Barcelona.

The first idea, by Marysol Bahena, Karina Figueroa and Alessa Benatton, is based on the sunset in particular moments of the year, when the quasi-horizontal sun takes along the main street (Fig. 5); correctly oriented, the pavilion seems to escort the sunset. There is no energetic idea, only a powerful but simple visual effect that needs a very easy geometrical consideration. To be shown, and understood by the public, such an effect just needs a good photomontage.

The second idea, by Christina Roussou and Fernando Maia, is based on a more complex configuration (Fig. 6): a minimal energetic control is necessary and is provided by the stereographic projections, where we can verify the radiation received by the different parts of the construction along the day and the year. A meticulous gradation of the transparencies results of this study.

The third idea, by Marisa Egea and Daniela Fronza, is a modular pavilion whose geometry changed in each season: it is smaller in winter than in spring/autumn and in summer (Fig. 7 at the bottom). The three dispositions are illustrated with maps showing the number of sunny hours, and this number is shorter inside the summer pavilion than inside the winter one: solar protection is thus efficient. On the top of Fig. 7, daylight is compared with artificial light in the night. These two pictures have needed a rendering engine able to compute radiosity (diffuse reflection), and the final photomontages appear very realistic. However, the entire project has been designed with “Heliodon”, and the renders had only an illustrative purpose.

Finally the project presented by Cecilia Betti, Oscar Martinez and Montse Puig, is a walk that is progressively guiding the visitor from the outside light to the obscurity of the central path (Fig. 8). The shape and the spacing between the wooden slats are fully determined by the double intention to get protection against the sun and to filter the sky light. The principal control parameter is the sky factor whose values are progressively transformed to the same as those found in the great gothic cathedrals (3 to 5 %).
This project has been smartly optimized thanks to the qualities of the Heliodon software: speed of simulations and permanent graphical control. This kind of process could be automated, because, here, it is possible to formalize an objective function [10]. As in the previous projects, such an optimization process doesn’t need a full knowledge of the yearly meteorological conditions, but, it could be well performed by checking the sun paths only during solstices or equinoxes.

From our present experience, such a simplification also holds for architectural projects related to housing or public buildings. It is important to note this point. Indeed the present evolution of official regulations (light, but also thermal an acoustic) is fundamentally based on the determination of a global energetic balance. Today the simulation tools are rather limited and the consequence is the lack of precision in these balances. This situation leads to adopt precautionary measures that limit the formal creativity in the project.

The examples presented here show that there exists an alternative logic that can help the imagination with a minimum of constraints, allowing at each step of the design an effective control of the energetic consequences of every decision about shape and materials.

6 Conclusion

Presently, young architects use easily a lot of software in their designs. However, most programs are oriented to analysis and not to design. Thus, they are mainly used at the final step of the project, when the principal ideas are already defined, and all their possibilities are not apprehended.

With “Heliodon”, we pretend to participate directly in the design process. The first consequence is that the other software and tools are enhanced, because they benefit of the greater conscience of the designer with respect to sun paths, local conditions and daylight.

Using “Heliodon” from the beginning of its development, the architect students have constrained the programmers to optimize continuously interactivity and graphic quality. So, this software is a perfect one for architects because it allows them to design freely, controlling both time and space aspects. The presented projects consider aesthetic expression, geometrical control and environmental conscience. Finally, the architect can find here his personal daylight.

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