469: D-LITE: a new perspective for searching and selecting light-control technologies as a designer

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Abstract

Even though a large variety of innovative façade technologies has been developed to refine the control of solar radiation and increase the amount of useful natural illumination, their effective implementation in buildings is still uncommon. Increasing the awareness of designers to their existence and facilitating an understanding of their potential thus appears as a priority. An important step in that direction is to make the search and selection process more intuitive. This paper proposes a way to address this issue with a new database format. It focuses on the generation of visual strategies to express technical aspects and performance data with a more intuitive and architecturally based language, adapted to a designer's needs and respectful of a realistic design process. The project takes shape as a freely accessible online *d*atabase of light-interacting technologies for envelopes, available at www.d-lite.org, that provides an efficient meeting space for professionals in the field.

Keywords: light-interacting technologies, energy efficient building envelopes, sustainable design

1. Introduction

Buildings play a predominant role in today's energy and environmental crisis, as they are responsible for 68% and 39% of the total electricity and energy consumption in the U.S., and for almost a quarter of the global annual energy needs of the planet [1]. Amongst the different end-uses of this energy, lighting purposes causes particularly high costs in terms of energy, ecological impact and economics [2]. Therefore, maximizing our reliance on natural lighting (daylighting) rather than electric lighting positions itself as a priority. The building's envelope, as the interface between exterior and interior environments, is of course the key element to effectively control this resource.

Controlling how solar energy is received and used or redistributed by building envelopes has taken shape in a wide range of technical solutions, such as complex glazing and shading systems and devices for redirecting the direct (sun) and diffuse (sky) components of natural light [3,4]. But, formalizing these different technologies as systems applicable to architectural spaces has been presented with certain limitations.

Although architects can easily get an understanding of the aesthetics of an enclosure that would include such components, they remain, in current catalogues, publications and selection softwares, primarily presented from an engineering point of view, in a format inappropriate to the needs of architects. As a result, a large portion of state of the art daylighting systems remain unknown to the majority of architects [5]. Furthermore, these emerging technologies are still distributed between research and commercial stages and it seems designers, at best, incorporate these technologies in their projects *a posteriori*. To make matters worse, there is no standard metric and no database of Bidirectional Transmission or Reflection Distribution Functions [6] available yet even for the commercially available products.

This research proposes to generate a database that provides an exhaustive directory of light-interacting technologies, together with an adequate way to present, classify and navigate through the information. Technical data are simplified and expressed through architectural means. The search process is based on the ability to easily compare different systems (which ultimately will guide the user towards an "optimal" solution).

The overall objective of this project is to generate a platform through which to engage architects in the area of advanced fenestration technologies and promote collaboration between designers, scientists and manufacturers to obtain functional and better integrated solutions.

2. D-LITE: Database of Light-Interacting Technologies for Envelopes

Besides the motivation to promote architecture that is environmentally responsive, this project intends to address two issues critical in our contemporary social context: the colossal amount of information produced and disseminated and the velocity with which this

production happens, provoking continuous needs for almost real-time updates. Combined with the proactive character of today's society, it appeared that a web-based format for such a database, envisioned as a free online resource, could become a powerful vehicle to disseminate information particularly adapted for the target audience. Amongst some of the critical capabilities a database should have, we focused on an efficient data sorting and retrieval and on enhanced web interactivity.

In terms of database content organization, several criteria can be used to classify light-interacting technologies. These include: scale of the systems and physical characteristics, optical properties of the materials involved, position in the building, functionality etc. For these "performance driven" systems, and since the user will search for solutions to answer specific needs of a design project, it appeared to us that their functional aspect should be at the core of the search process and is therefore the criterion that organizes the database structure.

The structure is based on two key concepts:
. First, the generation of a catalogue is understood as a dynamically interactive infrastructure (search interface) through which the range of technologies can be accessed.
. Second, the representation of these light-interacting technologies is architecturally based.

These concepts take place as complementary steps when using the database. The user is first invited to navigate through the database from a search interface or matrix (section 3): this is when the user selects a certain number of searching "filters" (criteria) that the façade technology needs to fulfil. In response to the user's input, the database search structure adapts its "offer" of

suitable light-interacting technologies. When the user is willing to access the description of a particular system, a second working space opens to show detailed information of that technology that includes relevant information for that system, how it compares to others, and a visualization of how it interacts with light (section 4).

3. The search interface

The idea behind the proposed search matrix was to provide guidance towards adequate light control systems through different search paths. The flexibility of the system lies in the personalized selection of criteria allowing the user to be guided towards a suitable set of technologies that best fits his/her requirements.

This structure, in which all the data are connected at many levels, avoids the traditional hierarchical categorization (tree structure) that typically leads the user through a few pre-determined search stages. Indeed, these may prevent the selection process from being intuitive or flexible enough for the user's needs, or not adapted to his knowledge of the field.

The search interface consists instead of two sets of elements: a categorization matrix containing the set of light-interacting technologies clustered by categories or families; and a set of functions to filter the search for information.

At this point, one hundred and fifty seven light-interacting technologies were inventoried. The criteria used to group them in "categories" were based on their functional optical properties, which are closely linked to more general features such as shape, appearance, size, materials and building integration strategy. This first-hand classification was then refined so as to gather systems responding to the same set of search filters, listed below.
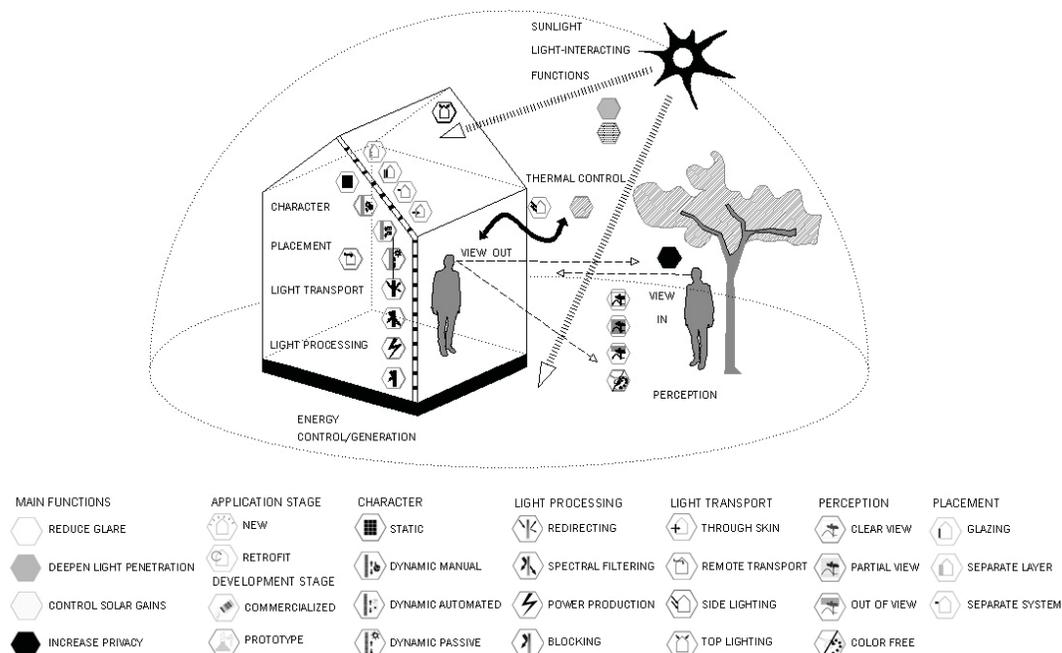

Fig 1. Envelope light-related functions and the identification of the set of searching filters.
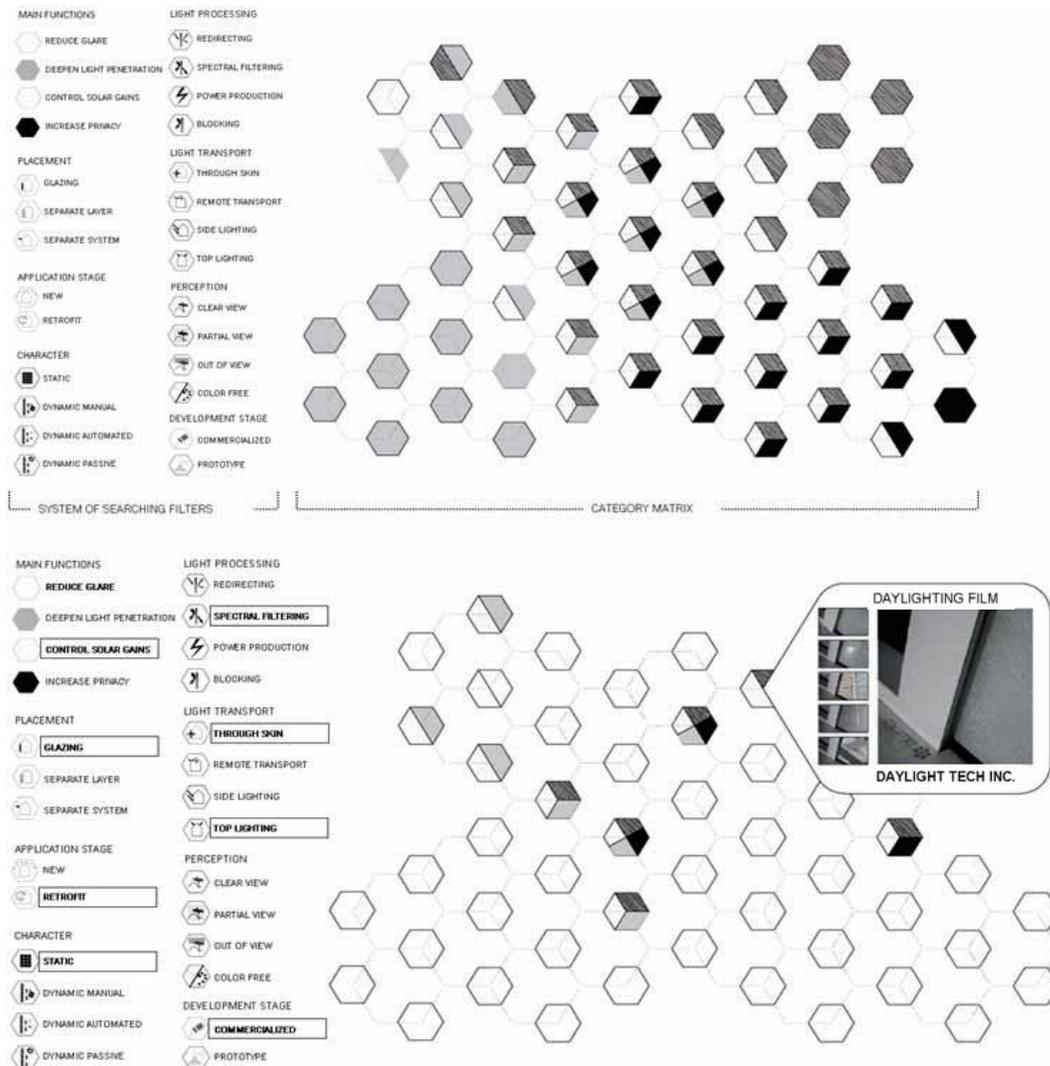
Fig 2. Searching interface and category matrix in two steps of the search process. Top: starting interface where no features are selected yet. Bottom: interface showing a stage in which several filters and a few hexagons-families are selected; one of the categories is consulted with the popup window showing the technologies contained.

Because users are likely to resort to more advanced light- or sun-control strategies to solve issues that conventional systems would have, we used the four following functions as the main filters to structure our search matrix: their ability to deepen light penetration, control solar gains, reduce glare and/or increase privacy. In addition to these, a list of desirable functions was established, which appeared to be closely related to architectural considerations and likely to be known by the architect early on in his /her search or design process. The list appears in Figure 1:

-*Placement* relates to key design factors such as integration, space and visibility of the technology involved (within the glazing itself, as part of a multi-leaf assembly or as a free standing system).

-*Application Stage* allows the user to identify technologies suitable to retrofit existing buildings versus those applicable only to new buildings.

-*Light Transport* relates to how light penetrates the envelope (`side lighting' vs `top lighting', through building skin vs remote guiding system).

-*Light Processing* describes the way in which light interaction occurs: light may be `redirected' (angularly-selective material), blocked (shading) and/or filtered spectrally (spectrally-selective materials), and it may also produce electricity.

-*Character* relates to the way in which the user will be able to control the technology: it may be 'static' (no control), 'dynamic manual','' dynamic automated' or 'dynamic passive' (responding to environmental changes).

- *Perception* determines how the system will be perceived visually, allowing a `clear view', a `partial view', or to be placed `out of view' (in a clerestory window e.g.); perception also relates to the intrinsic colour characteristics of the system (hence its capability to render colours accurately).

-*Development Stage* categorizes systems in commercialized' or prototype' (research) stages.

After the user has determined the most suitable list of functions for his/her design project, a "shortlist" of system categories is established, for which all the systems fulfil these characteristics. As a consequence, each individual category of systems has to include elements that all fulfil the same set of filters (criteria). The total number of categories is currently fifty three.

These categories are represented graphically according to an arrangement that expresses their light-control performance based on the four principal functions. These determine both their colour code and their position in the matrix, along or around the two cross diagonal axes. A hexagonal geometry basis was chosen because it allowed us to generate a compact diagram, able to grow in several directions and offering a convenient flexibility for future inclusions of new categories. Thus, each category took the shape of one hexagon, and in each of the fifty three hexagons the current one hundred and fifty seven light-interacting systems could be catalogued.

To use the search interface, the user starts by clicking on the desired functional and design features; through this action, only the families that fulfil the selected features will remain visible in the matrix, which allows the user to refine the number of product categories that are appropriate for his/her design project. To get more information about these categories, and the systems they include, the user has to click on the corresponding hexagon, which will activate a pop-up window displaying an image-based list of products belonging to that category, as shown in Figure 2. Then, the user can choose to view the description of a specific system by clicking on the corresponding picture, which is a link to its description page (opening in a new window).

4. Technology description page

The technology description page is meant to give a highly visual understanding of each product. It contains information about the chosen system itself, but also about its performance relative to the most recent selection on the matrix.

The structure of the system's description page is based on four sections. The first section presents a brief overview of the system. The second describes the system's performance mostly in terms of light- and or sun-interaction or control. The third provides a physical and mechanical description of the system. And the fourth presents one or more case studies to illustrate how it has been integrated in architecture from a global building design standpoint. Each of these sections is highly illustrated and visual. Indeed, designers are trained to understand space graphically, which makes it important to use the same language when transmitting information to them. Information is then more easily incorporated in an architectural project, but also conveys the sensation of belonging to the same

field, which should facilitate the integration of this search process in the more general design process and in the architect's usual body of tools.

4.1 System overview
The first section of this site is designed to present the selected light-interacting technology, comprising the following items (Fig.3): small simplified diagram to show the position of the family in the matrix; name of the system; name of the category, name of the system developer and the author of the patent (if applicable); clicking on either one opens a description pop-up that contains further links. Each of the performance filters has been assigned an icon that intuitively illustrate their function; the set of relevant icons is thus displayed across the width of the page. Finally, a brief overview text of the system is provided with a photograph of the system and a banner with links to the main sections of the description page.

4.2 System performance
This second section describes the system from the perspective of its light-interacting and/or sun control performance; it defines the technology involved and its main attributes.

Fig 3. Screenshot of the technology description page showing the heading of the site and the system's performance through physical models.

Because the vast majority of these systems would be extremely difficult to model with computer simulation softwares (either because their properties are not well known or too complex), we chose to resort to the more traditional (but highly effective visually speaking) physical models to represent the light redistribution capabilities of each system. The produced visualizations are thus very realistic (the colours and the systems' samples are real), bringing nearness to the designer's work environment. As mentioned before, the intent of this document is to show the performance, not assess it.

To generate images of these models, we used a fixed HMI spotlight producing a collimated beam of spectrum reasonably close to the sun's. The models were placed on a motorized rotating table [7] so that any incident direction could be investigated. Keeping the light source fixed and securing the camera, the model and the system

on the rotating platform, three angles of incidence were chosen, corresponding to elevation angles 25, 50 and 75 degrees (azimuth = 0). The modelled space is square in plan (60cm x 60cm) and 38cm high.

The set of scale model images is displayed to the user as a slide show. Two photographs of the model viewed in section (Fig. 3 bottom) allow the user to compare how light distribution is altered between standard glass and the technology's sample. An view outwards is also provided, at human sight height, in order to understand the system's performance in terms of visibility and glare.

An interactive performance graph, shown in Fig.4, provides an original an insightful way to compare the consulted system's performance (red) to the systems currently "shortlisted" in the matrix selection (grey) or, if preferred, only to the systems belonging to the same category (black). Along the horizontal axis, traditional performance metrics are represented, related to thermal behaviour, cost, solar factor, light transmission and light reflection. For active light-interacting systems, the chart represents the range of light transmission for the `on' and `off' states and their respective time response and power needs. Some systems also produce electricity, in which case the 'Power out' value is non zero. The vertical axis represents the value of these metrics, whose range is always expressed as an interval from a generic 'Min' to a generic 'Max'. The absolute value of these extremes is determined for each metric individually depending on the range of values found so far. Through this comparison, the user can find products with a better general performance than the one consulted, enabling a fast way to reach a more optimal solution for the user's demands (description pages of the other systems can be opened directly from the graph).

4.3 System description
The aim of this third section is to provide a description of the physical characteristics of the system and get a better understanding of its installation requirements. It contains a brief definition of the system, available dimensions and parts listing; notes about special materials, maintenance or geometrical features; and information about the system's optical properties and the performance of the unit as a whole.

This description is associated to a set of technical drawings mostly based on constructive details of the unit and to close-up photographs of the system. A selection of relevant literature references closes the section.

4.4 Case study
Case studies are meant to provide the designer with examples of applications of the system in existing buildings, with a focus on construction and building integration information. These case studies include information related to the project, the architecture firm and the date of construction. It also includes a general explanation of the project's daylighting design; and again, technical drawings, constructive details, photographs, global frames and close-ups of the system's installation in the building.

To provide an objective comparison between systems, all the description pages follow the same format in terms of page layout and type of content, and all the graphical representations are based on the same parameters (light incidence, viewpoint etc).

Likewise, technical drawings are expressed with a reasonably consistent level of detail for all the systems and case studies, defined so as to clearly express the architectural application of the system.

	U value	Cost	g value	T vis	R vis	T closed	T open	Rapidity	Power in	Power out
Min	0.01 W/m²K	100 US$	0.01 %	0.01 %	0 %	0 %	0.45 %	0.1 sec	0.1 W/m²K	0.1 W/m²K
Max	1.55 W/m²K	7800 US$	1.55 %	1 %	0.99 %	0.55 %	1 %	15.5 sec	15.5 W/m²K	15.5 W/m²K

○ show all systems in same category   ● show all systems in current matrix selection

Light Channelling Panel vs   [Chromogenics Electrochromic Glass   ▾]
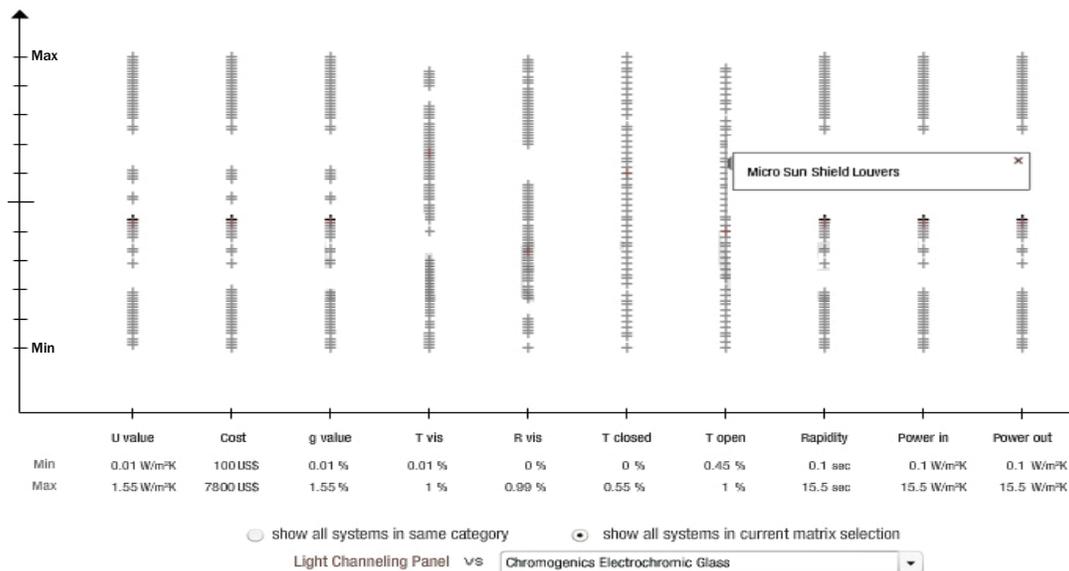
Fig 4. Screenshot of the technology description page showing the interactive graph where the consulted product can be compared with the rest of products of the database according to its energy performance.
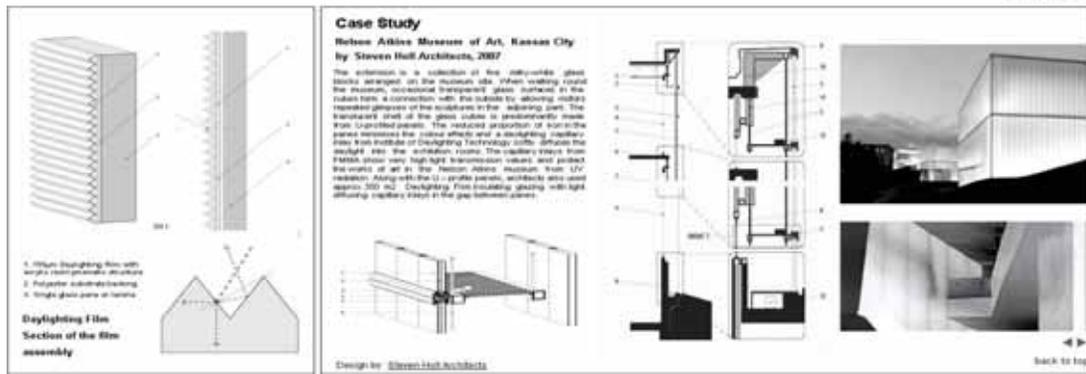
Fig 5. Screenshot of the system physical description with constructive and building integration information

5. Conclusions

This paper describes a new form of interactive database for light-interacting technologies, based on a format adapted to a designer's needs and respectful of a realistic design process. It relies on an flexible selection process of critical performance and façade design parameters relating to decisions the architect is likely to have made or be about to make in the schematic design phase. A major strength of the proposed system description format also lies in offering a comparative perspective amongst shortlisted options, including cost, lighting and thermal performance, construction drawings and relevant case studies. This search platform is now available as an on-line, freely accessible web-based interface at *http://www.d-lite.org*.

Because this project privileges intuitive, visual and easily understood information, it should ultimately be combined with a more in-depth level of technical information such as BTDF or BRDF data and advanced simulation program results [6], especially once these will be able to incorporate more advanced materials and be better integrated in the design process [8].

The intent of the developed platform is to enable architects and designers to visualize the performance of advanced façade systems in a meaningful way. Ultimately, this project seeks to support manufacturers in their product design process and to support designers in their product selection process from an integrated perspective. Offering a portal to show advanced façade systems intuitively will hopefully lead to even closer and more valuable links with the industry, including prototype developments and advanced capabilities for simulation tools for energy and light. The proposed designer-oriented, graphical and interactive search method will greatly facilitate the selection process of innovative façade alternatives. It will hopefully become the sorely missing link between the fragmented information a knowledgeable designer could find in existing resources, and the decision to try out a system or start a collaboration with a manufacturer. The outcomes of this research will enable a rising interest from the glazing and shading systems industry that will hopefully lead to further collaborations and to an increased awareness, and thus increased use, of such advanced façade technologies by designers.

6. Acknowledgements

7. References

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