ARCHITECTURE AS A REFERENCE FOR THE DEVELOPMENT OF A CAD LIGHTING TOOL

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Abstract. As light is increasingly perceived as a factor of quality of urban life, it is not surprising that cultural heritage buildings and even civil engineering works are being more and more often illuminated at night. The designers of the projects are revealing a nocturnal vision of the buildings which is often a reflection of the architecture: rhythm, pattern, evenness, symmetry, composition, axes, and so on. The idea of developing a "lighting-modeller" is based upon this assertion. Thus, if we express the needs in terms of functionalities, we can conclude that the hierarchical structure of the architectural edifice can fit in with a "lighting-structure". As a result, concepts like hierarchy, linking, grouping, networking, linearity-polarity, are the basis of the objects and functions that are effective for the great majority of buildings and projects. This "lighting-modeller" can then lead beyond its simulation capabilities to become a design conception tool: hypothesis and variants are quickly realized and tested, and technical data (illumination data, visual comfort) can be obtained as well.

1. Introduction

As light is increasingly perceived as a factor of quality of urban life, it is not surprising that cultural heritage buildings and even civil engineering works are being more and more often illuminated at night. The projects that define these illuminations can either emphasize the nocturnal vision of a particular building as a standalone highlight or be part of a greater plan to light up a city district or an entire town. In both cases, the designers of the projects are revealing a nocturnal vision of the buildings which, even though completely different from the daily perception, is still often a reflection of the architecture: rhythm, pattern, evenness, symmetry, composition, axes, and so

on. The idea of developing a "lighting-modeller" is based upon this assertion.

The second part exposes several existing illumination projects that point out various approaches to how light can contribute to architectural nocturnal vision. Afterwards we shall discuss essential particularities of existing software destined for simulation. The third part is a study of the usual methods for depicting lighting projects (artistic concept, texts, sketches, technical specifications as well as those more recently used -photo-retouching, empiric or physically-based simulation). The fourth part explains the concepts on which the lighting modeller is based. In order to do this, the Saint-Sauveur abbey-church is taken as an example.

2. Light traces the architecture

Since the last decade, illumination tends to offer other aspects than the functional one, as it had before: scenography, symbolism, graphic means of signalling, cultural heritage development, and so on.
These illuminations are realized through processes called "lighting projects", which are generally part of a greater design project involving a whole urban or landscape area: the light planning diagram.

Just like usual design and construction processes, there are several steps corresponding to a particular stake: work schedule, conception, techniques, methodology, budget, etc.
The program or technical specifications establish the administrative management of the project and the design competition, if any. They also define the area of the lighting project, urban and environmental interests, desirable lighting ambiances, photometric data and economic data.

We are interested here in the design step and more precisely we will try to explain how architecture itself is often the main medium for the lighting concepts of a project. We will discuss three examples: a building (museum), an infrastructure construction (bridge), and an urban space (place).

2.1. THE SAINT JEAN MUSEUM, QUITO, DESIGNER M. ALBOUY, EDF:

The two cloisters of this former hospital have been converted into a museum (See Figure 1). They have about the same dimensions, but they can be distinguished by the materials they are made of and by the proportions of their constitutive elements:

- the "Republican" cloister has a patio lined with four galleries. These arcades are massive stone pillars around the central fountain.
- the "Andalusian" cloister has the same spatial organization: galleries and central spring fountain but it is more flimsy because of its post-and-beam wooden structure.

Figure 1: Quito cloisters, Ecuador. MAP-CRAI physically based simulation.

The project design made use of these morphological and architectural differences, mainly based on the rhythm of the arcades and the materials of the structure. Thus two lighting modes were proposed:

- the first cloister is lit up with frontal and low-angled floodlights emphasizing the dimensions of the pillars. A lighting complement is given with a low-angle shot from below in the galleries as well as at the foot of each tree. The dominating light colour is a cold yellowish white.

- the second cloister can be seen as a shadow-show, the light coming from the posts' bases is widely spread on the yellow walls and ceilings behind. The wooden structure is rendered dark and the dominant light colour is a warm yellow-orange.

We see here clearly that architecture, forms, sizes, rhythm is guiding the design. The choice to deal with lighting-backlighting, warm-cold, high and low lighting is a consequence of an aim: to change the diurnal aspect of the building, revealing it through its differences.

2.2. THE NOTRE-DAME BRIDGE, PARIS, DESIGNER J-F ARNAUD, ECA:

Generally speaking, lighting projects of bridges call to mind concepts of linearity, overstepping, structure in tension. The bridge of Notre-Dame in Paris (Figure 2) matches these ideas induced by shapes and building construction techniques: two massive stone abutments, a continuous and thin breast wall and a metal arch supporting the block pavement with a complex metal lace.

The abutments are brightly illuminated, the breast wall gently and continuously underlined and the metal structure is seen against the light. The symmetry of the bridge is followed by the project and street lamps punctuate the sidewalks regularly.

The light designer chose to emphasize the lighting on each of the river banks (made of stone) and to minimize the lighting on the central part (made of metal) to render it thinner.
To achieve these goals, he based its project on the repetitive elements (guard rails, metal posts of the arch, street lamps) on the symmetry between banks and on some punctual elements (rustic work abutments, stone vaults).

Figure 2: Notre-Dame bridge in Paris, France. MAP-CRAI physically based simulation.

2.3. THE TERREAUX SQARE, LYON , DESIGNER L. FACHARD

This rectangular square in the city centre (Figure 3) is lined with two major buildings (city hall and Saint Pierre Palace) as well as by a row of houses about seven or eight storeys high. The outlying fountain by Bartholdi is dominating a mall with 69 small water fountains. It is intensely illuminated with a cold coloured light. The project emphasizes the official character of the main buildings: a framework of light sources underline the horizontal levels, the other facades are left in half-light. The horizontal plane of the place is criss-crossed by a network of luminous points, marking out the pedestrian ways.

Light is differentiating the geometric planes of the square and the various types of architecture:
- vertical planes of the facades of the culture heritage buildings, discreet luminous ambiance for the commercial shop windows,

- horizontal planes of the ground which strengthen perspectives, intense flood lighting for the fountain basin arranged like a polar array of immerged sources.

Figure 3: The Terreaux Square, Lyon, France. Photograph.

In this example as well as in the above, architectural geometry and spaces are the basis of the lighting project design. All the lighting objects are arranged depending on the arrangement of the illuminated objects.

These three examples create nocturnal visions of the architecture treating lighting far beyond its functional side. Thus we can consider that a simulation tool that would be able to trace a lighting structure on a building or space must include functionalities that are the same as those used by architects and urban planners when they design their projects.

Various simulation tools exist now, but few of them are involved in the design process of lighting, they often only focus on the accuracy of radiosity computation (Goral *et al*, 1984) and rendering or on technical outputs (measurements of luminance levels in the project, colour analysis at any point of the scene, for instance).

The DeskTop Radiance plug-in for Autocad is using standard commands to insert and orient spots lights. This excludes any relationship between architecture and light. The same goes for Phanie (CSTB) and Lise (LCPC) where the geometric model and the lighting scheme are independent, the lights being placed manually with their 3D coordinates.

With Speos Lighting Studio (Optis) or Inspirer or In-Sight (Integra) one can use the internal modeller to locate and orient the light sources and sensors. An attempt to link objects and light sources has been implemented in 3DS Viz (the former LightScape).

Thus we think that linking, arranging sources in networks or grouping them is a great help when designing the project which is elaborated according to architectural elements. The Modlum module has been developed to achieve this time consuming task, reducing it to a minimum.

3. Graphic representation of light and new technologies

Lighting heritage monuments is a recent activity, going back ten to fifteen years. Design and technical progress have been considerable. Projects were composed of several light sources that illuminated the building in its totality. Nowadays, lighting projects are more subtle and complex and can sometimes use several hundreds of light sources (Narboni, 1995). These lights reveal the architectural complexity. With the growing number of light sources used in a project, designers have difficulty presenting their project with classical methods. The jury for the contest (mayor, architects, …) encounters trouble imagining how the illumination will be, and the understanding of the project is not very reliable.

The presentation of a lighting project generally follows these steps: the artistic concept (see Figure 4), the lighting project by various means of graphical representation and finally the technical description of the material (kinds of light sources, position, aim, power, wiring, etc).
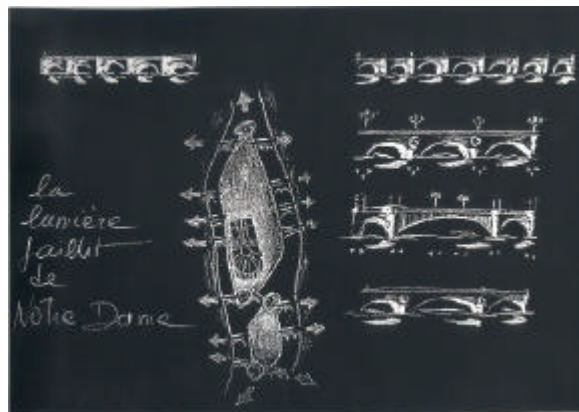

Figure 4: Louis Clair – Pont Neuf (Paris) : Sketch of the artistic concept.

Artistic means (watercolours, colouring, etc) (see for instance Figure 5) have been enhanced for several years by the use of photo-retouching software.

Night or day picture of the building is scanned and modified with the help of a graphical palette. Some tools allow the user to reproduce the effect of the light on a picture (see Figure 6). However, these kinds of performing software can not simulate the physical behaviour of the light. The resulting images show much more the artistic sensibility and the know-how of the graphic designer than the reality. We do not question the utility of such artistic images because they play a great part in the communication of artistic concept. Our goal is to provide additional tools for the designers that want more reliability in their representations (according to the real phenomena). *In situ* tests can be an answer to that problem. However, this brings additional costs (setting-up, adjustments, tests, taking down). That's why the utilization of performing tools for the illumination simulation (based on the physical behaviour) is of particular interest for the designers. These tools can be a great help during the conception stage but also for the decision makers as an aided decision tool. Indeed, it is difficult if not impossible for a non-specialist to imagine the result of an illumination. It is then essential to dispose of so-called realistic images.

Figure 5 : Roland Jéol – gouache for the Louis Philippe Bridge project (Paris)
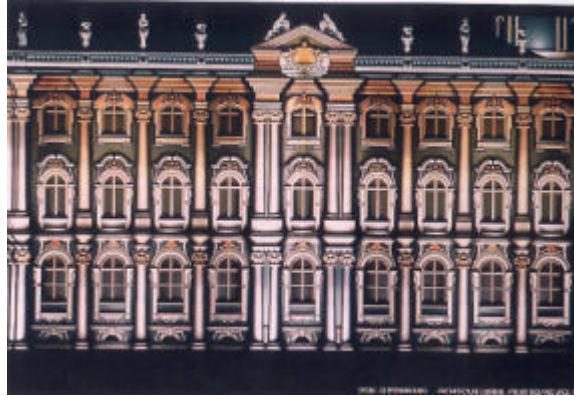
Figure 6 : Roland Jéol – Ermitage Palace in St-Petersburg (Russia) : photo-retouching

Even if the computer graphics image can not model the entire complexity of the illumination process (whatever the quality of the methods and software used), it simulates the reality in a better way than the other means of graphical expression and is useful for the understanding and the communication of the project. However, the produced images can never be considered as contractual for the contracting authority. S. Fiori (2001) in her PhD thesis analyses numerous aspects of the relation between graphic representation and light.

The design of an illumination project depends on the architecture it has to highlight (see Figure 7). This observation, based on the numerous projects we have simulated, is the starting point for the development of ModLum software.
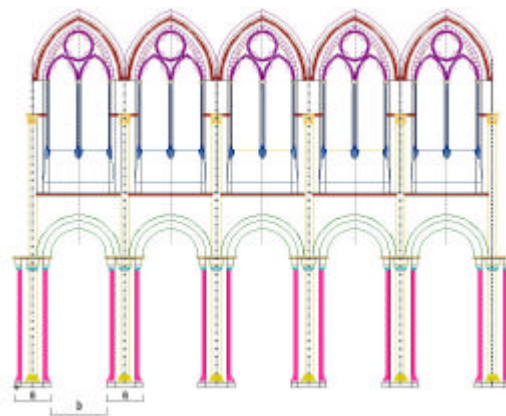

Figure 7 : St Sauveur de Figeac abbey-church: bay network

Architectural monuments can be described by a set of composing rules applied to architectural components. These components can be hierarchically organised. The rules are based on geometric computations such as translation, rotation, symmetry, scaling, and combinations of these elementary operations to produce general transformations (see Figure 8).
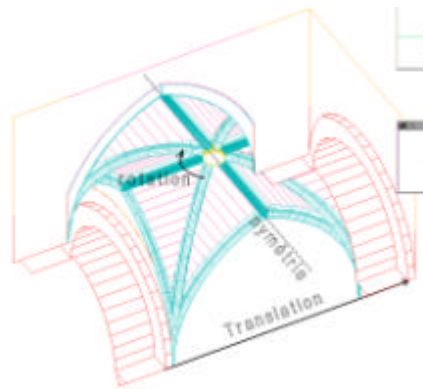

Figure 8 : Geometrical operation based modelling

The analysis of the architectural composition of a monument and its decomposition in basic elements allows us to understand the construction rules and to facilitate the 3D modelling. This hierarchical organization is stored with the 3D model and will be used during the setting of the light sources and their association to the architectural component.

4. ModLum

In this part, we will describe some specificities of ModLum software. To do this, the illumination of Saint-Sauveur abbey-church (Figeac – France) will be taken as an example. For a complete description of ModLum, see Chevrier and Perrin paper (2003).
The abbey-church is a Romanic and Gothic monument. Beginning in 1096, the work finished in the 13th century. The aim of the illumination project is to revalorise the inside and outside vision of the church by the illumination of the most important architectural elements: the nave, the choir, the transept vaults…The lighting must emphasize the regularity and the height of the building, by highlighting the columns and the left-right dissymmetry. The outdoor lighting has to bring out the stained-glass windows. The apse vault

deserves a special lighting as it is the oldest part of the church: a unique projector lights up the vault and the walls with a warm light. The nave is brilliantly put into light. On the contrary, the side bays and chapels are in relative darkness: just enough light to wander and to keep part of the mystery of these sides. There is no light source on the floor. The walker is guided by the lighted vaults.

4.1. POSITIONING A LIGHT SOURCE IN A SIDE VAULT

In order to assign a light source to an element, the user has to select this element in the scene (if it is a tree leaf) or in the hierarchical graph representing the scene (if it is an intermediate node in the tree). Then a specific window (Figure 9a) appears to graphically and numerically specify the parameters of the light. The principle is to use the bounding box of the selected element (manually adjusted to best fit the shape if necessary) to indicate the position and the aim of the light source. These values can be adjusted numerically.

A light source is also characterized by a kind of source, a representing colour and an intensity. A photometric 3D solid and an emission spectrum (both graphically represented) define a kind of source. The various kinds of sources are stored in a library, extendable by the creation of new kinds of sources from ModLum graphical interface.
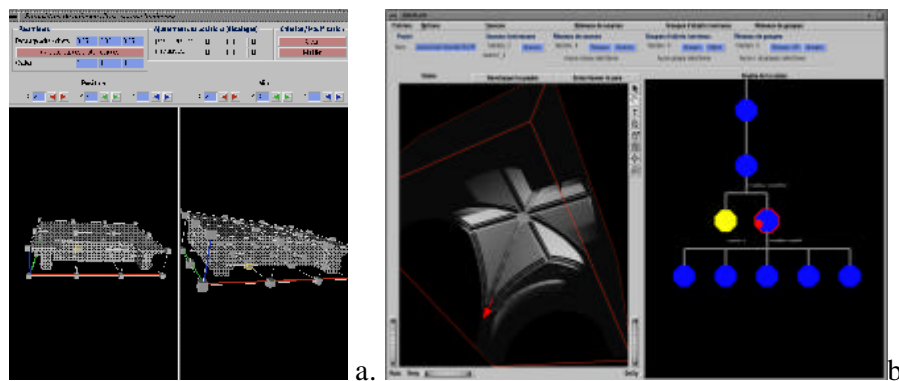

Figure 9. a-Dialog boxes for the creation of the light sources. b-The effect of the light source on the vault and the graph representation.

On Figure 9b, a rough pre-visualisation of the light source effect on its associated element (the vault) allows us to appreciate an approximate result: this computation is processed in real time with a local illumination model. Figure 9b shows also the scene graph with the representation of the light

source. To a light source is associated a set of handling actions: create, delete, modify and copy.

4.2. POSITIONING A LINEAR NETWORK ON A SIDE BAY

A light source network is a linear or circular organisation of light sources, allowing simultaneous manipulations (placement, orientation) of all the sources in the network (Figure 10). Required data for the creation of a linear network are the length and direction of the network and number of light sources. Length and direction can either be filled accurately with numerical values or approximately by pointing them in the geometrical vindow (a specific window appears like for a light source creation). A network is created from a light source and is attached to the same component as the light source.

Network light sources can be linked together (their characteristics depend on those of the primary light source ; modifying this source implies modifying the set of sources in the network), or can be independent (they are created with the same characteristics as the main light source but can then be modified independently of eachother).
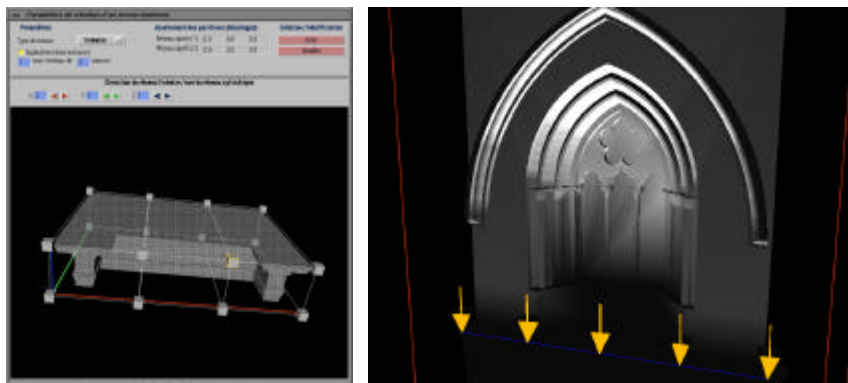

Figure 10. A linear network that illuminates a window

4.3. CREATING A CIRCULAR NETWORK IN THE CHOIR

A circular network is created in the same way as a linear network (except for an axis and angle instead of a length and direction) and has the same properties (Figure 11). The light sources of the network are obtained by rotation of the first light source around the specified axis.

4.4. CREATING AN IMPLICIT NETWORK OF LIGHT SOURCES ON THE VAULTS

A good hierarchical organisation allows one an easy location and handling of the elements in a semantic manner. Implicit networks exploit repetitive geometries in the model: when a building has been modelled in a hierarchical and modular manner, its model describes only once the repetitive elements; the whole geometry is then obtained by transformations of elements. In this context, affecting a light source (or a light source network) to an element automatically affects the same light source to every instance of this element (see Figure 12 where a light source was created for one vault and the other vaults are illuminated too). Whatever the modification to the light source is, it is transmitted to each of the associated instances.
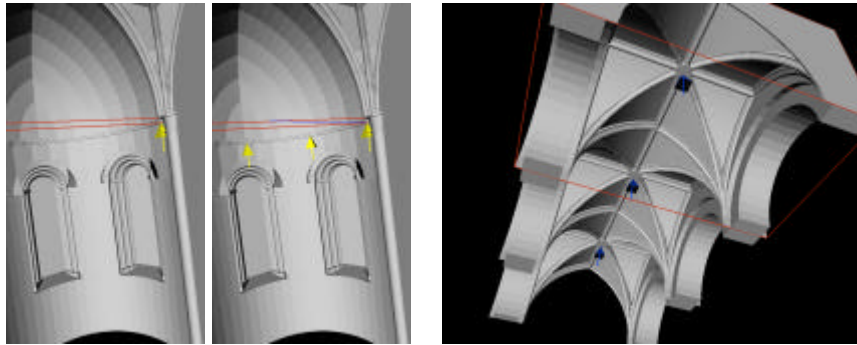

Figure 11. a circular network in the choir   *Figure 12.* Implicit network on several vaults

4.5. GROUPING LUMINOUS OBJECTS FOR EASY DUPLICATION

A set of luminous objects is composed of light sources, light source networks or sets of luminous objects. These luminous objects are not necessarily attached to the same architectural element. A set permits us to put together luminous objects linked to various architectural elements. Objects can be added or deleted in a set. A set can be duplicated (it means each element of the set is duplicated). A set is not linked to a scene component ; it does not dispose of any representation neither in the scene nor in the graph, except the representation of each of the luminous objects that composed it. The interest of a set is to duplicate easily and rapidly each of the members of the set (Figure 13).
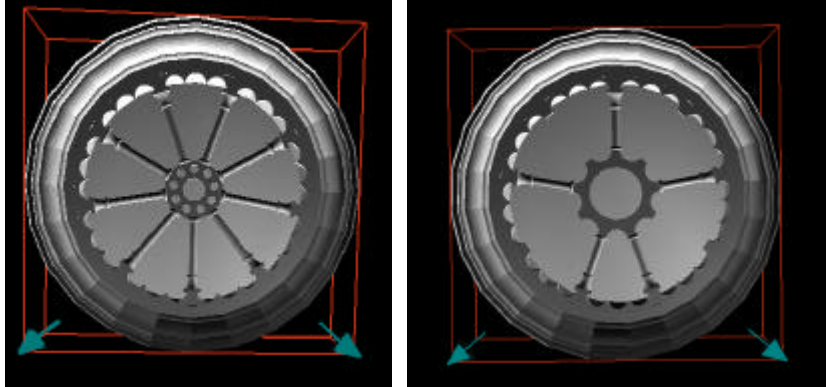
Figure 13: The illumination is processed with two light sources. These two lights have been grouped and the set has been duplicated with a translation to illuminate another element.

4.6. NETWORK OF SETS

The interest of a set is to duplicate easily and rapidly each of the members of the set. A set duplication creates a network of sets. Such a network is characterised by a transformation list (translation, rotation, scaling) and by the numbers of sets duplicated by transformation. This confers a great suppleness on the possibilities. As for the light sources in a light source network, sets inside a set-network can be independent or not. For instance, a set-network can be used for example to quickly copy the luminous objects of a temple column to the other columns.

4.7 ILLUMINATION COMPUTATION

On Figure 14 you can see the results of the computation on respectively the side vault bays, the choir and the nave. The illumination computations have been processed with Candela software, a prototype developed by the Isa[1] computer graphic research team.

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Figure 14. Figeac (France) MAP-CRAI illumination simulation

5. Future work and conclusion

We have presented in this paper specificities of illumination projects and the tool we have developed to help with the positioning of light sources, an essential and very time-consuming step in every illumination project. Such a tool can be a great help for designers (architects, lighting designers) in their illumination project design and for non-specialists in order to better imagine the results of the illumination. It offers interactive manipulation facilities, hierarchical handling of the light sources and real time simulation during the design step.

From the positioning of light sources in the Saint-Sauveur abbey-church 3D model, it emerged that several aspects were lacking:

- We should have the possibility to apply a symmetry of a light source according to a plane,

- A direct manipulation of a light source position and aim with the help of manipulators would be of great help.

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3DS Viz 4 avec plug-in LightScape: http://www.cgarchitect.com/gallery/galleryList.asp

DeskTop Radiance: plug-in Autocad: http://radsite.lbl.gov/deskrad/dradHOME.html

INSPIRER: http://www.integra.co.jp/eng/products/inspirer/applications.htm

Light 3D: http://www.optis.fr/software/html_software/light3d/software_light3d.htm

Lise (LCPC)   http://www.lcpc.fr/LCPC/Service/LISE/

Phanie (CSTB)   http://www.cstb.fr/gpc/logiciels/eclairage.asp

Optis   :http://www.tgs.com/pro_div/solution/optis.htm

SPEOS: http://www.optis.fr/metiers/luminaire.htm