ModLum
Illumination project aided design tool

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Abstract: Illumination phenomena simulation is important for architectural project design and communication: simulation tools must assist efficiently the designer; results have to be reliable and realistic for the decision-makers. Indeed, it is very difficult, for a non-specialist to imagine the result of an illumination from the light designer plans. Experience shows that the success of a photo-realistic simulation relies essentially on the choice of the light source characteristics and their correct positioning in the scene. This paper first presents the specificities of illumination projects (very large geometrical data bases enlightened by a large amount of light sources) and the difficulties of their set-up. Light arrangement requires tricky compositions, judicious choices and accurate studies. Currently there is no specific modeller for the handling of light sources as they are considered in radiosity software. Then we present the interactive tool we have developed, named ModLum, in order to set up light sources in a 3D architectural model in order to save time during the design step and simplify the source handling. ModLum specifications and principles are presented. Finally, an application is presented: the illumination project of two cloisters in Quito (Ecuador, South America).

1   INTRODUCTION

Illumination phenomena simulation is important for architectural projects for conception and communication: simulation tools must assist efficiently the designer during his research. Results have to be reliable and realistic for the decision-makers and the wider public. Indeed, one of the main difficulties is to present in a realistic manner an illumination project, with regards to real physical behaviour of the photometrical and colorimetrical properties of the light sources and of the material characteristics. Experience shows that the success of a simulation with photo-realistic software (such as Candela developed by the ISA team[1]) relies essentially on the choice quality of the light source characteristics and their correct positioning in the scene.

The lighting-modelling step requires lots of adjustments demanding intermediate

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computations, and thus is time consuming. It is also necessary to establish a work method aiming at improving this preparation step. A greater interactivity during this design step would increase the final results, so the use of ergonomic tools has to be the clue to the development.

This paper presents in the *second part* the specificities of illumination projects and the difficulties of their set up. We also present in this part the reasons that lead us to the necessity to have at our disposal other illumination conception tools. In the *third part*, we present ModLum, the tool we have developed to answer this problem by facilitating the positioning and the handling of light sources in an illumination project. We will finish with an application example, the illumination of two cloisters in Quito (*part 4*) before concluding (*part 5*).

2   ARCHITECTURE AND ILLUMINATION

2.1   Specificities

Light arrangement requires tricky compositions, judicious choices and accurate studies. Today, the improving performance of the lamps and light sources and also the great diversity of products are elements that answer the most exigent needs.

Luminous ambiance realization is a complex task, requiring the taking into account of considerations of several kinds: *architectural* for the volume organisation, *luminous* for the shadow and lighting area distribution, for the dazzle phenomena, but also *physical* for the light source chromatic melting, luminous inter-reflections, transparency and reflection and *technical* for the position and fixation of the light sources and the power adjustment.

In order to simulate and visualize in a realistic manner luminous effects (Goral et al. 1984, Sillion et al. 1991, Wallace et al. 1989) desired by designers, light source and surface radiation properties have to be accurately described. Mathematical models allow accurate light source representations. For the luminous propagation computations (inter-reflections), the radiosity method (Goral et al. 1984) allows precise results (Candela software of the ISA Team Loria (Merzouk 1998, Chevrier et al. 1999]). This research and the use of Candela and its predecessors for a large amount of projects carried out by our team (Louvre museum courtyard (Fasse 1996) (Fasse and Paul 1995), Stanislas square, historical bridges in Paris, Institut de France, Kairouan Great Mosque (Chevrier et al. 1999, Bur 2001), Quito Cloisters, etc) lead us to prove that computer graphics techniques are very promising in the case of illumination studies on existing buildings.

Our works of illumination simulation rely essentially on historical monuments whose main characteristics are that they are represented by very large geometrical databases, and they are enlightened by a large amount of light sources. For instance, the illumination simulation of the Louvre museum courtyard required more than 400 000 polygonal surfaces and the positioning of several hundred light sources. First

project of a long succession, it required a lot of tests, adjustments and modifications.

Simulation of several illumination hypotheses, as was the case for the bridges in Paris or Stanislas Square in Nancy, revealed themselves to be a considerable help for the decision-makers (Paris or Nancy mayors for example). Indeed, it is very difficult, if not impossible, for a non-specialist in the field to imagine the result of an illumination from the light designer plans.

The need for such a system appeared several years ago when "Electricité de France[1]" showed its intention to modernize and enhance the way lighting designers present their projects. It was a matter of assisting decision-makers to better understand the lighting projects with the help of computer-generated images. Beyond this first objective, the idea of an implementation of a more conception-oriented software appeared to be essential to complete the first simulation tool.

Furthermore, such computer graphic simulations are often less expensive than *in situ* tests (scaffoldings, setting and dismantling of the light sources…).

2.2   Difficulty in putting into effect

A specificity of these projects is the great number of light sources to position in the 3D scene. Currently there is no specific modeller for the handling of light sources as they are considered in radiosity software (LightScape (LightScape 1998), Candela (Merzouk 1998, Fasse 1996), Phanie from the CSTB (Phanie), Lise from the "Ecole des Ponts"). This means taking into account physical characteristics of the light. Most of the lighting parameters are set by means of description files (data files), unique interface between the user and the illumination computation software, providing little ergonomics.

Otherwise, illumination simulations carried out by our team allowed us to show the strong correlation between architectural composition and luminous composition, based on geometrical notions such as symmetry, translation, rotation… Introducing the concept of light source network (set of light sources with the same characteristics that can be globally modified) associated to an architectural element should facilitate the project conception.

From these statements, we have decided to develop an interactive tool, named ModLum, to position light sources in a 3D scene in order to: save time during this step by simplifying the source handling, and export the light sources under various file formats depending on the illumination computation software used (Candela, lightscape…).

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3 MODLUM

The specifications of our tool are as following. It should dispose of interactive and automatic placement and orientation of the light sources, relating to architectural elements. A light source or a light source network has to be linked to an architectural component. Light source manipulation has to be facilitated, and the effect on the geometry must be visualized in real time; this will confer on the tool a role of aided decision and lighting experimental tests. An abstract representation of the scene by a graph representing the hierarchical organisation of the geometrical elements and light sources will be proposed in order to easily locate elements.

The user interface should facilitate source creation, addition, deletion and modification. Furthermore, it should offer accurate pre-positioning of the light source according to its associated architectural component, saving time compared with totally interactive placement. Then the user will be able to adjust the light source characteristics with numerical values.

3.1 Principle

3.1.1 Linking a light source to an architectural component

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 (or the same network) to every instance of this element (see Figure 2b where a network was created for one column and the other column is illuminated too). Whatever the modification on the light source is, it is transmitted to each of the associated instances.

3.1.2 Easy location in the scene

Scene components can be selected in two ways (Figure 1): in the architectural representation of the scene or in the hierarchical graph of the scene. Selection in the scene is underlined with the component bounding box. Only geometrical components (tree leaves) can be selected; in the scene an intermediate node can not be selected. To do this, the graph is used. Tree branches grow automatically when needed, avoiding an unreadable representation. Selection in the scene or in the graph allows us a simple and effective location.
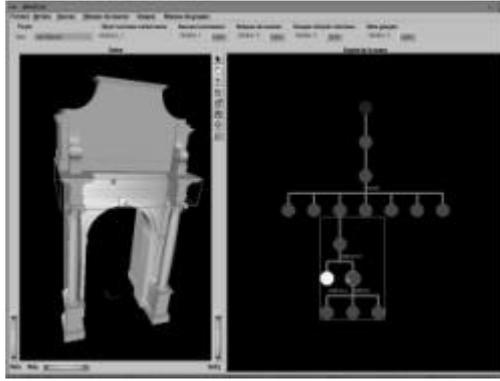
Figure 1 The selected object is located in the scene and in the graph.

3.1.3   Rough pre-visualisation

A rough pre-visualisation of the light source effect on its associated element allows us to appreciate an approximate result: this computation is processed in real time with a local illumination model. The luminous effect does not correspond to what we would obtain with the exact illumination computations but allows us nevertheless to judge the impact area of the light source.

3.2   Luminous object functionalities

Four kinds of luminous objects are defined. Here is the list and their specificities. To each luminous object is associated a set of handling actions: **create, delete, modify and copy.**

3.2.1   Light source

The light source characteristics are: position, orientation, kind of source and intensity. A photometric 3D solid and an emission spectrum 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. A light source is associated to an architectural element of the scene: a final element (tree leaf) or a group of elements (intermediate node in the tree). On Figure 1, you can see the effect of a light source and its representation in the graph.

3.2.2   Light source network

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 2). A network can be composed of several subsets of light sources.

Required data for the creation of the network (i.e. length and direction of the linear network, axis of the circular network, number of sources in the main subset, number and direction of subsets) can either be filled accurately with numerical values or approximately by pointing them in the geometrical view. A network is created from a light source and is attached to the same component as the main light source.
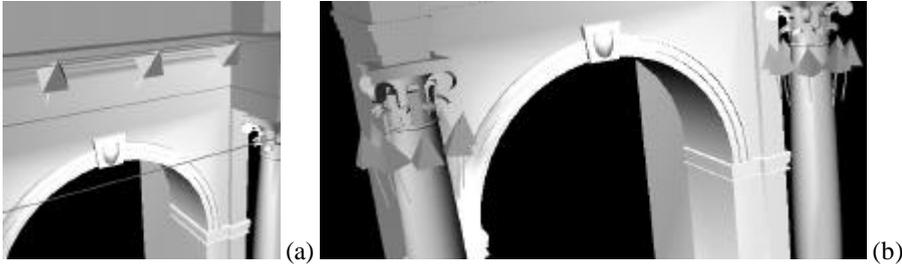

(a)   (b)

Figure 2 Example of linear and circular network.

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 each other).

A light source (given by its index) can be deleted from the network if needed. A light source can be extracted from the network: it is not a part of the network any more but still exists; it becomes independent and is handled like any other light source.

Some geometrical models are not hierarchically organised. For example we want to enlighten the windows of a frontage of such a model. This frontage presents some similarities and repetitions we want to exploit. Due to the lack of organisation, a network can be associated to the whole model (the frontage); each light source of the network will enlighten a repetitive element (window).

3.2.3   Set of luminous objects and network of sets

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. 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.

3.3   Graphic interface description

3.3.1   Creating the luminous objects

Dialog boxes for the creation of the light sources and light source networks are presented in Figure 3. The principle is to use the bounding box of the selected element (or the group of elements). The box can be manually oriented and adjusted according to the shape of the element. This box is then subdivided according to its three main axes into user specified numbers of subdivisions. We obtain a 3D grid whose intersections are materialised by small cubes (Figure 3). The bounding box can be grown in the three axes (translation vector) because we know that the light sources are often a few centimetres from the walls of the frontage for instance.
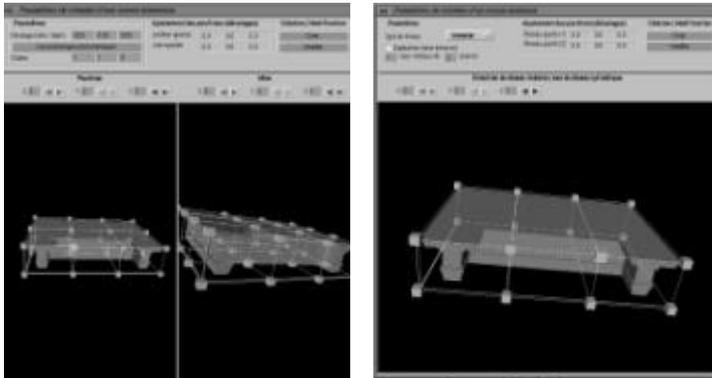

Figure 3 Dialog boxes for the creation of the light sources and networks.

Source position is pointed out by selecting a cube on the grid. It is the same for the aim, in a second window with specific aim subdivision parameters for the grid. These coordinates (position and aim) can be adjusted with two translation vectors. This is useful if the aim coordinates are known according to the source position and not according to the bounding box. A name and a representation colour can be given to each light source for easy locating between luminous objects. Finally photometrical characteristics are associated to a light source, see *§ 3.3.3*.

As far as the light source network is concerned, one can choose the kind of network (linear or circular), dependency or independency of the light sources, the number of subsets in the network and the number of light sources in a subset. As for the

position of a light source, one or two cubes are selected in a grid: the first one is the end of the first sub-network (the origin point is the position of the main light source -the source that is used to create the network-) and the second one is the origin position of the last sub-network. These two coordinates can be adjusted with two translation vectors. In the case of a circular network these two points define the axis. A third point represents the angle occupied by the circular network.

3.3.2 Data visualisation

In the scene, light sources are represented by a pyramid or, if the user prefers, by a sphere, a cone, a cube… The aim is drawn as a line (see Figure 2). Only the selected light source is shown by this representation; a simplified shape with the same colour displays the other light sources. This avoids visual overload. The detailed representation of a network is the displaying of each light source that composes it. Various displays of the scene and the light sources are proposed: the scene and the selected component either in flat shading, wireframe or invisible.

In the scene graph, the luminous object is inserted into the graph as the brother of its associated component (see Figure 1). The set "luminous object – component" is put together in a group node. A light source is represented as a yellow hexagon and a network as an orange one.

3.3.3 Photometrical Characteristics

In order to choose the photometrical characteristics of a light source, one can choose a kind of light source in a library or choose a spectral distribution and a photometrical solid (both graphically represented) from which a new kind of source can be created. For a given kind of light source, a picture of the illumination of the light source on a reference surface is displayed and also constructor information.

3.4 Realisation

We developed an interactive tool in order to make easier the set up of light sources in an architectural scene for an illumination project design stage. Till now, the main applications were the illumination of historical monuments. However other utilizations based on vision physiology or on visual ergonomics (visual comfort) could be the indoor illumination of museums or work places.

This tool is written in C++ for Silicon Graphics workstation with Unix as operating system. The Open Inventor library was used (Wernecke 1995). The tool will be transferred on Windows (NT, 2000).

The choice of Open Inventor is based on several reasons: real time visualisation based on Open GL, 3D graphic object library, real time and simple interactivity (manipulators), local illumination model in real time: till now we have chosen a diffuse colour for the surfaces and a spot light to represent the light sources.

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We did not choose a CAD modeller (such as AutoCad) as development environment for several reasons: it does not allow us real time visualization and manipulation databases and it does not dispose of a real time illumination simulation. We also do not choose an illumination simulation software (such as Maya, 3Dstudio, …) in order to be software independent (because the user of one software does not generally own the other).

4   APPLICATION EXAMPLE: TWO CLOISTERS IN QUITO

For EDF, we have modelled two cloisters in Quito (Ecuador), conceived the illumination project and computed simulation, images, QuickTime panoramas and movies (see Figure 4). The repetitive structure of the cloisters was exploited with set of light sources. As the space between each column is not regular, the light positions were adjusted independently. The orientation of the sources was vertically globally adjusted with the help of the real time rough illumination simulation. Thanks to Didier Bur who has carried out this project.

Figure 4 Quito cloisters

5   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.

REFERENCES

Bur, D. (2001) Les Nocturiales de Kairouan, *Professional Lighting Design*, Ed. EDLA, Décembre 2001.

Merzouk, S. (1998) *Architecture logicielle et algorithmes pour la résolution de l'équation de radiance*, PHD Thesis, Institut National Polytechnique de Lorraine.

Chevrier, C., D. Bur and J. P. Perrin. (1999) "A simulation system for architectural projects", 6th International IBPSA Conference, Building Simulation '99, Kyoto, 13-15 Sept. 99, p. 1085-1091.

Fasse, I. (1996) Simulation d'illumination d'édifices architecturaux en image de synthèse. PHD Thesis, Université Henri Poincaré, Nancy. 1996.

Fasse, I. and JC Paul. (1995) Realistic Rendering and Computer-Aided Lighting Design in Architecture, *Sixth International Conference on Computer-Aided Architectural Design Futures,* Singapore, 24-26 September 1995, pp. 241-255

Goral, C.M., E.K. Torrance, D.P. Greenberg and B. Battaile. (1984) Modelling the interaction of light between diffuse surfaces. In H. Christiansen, editor, *Computer Graphics (Siggraph'84 proc.),* pages 213-222, July 1984.

Sillion, F.X., J.R. Arvo, S.H. Westin and D.P. Greenberg. (1991) A global illumination solution for general reflectance distributions. In T.W. Sederberg, editor, *Computer Graphics (Siggraph'91 proc.),* volume 25, pages 187-196, July 1991.

Wallace, J.R., K.A. Elmquist and E.A. Haines. (1989) A ray tracing algorithm for progressive radiosity. In J. Lane, editor, *Computer Graphics (Siggraph'89 proc.),* volume 23, pages 315-342, July 1989.

Wernecke, J. (1995) "*The Inventor Mentor: programming object-oriented 3D graphics with Open Inventor*", Addison-Wesley Publishing Compagny

Phanie, CSTB: www.cstb.fr/services/eclairage.htm

LightScape, (1998) http://www.lightscape.com