Expression of luminous ambience intention in CAAD

Vincent Tourre, Jean-Yves Martin and Gérard Hégron
CERMA (UMR CNRS 1563), École nationale supérieure d'architecture de Nantes, France
http://www.cerma.archi.fr/

This paper presents a research in progress dedicated to the development of a Computer Aided Architectural Design (CAAD) tool, which integrates design by ambience intention concept. A digital design by ambience intention framework is proposed, allowing intention expression of daylighting ambience through scene lighting properties. Lighting descriptors are introduced to represent theses properties, and combined to produce a lighting constraint set. These constraints are intended to be used in an inverse lighting model to compute geometrical raw solutions.

Keywords: *Design by intention; Daylighting ambience; Intention expression; CAAD tools; Inverse rendering.*

Introduction

Design by ambience intention is a method widely used by architects long before the creation of CAAD. It can be seen as the expression of ambience intentions in the early stages of conceptual design, and the use of these expressions as guidelines to design the building.

Lighting ambience can be displayed thanks to lighting simulation from a geometric model. However, a completely known architectural project is required to compute lighting simulation, although this project is precisely being designed from lighting ambience intentions.

The integration of design by ambiance intention in CAAD tools leads to digital design by ambience intention concept. However, such an approach needs translation of lighting ambience intentions in scene lighting properties, and processing of these lighting descriptions to obtain useful results for architects.

An intention expression tool is proposed in order to reveal daylighting ambience intentions in a designed space layout, through using lighting data visualization. Then a lighting constraint set is produced with a view to computing expressive geometrical guidelines for the design.

Section 1 presents an analysis of intention expression features in previous works. Section 2 delineates our approach of digital design by ambience intention. The section 3 shows an expression tool for lighting ambience intentions, which combines intention sketching, daylight ambience, and surroundings influence. In section 4, we present further work, and discuss the use of an inverse lighting technique to compute raw geometrical solutions.

Previous works

This section presents some description methods of lighting ambience intentions in inverse rendering techniques. We classify these approaches following lighting data criterion, which describes lighting properties displayed.

These approaches could also be classified depending on problem type (Marschner, 1998), according to whether the required element depends on the scene geometry - inverse geometry, the reflectance properties of surfaces - inverse reflectance, or the position and intensity of light sources - inverse lighting.

Direct light

The intention expression of direct light in previous works (Poulin, 1992; Schoeneman, 1993; Siret, 1996) has been done by the delimitation of light presence area, suggesting that other scene parts are not directly lighted. Intention expression interfaces were not designed to describe other direct lighting properties like intensity or direction, although architects could have some intentions about them.

Daylighting

Daylighting sources (Mahdavi, 1995; Siret, 1996) are dynamics, as they depend on climate, date and hour. Moreover, daylighting sources are not configurable, as we cannot control their position and intensity. So the problem may not be an inverse lighting problem, but an inverse geometry or inverse reflectance problem.

Lighting direction

Costa's (1999) scripts allowed to specify light and shadow, and lighting direction, to model visual comfort. Moeck's (2004) work on object perception handled direction data through object's appearance. The lighting direction provides a parameter as useful as intensity or luminance, but is not present in graphic interfaces.

Jung (2003) used symbolic data to describe light source positions. Drawing conventions can be used as well to describe lighting properties (direction or period).

Lighting quantities

Measurable lighting data (intensity, emittance, luminance, etc.) describe light exchanged between surfaces or viewed by users. Their expression means have been based on explicit lux amount (Costa, 1999), texture qualities (Moeck, 2004), declarative modeling (Jolivet, 2002), implicit light sketching (Kawai, 1993; Schoeneman, 1993; Siret, 1996; Jung, 2003) or pictures (Marschner, 1998; Yu, 1999).

These approaches could be classified according to description features (known parameters or perceived light), and interface features (graphic or text). A graphic interface to describe known parameters about daylighting ambience was not found in previous works.

Moreover, Costa (1999) pointed out some difficulties to combine precision and easiness in the same description method. Theses difficulties can explain the fact that very different methods are proposed to achieve lighting description.

Lighting quality

Lighting quality was explicitly mentioned in few works (Mahdavi, 1995; Moeck, 2004), may be due to the difficulty to deal with subjective impressions. Besides it is difficult to measure a quality, it can be expressed through a set of quantities. A lighting quality can be represented by various lighting properties according to spatial configuration. The problem is about choosing relevant properties to represent a given lighting quality.

Digital design by ambience intention : an approach

Our goal is to provide an aid to opening design starting from daylighting intentions. As light reveals architecture, we suppose that lighting ambience intentions reveal architecture design, and in particular that daylighting intentions reveal opening properties (Figure 1).

This goal leads us to add daylighting intention expression feature, with influence of skylight and built environment, to design by ambience intention research project developed at CERMA laboratory (Siret, 1996; Nivet, 1999; Houpert, 2002).

The sky is an extended, heterogeneous and dynamic source, which influences indoor lighting ambience as well as surrounding lighting. The lighting

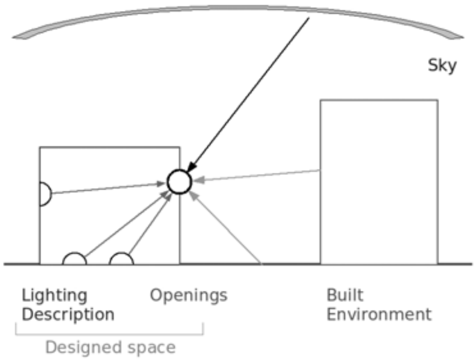

Figure 1
Lighting ambience intention and daylighting conditions combined in a tool in order to aid opening design.

ambience provided by skylight can be described in space and time dimensions. The resulting lighting distribution on surfaces cannot be a binary expression like sun lighted area descriptions represented by cast shadows.

In an attempt to add lighting quality to intention expression, we present a direct daylighting quality feature to materialize the relationship between daylighting and indoor spaces through opening properties. By pointing out that an architect can express more than light levels through lighting ambience intentions, we try to understand more deeply lighting ambience role in conceptual design.

An inverse lighting method needs to be adapted to match with architectural design needs. In inverse rendering framework (Patow, 2003), this is an inverse geometry problem as we are looking for scene geometry. However, this geometry defines also source visibility, thus this problem can be seen as source positioning and proportioning.

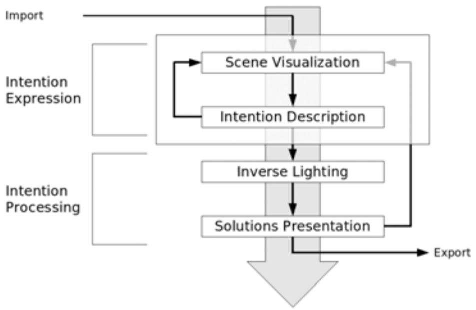

Figure 2
A design by ambience intention framework; intention expression is the first stage of the process, and supply input data for the second stage: intention processing.

Framework description

Our framework (Figure 2) is intended to be used in early stages of conceptual design, when lighting ambience intentions and spatial layout are known. We deal with direct light coming from the outside into the designed space, which encompass skylight and reflections from external built environment.

The initial direction of diffuse daylight has a great influence on lighting ambience. This direction is mainly conditioned by opening properties (orientation, position, size). Openings act as interfaces between indoor designed space and surroundings, and materialize they relationship. We thus focus our research on direct daylighting direction in order to develop computer aided design of openings.

The first step in digital design by ambience intention process is to provide a lighting ambience intention description. Lighting description features have a critical impact on architect's intention expression and input data of inverse lighting model. The objective is to allow daylighting quality expression as lighting properties with a graphical interface. We propose a tool allowing lighting ambience intention description through lighting properties.

The second step is an inverse lighting simulation, that allows to transform light properties of an architectural space in geometry and materials properties of this space. We will use source positioning methods in inverse lighting framework to compute geometric solutions. We discuss this issue in Further Works section.

Expression of ambience intentions

An intention expression tool is proposed in order to describe lighting ambience intentions in a given spatial layout, with heterogeneous daylighting distribution, lighting direction and contrast features (Figure 3).

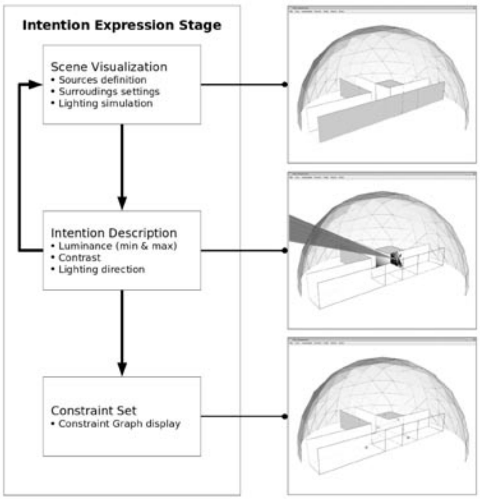

Figure 3
Intention expression tool use scenario: after defining scene settings, intentions are described in order to obtain a lighting constraint set.

Lighting data

We deal with natural light coming into the designed space from skylight, the main light source, and reflections of external built environment, considered as a secondary light source. Direct daylighting provided by these sources is defined only by opening properties. Therefore, a direct daylighting description allows to work directly on opening design.

The light received on designed space surfaces (e.g., floor, working desk, virtual wall) is described by a heterogeneous spatial distribution. This distribution represents luminance, an absolute light quantity in Lux, and is specified over a time period. Luminance minimal and maximal values can be specified to express light and shadow intentions, respectively.

Lighting contrast is a lighting data directly related to human perception. We define contrast as a lighting proportion, which is a relation between areas. This relation creates dependencies between several areas, on a single surface or different surfaces.

Direct lighting directions are links between surface lighting and opening properties. A lighting direction is described with a main direction, a solid angle and a luminance value. The solid angle shape can be a cone (Figure 4), to give a rough direction indication, or a set of boundary directions, that yet defines an opening form. This shape is centered on the main direction which indicates a source position relative to the surface.

Lighting quality is generally closely related to perceived light and not to direct light. As we aim to aid space design in relation with daylighting, the concept of quality is viewed as the interrelation between designed space and natural lighting. The preceding relationship is expressed through the concept of direct lighting quality, and represented by preceding quantified parameters.

Graphic interface

Light and form are perceived simultaneously, and graphic interface allows to represent and distinguish them. Indeed, direct lighting is not well understood with realistic rendering, because it is not directly perceived and it is difficult to abstract reflections. Thus, a photometric rendering is used to supply a more precise representation.

We retain the idea of sketching lighting intentions directly in virtual scene as in Schoeneman's (1993) work. Sketches describe luminance or contrast on each time step. A texture (picture or sketch) can also be imported to describe surface luminance or contrast parameters (Figure 5).

Direction descriptor is described by solid angle definition. The representation of several lighting directions can be a bit confusing, in particular when these directions do not start from the same surface. Therefore only direction boundary intersections with designed space are showed to clarify multiple lighting direction display.

Lighting descriptors

The objective is to translate lighting ambience intentions, according to their values, directions or period. An area can be described in terms of absolute (luminance, direction, period) or relative (contrast) lighting quantities. It is possible to set the luminance interval of an area by relating opening properties to direct daylighting properties. Then, it is possible to set contrast interval by

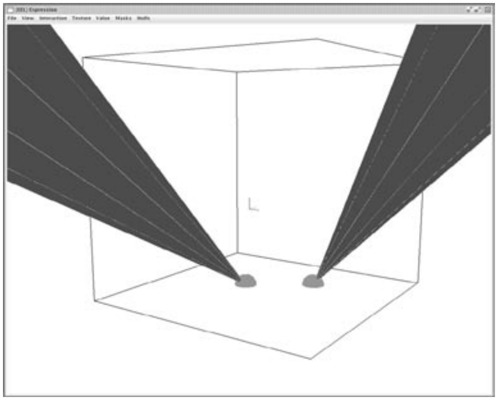

Figure 4
A lighting direction cone can be assigned on every designed space patch to give a rough lighting direction intention.

relating luminance intervals together. This problem can be seen as a constraint satisfaction problem.

A luminance constraint contains a value descriptor (minimal and maximal), a direction descriptor (main direction and bounds) and a time descriptor. This constraint influences opening properties on a specific area of designed space. This area is defined by the intersection between solid angle delimited by direction bounds and designed space. Area opacity is set following value descriptor. The permanency of all these opening properties is defined by time descriptor.

A contrast constraint contains an area relation descriptor set. One area relation descriptor defines a relationship between two areas belonging or not to the same surface. The descriptor set defines a relationship between several areas, assuming at least that one of these areas is constrained by a luminance constraint.

Descriptor domains can be reduced by the framework according to the situation (geographic position, surroundings, etc.) (Figure 6). Then the designer can reduce descriptor domains through graphic interface so as to express his intentions more precisely.

A contrast constraint graph can be produced to visualize the system (Figure 7). The resulting set of constraints is intended to be used as input data of an inverse lighting model. This model will be based on a constraint based simulation model Jolivet (2002) that would provide a set of geometrical raw solutions. These solutions will be interpreted from an architectural standpoint.

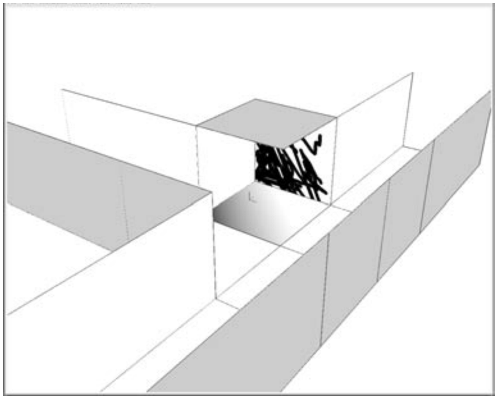

Figure 5
Surface luminance and contrast are imported from external files (.jpg, .gif, .png) or sketched directly on the scene.

Further work

This research links a cultural heritage method, design by ambience intention, and CAAD tools through using computer graphic techniques.

Our main contribution concern the way of sketching daylighting ambience intentions with contrast, lighting directions and an approach of direct lighting quality. Our choices are justified by the lack of such work in previous works: an alliance of graphic interface, photometric data, and symbolic data.

These ambience intentions are intended to be

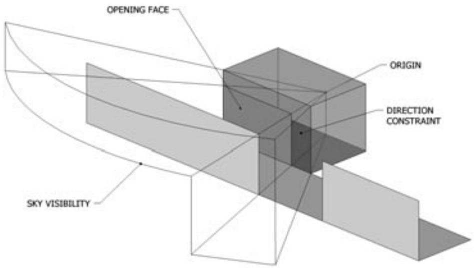

Figure 6
A direction descriptor is reduced by surrounding in order show sky visibility. Visual clues of direction bounds are given to the designer so as to choose lighting intention direction.

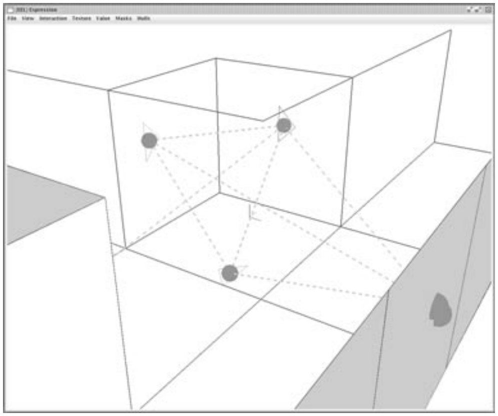

Figure 7
The contrast constraint graph is displayed directly on the scene in order to re-iterate the intention expression cycle more quickly.

used as input data for an inverse light simulation model. This research currently goes ahead with adaptation of an inverse lighting model to match architectural design needs, and opening computation.

Therefore, we will look for a way to explore several interpretable geometric configurations resulting from the preceding computation. The presentation of these solutions, which is an information visualization problem, will allow the designer to continue his own research of architectural solutions.

References

Costa A.C., Sousa A.A. and Ferreira F.N.: 1999, Lighting design : A goal based approach using optimization, Rendering Techniques, pp. 317–328.

Moeck M.: 2004, Constraint satisfaction software for architectural lighting design, Leukos, 1(1), pp. 101–127.

Patow G., Pueyo X.: 2003, A survey of inverse rendering problems, Computer Graphics Forum, 22(4), pp. 663–687.

Houpert S.: 2002, Svr 1, a software to solve solar constraints: A help to better take into account architectural, environmental and ecological problems, in PLEA 2002 : design with the environment, James and James Publisher, pp. 170–175.

Jolivet V., Plemenos D. and Poulingeas P.: 2002, Inverse direct lighting with a Monte Carlo method and declarative modeling, in International Conference on Computational Science (2), pp. 3–12.

Jung, T., Gross, M. D., Do, H. Y.-L.: 2003, Light pen – sketching light in 3d, in CAAD Future 2003 Conference Proceedings, Kluwer Publisher, pp. 327–338.

Kawao J.K., Painter J.S. and Cohen M.F.: 1993, Radioptimization - goal based rendering, in Proceedings of SIGGRAPH-93: Computer Graphics, pp. 147–154, Anaheim, CA.

Mahdavi A. and Berberidou-Kallikova L.: 1995, A generative simulation tool for architectural lighting, in 4th International Conference on Building Simulation.

Poulin P. and Fournier A.: 1992, Lights from highlights and shadows, in Proceedings of the 1992 symposium on Interactive 3D graphics, pp. 31–38.

Schoeneman C., Dorsey J., Smith B., Arvo J. and Greenberg D.: 1993, Painting with light, in Proceedings of the 20th annual ACM Conference on Computer graphics and interactive Techniques (SIGGRAPH), ACM Press, pp. 143–146.

Siret D.: 1996, A generative computer tool to model shadings and openings that achieve sunlighting properties in architectural design, in Development and application of Computer techniques to environmental studies VI (Proceedings of ENVIROsoft'96), Computational mechanics Publications, pp. 695–704.

Yu Y., Debevec P., Malik J. and Hawkins T.: 1999, Inverse global illumination: Recovering reflectance models of real scenes from photographs, in Alyn Rockwood (ed.), Siggraph99, Annual Conference Series, Addison Wesley Longman, Los Angeles, pp. 215–224.

Marschner S.R.: 1998, Inverse rendering in computer graphics, Ph.D. thesis, Cornell University.

Nivet M.L.: 1999, De Visu : un logiciel pour la prise en compte de l'accessibilité visuelle dans le projet architectural, urbain et paysager, Ph.D. thesis, Université de Nantes, Ecole d'architecture de Nantes.