A "green design" method to integrate daylight in the early phase of the design process

The use of intentions knowledge base to generate solutions

Mohamed Anis Gallas[1], Didier Bur[2], Gilles Halin[3]
[1.2.3]MAP-CRAI, Centre de Recherche en Architecture et Ingénierie, France
[1.2.3]http://crai.archi.fr
[1]gallas@crai.archi.fr, [2]bur@crai.archi.fr, [3]halin@crai.archi.fr

Abstract. *In order to assist the designer to integrate the daylight on the early steps of the design process, we propose a computer aided method that uses designer intentions to generate potential solutions materializing these intentions. The early evaluation of the energetic implications of the generated solutions helps designers to think about a green way of design. An intentions knowledge base is created to characterize the designer intentions and to provide the necessary information to make possible the solution generation process. The intentions features will be characterized at different levels and will use the concept of indices and parameters. The parameter values will be defined by analysing the simulation results of different spatial configurations applied on a parametrical model.*
Keywords. *Daylight integration; early phase; assistance method; intentions knowledge base.*

INTRODUCTION

"Creating with lights with an understanding of daylighting principles and techniques: an ideal for future architects" (Demers, 2000). The architects cannot fully control and integrate the daylight into the early stages of the design process due to the complex relationship between daylight and architectural space. This complexity lies in the ability to design an architectural space that can generate a given quantity and quality of a well-defined natural daylight effect. Generating a lighting effect involves parameters related to the architectural space itself (shape, type and size of openings) and the environment where it is located (orientation, relative position to the sun).

During the primary stages of the design process, the designers and especially beginners are unable to master these parameters. Fuzzy and imprecise aspects characterize these research and gestation phase. The natural light is put away to the benefits of artificial solutions that are more adaptable and easier to implement. The environmental awareness and the lack of energy sources and their soaring prices has prompted designers to change strategy. They follow a new generation of "green design" methods that tries to exploit and to control all the natural resources to reduce the use of the artificial ones. During the last decades, research in computer aided architectural design participates in this movement and proposes simulation and optimization software to assist the finalization steps of design activity. They are used to evaluate the daylighting and the energetic behavior of architectural configurations at a very detailed state. The evaluation results are used as a reference to realize some superficial modifications and optimize the architectural project behavior. These "evaluation methods" are not corresponding to architects needs due to the lack of exchange and contribution to the design activity. They need detailed data that are not available for the architect particularly at the beginning of the design process. Elsewhere, decisions taken during the formalization design phase have more effect on the architectural development process compared to that taken during the finalization stages.

Architects need methods that propose a real assistance by finding solutions that help them to resolve the design constraints during the early phase of the design process. Designer deals with qualitative constraints view of the lack of enough information about the project to make possible the use of quantitative ones. At the same time, existing computer systems have problems to take into account and integrate the qualitative constraints. On the other hand, they are more appropriate for quantitative constraints integration, well defined and ready for repetitive and iterative evaluations. Different research groups in architecture propose a new generation of methods that integrate the qualitative constraints and respects the imprecise aspect of the early steps of architectural design process. This type of method is structured as a declarative modeling method that integrate the qualitative constraints as main information to generate and propose a potential solution used as a base line model to aid the designer. The qualitative constraints concern the different aspects of the architectural project design as the environmental design, the morphological design, and the energetic behavior. They are expressed using an architectural language that respects the lack of detailed information during the formalization steps of the project.

This paper takes part in this context. The first part defines the different features characterizing the early phases of design process and introduces a computer aided design method using designer intentions to help him to integrate daylight and its energetic implications. The second part focuses on the intention description and characterization by proposing a references research tool integrated to an intentions knowledge base. The final part will expose the creation process of the intentions knowledge base.

THE PROPOSED METHOD

The architectural design is considered as a creative activity. So we use the structure of this creative design process to describe the architectural design activity (Howard and al, 2008). This paper focuses on "the conceptual design phase" where the designer tries to find solutions to the different problems and constraints analysed during the precedent phase ("establishing a need" and the "analysis of task") of

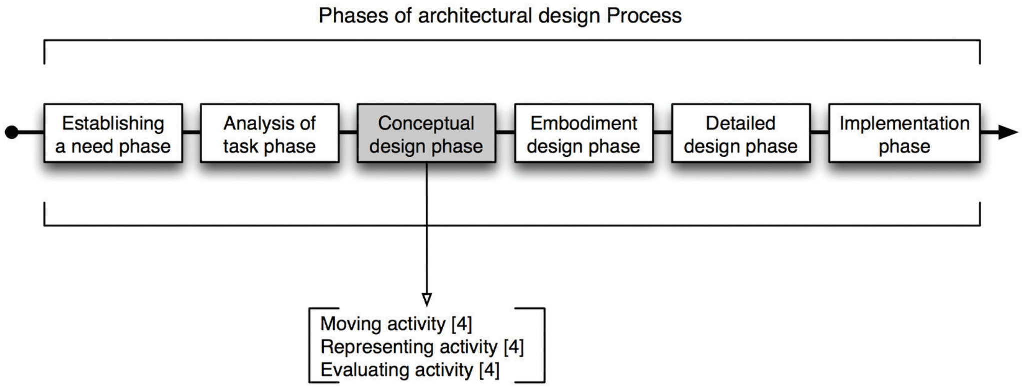


Figure 1
The different stages of the design process by Howard.

this creative design process. Lawson (2006) analyzed the designer tasks present in the different phases of the architectural design process. He classified the different tasks in five groups of activities (formulating, moving, evaluating, representing and reflecting). The "conceptual design phase" could be characterized by three of them (moving, representing, evaluating). The "moving activity" integrates the intentions generation and transformation tasks concerning potential solutions. The second group of "representing activity" is used to embody the designer intentions and idea by some representation tools as sketches, real models or virtual models. During the "conceptual design phase", the representation tools are used as a design activity support. The last group is the "evaluation group" where the designer evaluates the solutions that he found and compares them to the design constraints. (Figure1)

The declarative modeling method "allows the architect to manipulate some information of a high level of abstraction: that is to say intentions" (Lassance, 1999). The designer/user declares his intentions related to the daylighting atmosphere. The intentions will be translated using the generating system to propose potential solutions. During the assessing phase, the user/designer evaluates the generation results and compare them to the declared intentions to select those that are corresponding to his intentions. If he is not satisfied he could restart the process. The interface is used at the different steps to create a dialogue between the user and the system. A similitude exists between the different phases of the declarative modeling method and the activities characterizing the "conceptual design phase" of architectural design process. It make that the declarative method could be used to structure a computer assistance method dedicated to the early steps of architectural design process (Figure2).

The objective of the proposed method is to take into account the designer intentions and ideas related to the daylight atmosphere that he wants to create inside the designed building. The intentions will be

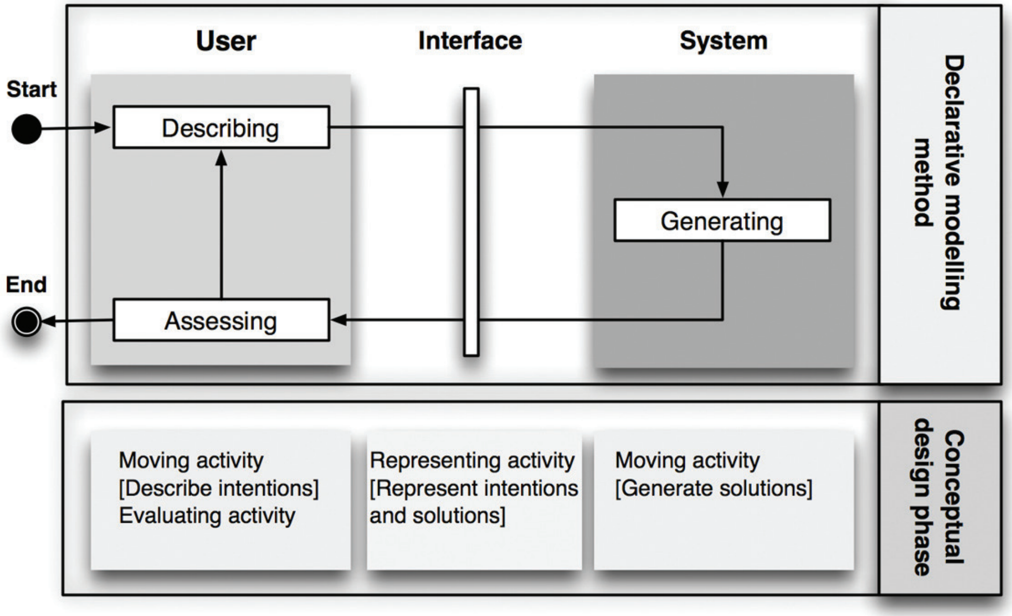


Figure 2
Interaction between declarative modeling process and the conceptual design phase.

interpreted to generate baseline models that materialize, at different level of fitness, the described intentions (Figure3). The generated models will be used as standard models to start the architectural project design. The evaluation of the energetic behaviour of the proposed solutions (solar gains and energy consumption) will help the designer to integrate the energetic features during the solution selection step.

This research is part of a global project proposing assistance tools dedicated to the design lighting scenes during the early phases of the design process.The first one is Day@mbiance (chaabouni and al, 2009) a reference research tool using pictures of daylight effects that help designer to formalize his daylighting intentions.The proposed method used an intentions knowledge base to characterize designer intentions and provides the necessary data to generate potential solutions which materialize the characterized intentions. Different simulation software participate in the method process to evaluate the daylight and energetic behavior of the generated solutions. The evaluation results will help the user/designer to assess and select the solution(s) corresponding to his intentions. If the user is satisfied, he could generate a 3D model that will be transformed using a CAD system. If he is not satisfied, he could restart the process (Gallas and al, 2011) (Figure4).

THE INTENTIONS KNOWLEDGE BASE

Different research works propose to identify the common features of the different daylighting atmospheres and effects characterizing the architectural space in order to create daylight effect classes (Audience [1]; Gallas, 2009; Reiter and De Herde, 2004). In our process, the user/designer manipulates a reference research tool to select a collection of images representing daylight effects and atmospheres. These images formalize the designer intentions. A keywords indexation is used to link the different reference images with the identified daylight effects classes. (Figure5)

The proposed method uses the designer intentions as the main information to generate solutions. We consider the identified daylight effect classes as intentions classes. The objective is to characterize the intentions classes at different levels and using data that could be used by a model generator to generate potential solutions (Tourre and al, 2006).

The structure of the intentions knowledge base is organized on three levels (Figure6). The upper level

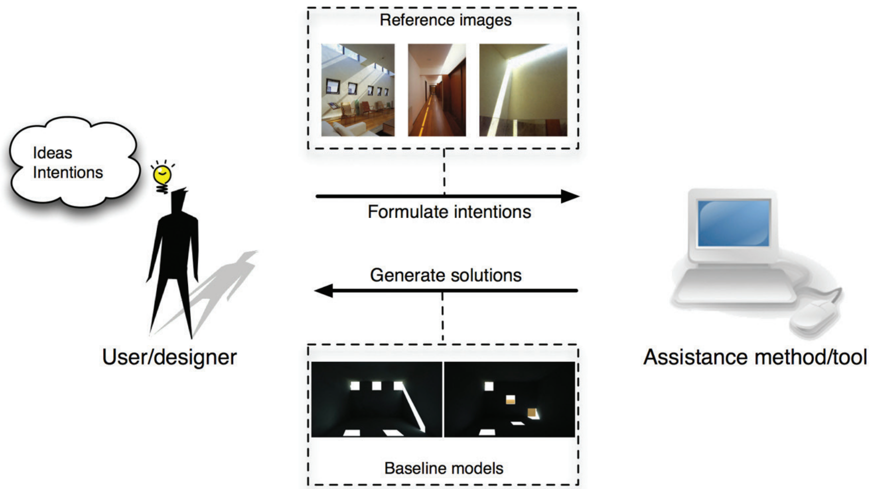


Figure 3
Objective of the proposed method.

Figure 4
Method process.

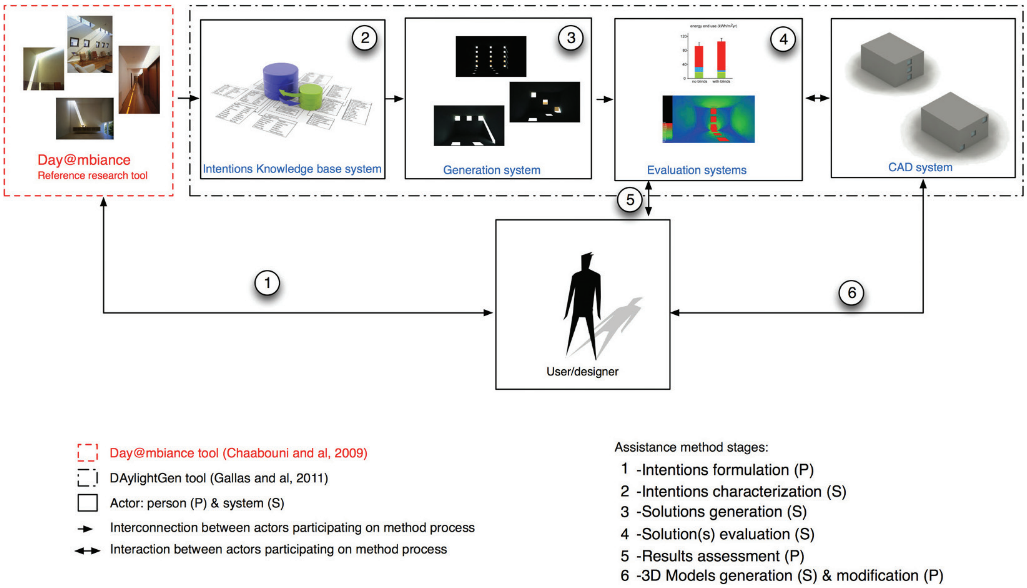
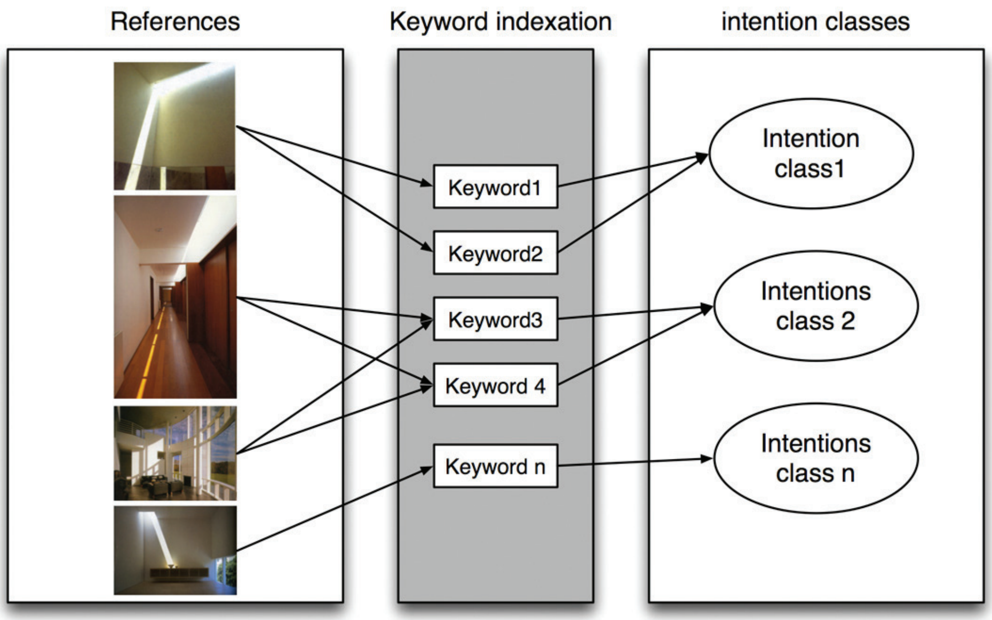


Figure 5
Relationship between references and intention classes.



concerns the daylight effects, which will be considered as designer intentions classes. The intermediate level concerns the characterization of the intentions classes by the use of the concept of indices. These indices represent the diversity of features describing the architectural intentions (Mudri, 1995). The indices are selected from different research works related to the characterization of the daylight effects and their energetic implications (Bodart and De Herde, 2002). The final and basic level is to concretize the different indices by physical and geometrical parameters usable to generate potential solutions. Ranges of values quantify each one of these parameters.

To define the ranges of values of the different parameters, we use a parametric model linked to simulation software. We select a simple parallelepipedic model to realize the different simulations (figure7). The size of the model is 300cm x 300cm x 450cm composed of one or more apertures of rectangular shape and located on one vertical side of the model. The DIVA component (Lagios and al, 2010) integrated to Rhinoceros® and Grasshopper® is used as a workflow for the evaluation of the daylight behaviour of the schematic design configurations.

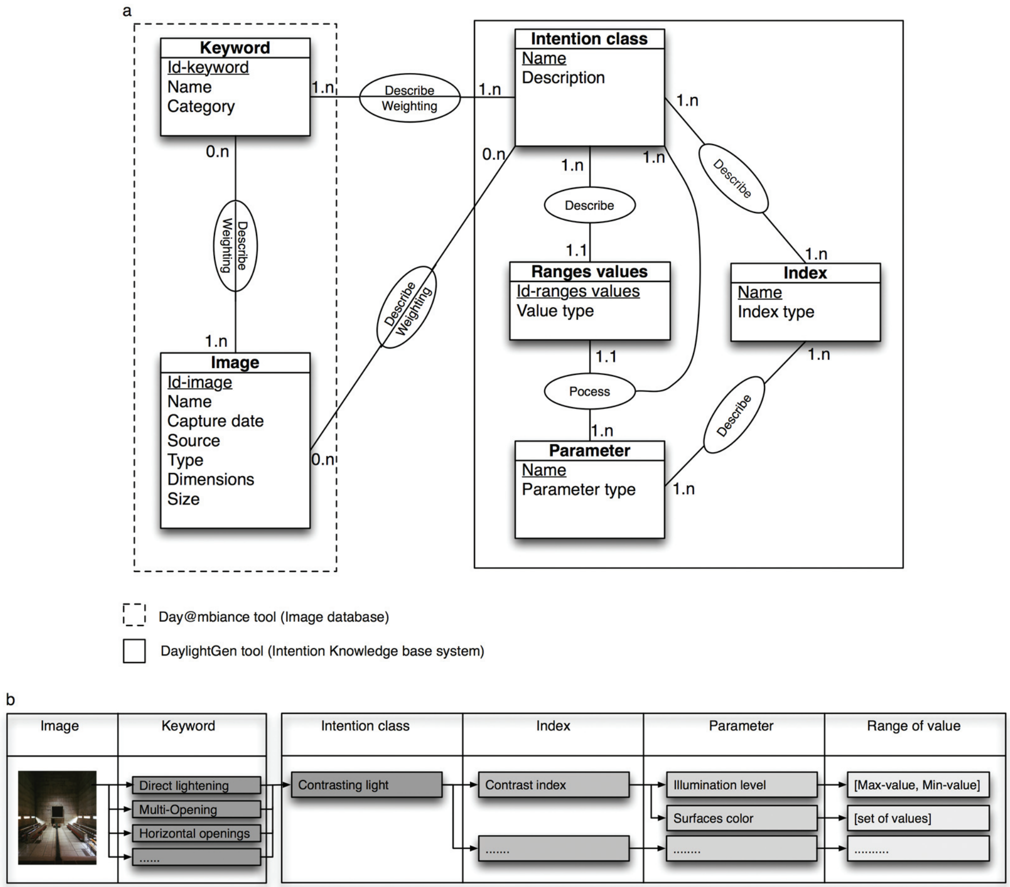


Figure 6
a) Entity-relationship diagram of the knowledge base.
b) Example of intention characterization

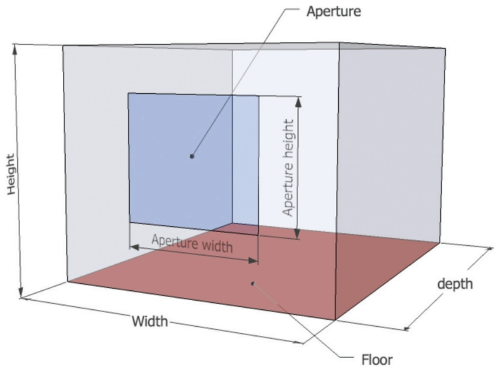


Figure 7
Model used to create the intentions knowledge base.

The parametrical model is defined by seven parameters that characterize the aperture features. These parameters influence the daylight effects genereted inside the spatial model. They have default values such as aperture one corresponding to default positions that was defined in the parametric model (Table1).

The aim is to make a qualitative and quantitative daylight simulation for each different spatial configuations by making one parameter vary at a time. The simulation results will be analyzed and linked to the daylight effect classes (cited previously) to find the ranges of values for the parameters characterizing these classes (Figure8).

CONCLUSION AND FUTURE WORK

This paper proposes an assistance method that helps architects to design with daylight and its energetic implications in mind, at the early phases of design process. Due to the complexity

Table 1
Structure of the parametric model.

Parameter	Range of Values	Details
Aperture rate	0 to 1	Regarding to floor surface
Aperture proportion	1/1 or 1/2 or 1/3	Ratio between height and width
Aperture orientation	1 to 7	From South to Southwest
Aperture direction	True or false	Vertical or horizontal
Aperture number	1 to 20	
Aperture position	1 to 11	The 4vertices, the the midpoints of the edges and the center of opening surface

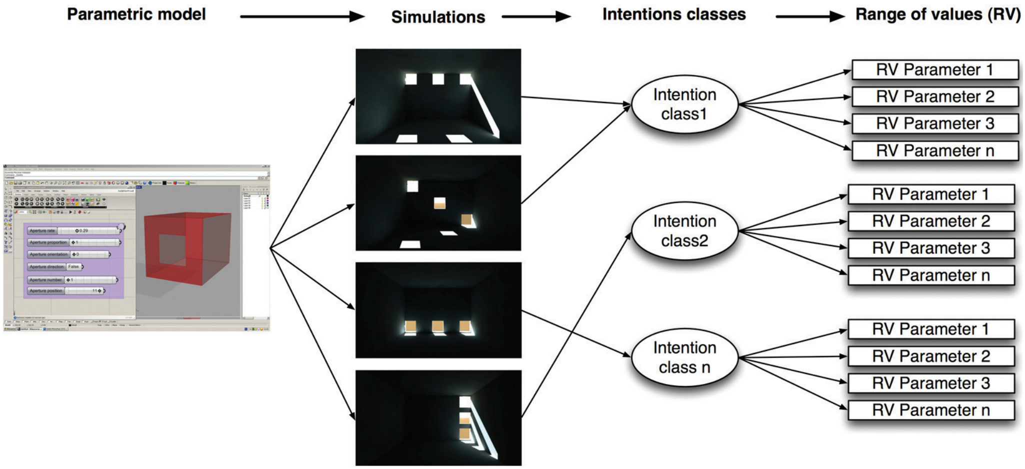


Figure 8
Intentions knowledge base creation.

characterizing the daylight behavior, the assistance method will help design to embody his daylight intentions and integrate them in the design process from the early phases. It will generate baseline solutions that materialize designer intentions. The early assessment of the energetic behavior of the generated solutions helps designer to adopt an environmental-friendly design.

With a reference research tool, the designer formalizes his daylighting intentions. The intentions knowledge base translates the designer intentions into physical and geometrical parameters that can then be used to generate potential solutions. Generation results integrate visual information that will be an initiator for the creative thinking (Demers, 2000). The intentions knowledge base integrates different levels of information characterizing the designer intents. The last level integrates the parameters which are the most detailed and concrete information describing the intentions. For each intention class, the range of values for these parameters is found. They are the result of simulations processed on a parametrical model.

This knowledge base is valid for spatial configuration having the same features than the parametric model. This is a limit of the currently proposed base but does not close the possibility of integrating other spatial typologies.

The next step of this research work is to propose an evolutionary algorithm to translate the designer intentions described by the intentions knowledge base into potential solutions. A prototype of interface will be developped to create dialogue between the different actors participating on the assistance method. The contribution of these assistance methods on the design process will be evaluated in pedagogical and professional environment.

ACKNOWLEDGEMENTS

This research work is supported by the Lorraine Region, France.

REFERENCES

Bodart, M and De Herde, A 2002. 'Global energy savings in offices buildings by the use of daylighting'. *Energy and Buildings,* vol. 34, no. 5, p. 421–429.

Chaabouni, S, Bignon, JC and Halin, G 2008. 'Luminous ambience designNavigation and reasoning by photographic images for formulation of intentions'. *Design & Decision Support Systems in Architecture and Urban Planning*, University of Technology Eindhoven, Netherlands.

Demers, C 2000. 'Light and the digital image: a proposed framework for design and analysis'. Architecture City Environment, *PLEA 2000*, July 2000, Cambridge, United Kingdom.

Gallas, MA, Bur, D and Halin, G 2011. 'Daylight and energy in the early phase of architectural design process: A design assistance method using designer's intents'. CAADRIA 2011, *The 16th International Conference of the Association for Computer-Aided Architectural Design Research in Asia*, April 27-30, 2011, Newcastle, Australia.

Gallas, MA 2009. *'La lumière naturelle en phase de conception : quels outils et méthodes pour l'architecte'*. Ecole Nationale Supérieure d'Architecture de Nancy, France.

Hégron, G 2003. 'De la modélisation à la conception assistée par ordinateur, La modélisation déclarative'. *Les annales des ponds et chaussées*. p. 107-108.

Howard, TJ, Culley, SJ and Dekoninck, E 2008. 'Describing the creative design process by the integration of engineering design and cognitive psychology literature'. *Design studies*, 29(2), p.160–180.

Lagios, K, Niemasz, J and Reinhart, CF 2010. 'Animated Building Performance Simulation (ABPS)–Linking Rhinoceros/Grasshopper with Radiance/Daysim', *SimBuild 2010*, New York City,USA.

Lassance, G 1999, 'A Pre-Design Aid Support for Archi¬tectural Daylighting', *The Shar-ing Knowledge on Sustainable Buildings*, 16-17 December, Bari, Italy.

Lawson, B 2006. *How designers think: the design process demystified,* Elsevier/Architectural, Oxford, Burlington MA, USA.
Mudri, L 1995. 'Interaction between qualitative and quantitative approaches in the teaching of architectural design', *Teachers in Architecture*, 28-30 September1995. Florence, Italy.
Reiter, S. and De Herde, A 2004. *L'éclairage naturel des bâtiments.* Louvain-la-Neuve Belgique, Presses universitaires de Louvain, Belgium.
Tourre, V, Martin, JY and Hégron, G 2006. 'Expression of luminous ambience intention in CAAD'. *24th eCAADe Conference Proceedings*, Volos, Greece.
[1] http://audience.cerma.archi.fr/