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A knowledge based CAAD system for passive solar architecture

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ABSTRACT

A computer-aided design tool for assisting the designer to set appropriate passive solar systems for heating and cooling is presented. The system is based on a knowledge base oriented design process (KBDP). The knowledge base stores design guidelines and procedural methods for determining the passive systems that best suit the local climatic conditions. This tool is aimed to be used already at the very early stages of the design process, the pre-conceptual and the conceptual, with the purpose of achieving a passive solar architecture from the energy point of view that will better fit local climatic conditions. At the pre-conceptual design stage the system determined the bio-climatic strategies and at the conceptual design stage the recommended passive systems are presented according to previously selected design strategies. This paper focuses mainly on the later one i.e. the conceptual stage, in which the geometry, as well as the building orientation are determined. The geometrical considerations include the determination of the type and size of the passive systems that fit the requirements of both climatic conditions in winter and in summer at the given location. In addition, the design tool that was developed includes knowledge bases that contain examples and descriptive explanations. The knowledge base may be retrieved automatically by the system or upon request. Thus the system can support the designer as an expert that provides advice when needed.

1. Introduction

The process of designing energy-conscious buildings can be viewed as a sequence of decisions made at different levels of abstraction, each successive level more detailed and specific than the former one [1]. These levels of abstraction correspond to discrete design stages, which include [2–4]:

1. *Briefing*: statement of user needs.
2. *Pre-conceptual design*: feasibility study and determination of detailed program requirements.
3. *Conceptual design*: exploring different schematic design alternatives that agree with the programmatic requirements. This stage is concerned primarily with geometry and orientations, without considering material compositions.
4. *Preliminary design*: determining material compositions and building details.
5. *Detailed design*: exploring different detailed design alternatives. This stage deals with the structure and material composition considerations.
6. *Design documentation*: preparing building documents.

The design process is characterized by being an ill defined problem, which means that while searching for solutions, a better understanding of the goals and constraints might occur. Therefore, the design process should be conceived as an iterative process (see Fig. 1). An iterative process allows to advance securely from stage to stage, but at the same time enables the possibility of returning to previous stages. As the design advances, it should acquire a greater level of knowledge and details. However, the availability of the required knowledge at the right time, and especially during the early design stages, may reduce the necessity for too many iterations, or the need to go back to very early design stages, after an advanced design stage has already been reached.

Most of the available design tools do not comprise the overall design process. They rather consider only one of the above mentioned stages. Moreover, most design tools for the early stages are manual, while the Computer-Aided Design (CAD) tools and simulation engines, like DOE-2.2 [5], eQuest [6] and EnergyPlus [7] for example, are aimed to serve as evaluative tools at the advanced design stages, after the architect has already proposed a solution [8]. At these advanced design phases only the building detailing and materials can still be altered, but it may be difficult to take major measures for improving the energy performance of the design, like changing the orientation and geometry of the building, that in most cases they had already been fixed. There are few exceptional CAD tools, though,

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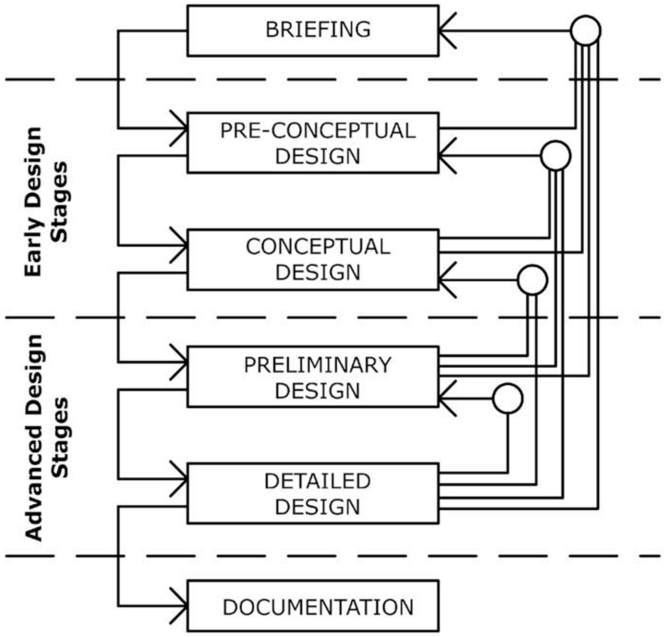

Fig. 1. The iterative design process.

that deal with bioclimatic and passive solar systems in the early design stages. For example, Sunshades [9], PSD [10], Energy Scheming [11], Sustarc [12], BDA [13].

For the early design stages different design tools were proposed in order to assist the designer in choosing and implementing the passive systems. The first type of design tools is manual methods. Mazria presented a book meant to be used as a manual design tool [14]. The book presents different bioclimatic passive solar heating systems that can be applied in the early design stages. It gives design guidelines about general required size for those systems, but lacks the accurate treatment of local climatic conditions. Balcomb suggested design guidelines as simplified methods for determining the various passive solar heating systems [15]. This work does not deal with passive cooling. Loeffler et al. [16] suggested a matrix that represents the different passive systems for cooling and heating. The matrix shows the building elements required for each system and their consistency for both passive cooling and passive heating. Their work is a manual design tool depicted by drawn schemes. As such, it is a fixed matrix that cannot be changed dynamically and automatically in order to fit to the specific local climatic conditions and the specific constraints of the project.

The second type of design tools for the early design stages is CAD systems. Brown presented a CAD system for evaluating different passive systems for a proposed design [11,17], but no recommendations on how to improve the performance of the design solution are shown. Shaviv and Peleg [10] proposed a knowledge based CAD model for the conceptual design stage, where suggestions on how to improve the building performance are presented. Even though their model deals only with direct gain system, it considers very accurately the required size of this system for passive heating and cooling. Balcomb and Prowler presented a CAD tool (ENERGY-10) for designing low-energy buildings [18,19]. This tool enables the designer to evaluate at the same time both standard and improved buildings. This evaluation gives the designer energy conscious guidelines for improving heating, cooling and daylighting in the building.

In this work, a CAAD tool that is aimed to be used at the very early design stages; the pre-conceptual and the conceptual one is presented.

2. The early design stages – the pre-conceptual and the conceptual design stages

At the early stages of a bio-climatic passive solar building design the following questions arise.

1. What are the design strategies that best suit the climatic conditions of the project site, so that the building will require non-renewable energy as little as possible? The pre-conceptual design stage deals with this issue.
2. What are the passive systems for both cooling and heating that best suit these strategies. Moreover, we need to know the right size for these systems in order to set the correct geometry, specially the massing and the orientation of the building. The conceptual design stage deals with this issue.

Nowadays, there is a wide range of knowledge related to bio-climatic and passive solar systems for both heating and cooling that allows us to reach a passive solar architecture, from the point of view of energy conservation. The problem is that the designers don't know how to reach the relevant information, or how to implement it. As a result, the proposed design may lack appropriate climatic solutions. This paper presents a knowledge based computer-aided design tool, PASYS (PAssive SYStems), that is composed by two parts. The first part helps the designer in selecting the best-suited thermal comfort design strategies at the pre-conceptual design stage. This part takes into account the local climatic conditions, as well as the building type to be designed. This part will be presented very briefly in Section 2.1, as it was presented with details in a former paper [20]. The output of the first part is a number of possible combinations of climatic design strategies out of which the designer selects one of them (see Fig. 2) which is the input for the second stage, the determination and the design of the passive systems for heating and cooling. The second part, setting the systems type and size for cooling and heating, belongs to the Conceptual design stage and will be presented in this paper. This part contains a wide knowledge base that was developed in different studies and will be presented in Sections 2.2 and 3. The system PASYS was developed as a continuation process, taking care of both parts, with the ability to go in cycles and return from the second part back to the first one, if no satisfactory solution is achieved.

2.1. The pre-conceptual design stage

In the pre-conceptual design stage first adaptations between project demands as is dictated by the program, specific constraints, specific conditions of the place and the available design strategies are taken place. In this stage local climatic conditions are verified and checked against goals in order to establish design principles that best suit both place and project.

From the climatic point of view the main goals for this stage are.

1. To achieve a thermal comfort solution that will require minimal use of non-renewable energy. In other words, to look for energy conscious design solution on one hand, and to use, as far as possible, passive solar and low energy cooling strategies on the other, so that thermal comfort conditions are achieved.
2. To reach goal 1 by using minimum thermal comfort design strategies, which mean that a smaller diversity passive systems for heating and cooling will be required in the building. Goal 2 will ensure that less different building elements should be added to the building in order to achieve the required thermal comfort, thus obtaining a simpler and more economical solution.