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AN APPROACH TO USE BUILDING PERFORMANCE SIMULATION TO SUPPORT DESIGN OPTIMIZATION

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Abstract: *Building performance simulation (BPS) is a powerful tool to support building and system designers in emulating how orientation, building type, HVAC system etc. interacts the overall building performance.*

Currently, simulation tools are used only for code compliance neither to make informed choices between different design options nor for building and/ or system optimization.

BPS could/ should be used in a way of indicating design solutions, introducing an uncertainty and sensitivity analysis and building and/ or system optimization.

In this paper some steps of ongoing research will be introduced and described briefly as well as some preliminary results will be presented.

1 Introduction and purpose

1.1 Introduction

Due to the fact that one third of national total annual energy consumption is consumed in buildings, it is estimated that a substantial energy savings can be achieved from a conventional building design through careful planning for energy efficiency [5]. Optimizing the façade of a building, supporting structure assisted thermal storage or optimizing HVAC systems would be rather beneficial to save investments or running costs but also to reduce the energy use in buildings.

Although there is a large number of building simulation available (e.g.DOE 2003), most of the tools start form the same level and are used in similar manner (Hopfe et al., 2005). They are used for code compliance checking and thermal load calculations for sizing of HVAC systems.

This research about using building performance simulation to support design optimization is dedicated to design optimization during the later phases of the design process, where currently building simulation is merely used for code compliance checking; it is determined to the duration of 4 years.

The work consists of a study of design optimization tasks in the field of building simulation resulting in the specification of requirements for building performance tools supporting design optimization. This specification will then be used to assess existing software on their applicability to support design optimization.

1.2 Problem description

Simulation tools are neither used to support the generation of design alternatives, nor to make informed choices between different design options, and they are neither used for building and/ or system optimization (De Wilde, 2004)

Building performance simulation could/ should be used in a way of indicating design solutions by for instance numbers and graphs, introducing an uncertainty and sensitivity analysis for guidance, supporting generation of design alternatives, providing an informed decision making: choices between different design options and last but not least building and/ or system optimization.

1.3 Purpose

The current project will focus on developing ideas in optimizing the current design during the final stage of the design process. Therefore first of all literature will be reviewed to analyze different optimization techniques. Secondly, the state of the art of the use of BPS in the final design is checked. This is done in finding answers to the following questions:

- How is software currently used in the final design?
- What are the requirements during the final design?
- What should be improved in current available simulation tools?
- What is the relation between design development and design optimization?

The requirement specification will then be used to assess an existing tool and to identify the applicability of this tool to optimize the design. Performance aspects considered of high importance to be optimized will be thermal comfort, energy efficiency, indoor environmental quality etc.

2 Research methodology

The research starts from existing and proven; design stage specific simulation software like IES, ESP-r and VA114 is considered.

The following steps are in progress and will be carried out in the following three years.

1. Literature review (current state, optimization techniques etc.)
2. Critical software review
3. Interviews with world leading building performance professionals
4. Design team observation

5. Developing of an initial prototype
6. Iterative prototyping (development of further prototypes, validation and testing)
7. Feedback of professionals (design development vs. design optimization, case studies)

The first step of the project is an in-depth study of design tasks of HVAC consultants. This results in a requirement specification in view of the intended role (function) of simulation tools. The specification will be used to assess an existing tool like e.g. VA114.

Specific scope of this research will be to support consultants in optimizing façade, structure assisted thermal storage and HVAC systems.

Steps 1 to 5 are already accomplished. The results are summarized in several papers (see references) and roughly in chapter 5 "Initial results".

The research methodology for the next three years will cover iterative prototyping, which implies the development of further prototypes and their validation and testing with "real-life" case studies regarding the feedback of professionals.

3 Initial results

The work of the first year was performed in collaboration with two other PhD-students.

At first, the following actions have been completed or are still in progress:
1 Critical Software Review: Several building performance simulation tools were tested and assessed for their use to the conceptual design stage
2 Interviews with Design Professionals: A number of interviews with international design professionals were conducted.
3 Literature research: On subjects as evolutionary computing especially in genetic algorithms, analytical target cascading etc.
4 Design team observations
5 Development of initial prototype

3.1 Critical software review

The focus of the critical review lays on finding answers to the following key questions:

- How is the software currently used?
- Who is the intended user group?
- Is the software validated and tested on usefulness and accuracy?

Six tools, Orca, MIT Design Advisor, h.e.n.k., Energy-10, Building Design Advisor and e-QUEST were considered.

These tools were selected more or less randomly on the basis that they claim to be of use during the design process. The selected tools give a representative overview of state of the art building performance software for professional use (Crawley et. al., 2005).

In addition, two case studies were conducted; on one hand to evaluate the tools from a specific research perspective, on the other hand to obtain an undisturbed view at the usability of the tools. Two buildings located in Amsterdam, the Netherlands were chosen for the hands on case study – one single family house and one office building.

The result and discussion section of the critical software review is divided in five categories: geometric building representation, defaulting, calculation engine, design optimization and applicability. This work is already published and can be found in (Hopfe et al., 2005)

3.2 Interviews

To date fifteen professionals were interviewed. Eight mechanical engineers, four building physicists, one civil engineer and two architects; three of them were academic, the other twelve were professionals.
The key issues of the interviews were:

A. Introduction of the interviewees and definition of their project involvement.
B. Problems repeatedly encountered during the design process.
C. Experiences using computational tools to support building design
D. List of issues future design support tools should address.

The results were divided in four categories and can be found more detailed in (Hopfe et al., 2006):

1 Classification of the interviewees
2 Perspective of the design process
3 Practice
4 Computational support

3.3 Design Team Observation

In order to cross check the theoretical results obtained from the interviews with experts, one design team observation was carried out.
The aim was to follow several design team observations. But because of the exchange of information which could be confidential, there was only the possibility to participate on one meeting consisting of eight participants. The projects aim is to redevelop an area in Amsterdam where listed warehouses are located. A number of variably sized and structured offices (100m² – 5000m²), several parking places and restaurants are planned to be build within these warehouses. The preliminary discussions run now for 12 month with no project proposal agreed upon.
The aim of this observation was to

1. Understand the structure of the design process.
2. Experience the difficulties of the decision making process.
3. Find out how soon or late BPS is used to support design.

As one preliminary conclusion it can be said that simulation did not support the inventive process. The overall aim should be to make it more creative and therefore usable during design team meetings.
For the future it is planned to observe more meetings.

3.4 First/ second prototype

In simulation tools several decisions need to be taken before a model can be build. The output of the simulation is therefore based on a number of uncertainties, which can have an enormous influence on the mode output. In order to estimate the range of those uncertainties as well as assessing the contributions of the inputs to the total uncertainty in analysis outcomes an uncertainty analysis (UA) and a sensitivity analysis (SA) were implemented.

Due to the fact that the research methodology is rapid prototyping, one in the Netherlands well-known simulation tool was chosen and via Simlab – a tool to analyze those uncertainties – a shell around this tool was build. Input parameters with a certain value were thermal conductivity, density, specific heat capacity and thickness. On the output side results like peak loads and annual heating and cooling were considered.
The case study which was implemented was the bestest case 600. The approach was also to build this case study with several other tools, like e.g. IES and henk, to analyze also the impact on uncertainties to different tools and their applicability to a certain design stage.

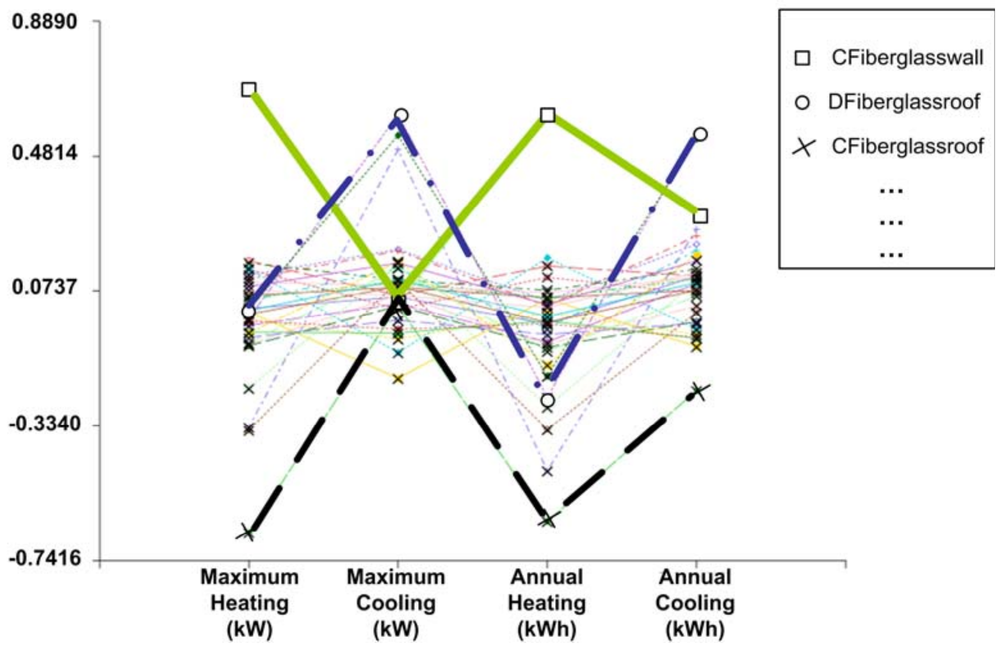

Abb. 1: Preliminary results UA/SA

The prototype will be refined and modified iteratively by extending the number of case studies being completed.

Next approach will be checking UA and SA in terms of thermal comfort.

4 Preliminary conclusions

The literature review, interviews as well as the design team observation show that there is a big need of using building performance simulation for design optimization in the detailed design stage. The conducted interviews and the software review on the other hand reveal that there is big mismatch between the user expectations and the implementation of the desired functions in those tools.

The results of the first prototypes give one direction in which way simulation tools can be improved. For the future work those prototypes will be iteratively improved and tested. A very important role in the further development of those prototypes will be feedback from professionals (design development vs. design optimization).

5 Future steps

For the next few months, it is planned to realize another prototype. The third prototype will probably implement one generic algorithm into a simulation tool. For instance, GenOpt is a module using a generic optimization program. For that reason not necessarily a genetic algorithms need to be implemented directly into the program to perform optimization with e.g. VA114. The tool GenOpt reads the output files of the simulation and generates new input files based on templates for the tool. A new optimized set of input parameters is then generated after analyzing simulation errors etc.. This process can then be proceeded several times.

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