Bartak, M., Drkal, F., Hensen, J.L.M., Schwarzer, J., Lain, M. & Sourek, B. (2003).
An approach to teaching and research of simulation for environmental engineering design.
Proceedings of the 3rd International Conference on Advanced Engineering Design, 1-4 June, pp. 1-6.
Prague: Czech Technical University

AN APPROACH TO TEACHING AND RESEARCH OF SIMULATION FOR ENVIRONMENTAL ENGINEERING DESIGN

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ABSTRACT
This paper starts out by elaborating why computer modeling and simulation is such an important technique/ tool for modern state-of-the-art environmental engineering. It then continues with how this is currently integrated in engineering analysis and design. The paper continues with describing what we do in this field in terms of teaching and research. The paper finishes with indications for (our) future work in this area.

KEYWORDS: building performance simulation, co-operation in higher education and research

INTRODUCTION

Simulation for environmental engineering covers physical processes in buildings. Simulating energy and airflows in buildings is perhaps the best-known activity, but simulation of light, smoke, moisture, noise and the quality of the indoor environment are often just as important.
The building performance simulation field is rapidly evolving; see e.g. [1-4]. The techniques and applications are undergoing rapid change. Dramatic improvements in computing power, algorithms, and physical data make it possible to simulate physical processes at levels of detail and time scales that were not feasible only a few years ago. Applications that were not attainable or practicable some years ago are now commonplace.

The building construction industry, without a doubt, is one of the most important industrial and economical sectors influencing the quality of life and the environment. And yet, planners, designers and property developers pay very little attention during the design process to the life-cycle cost of owning and operating buildings. Modeling and simulation offers the potential to cope adequately with building performance related concerns, as well as with the construction process. Increasingly, computer based models (programs) are being employed to aid in the design, operation, or management decision making process.
Simulation-based information has the potential to improve competitiveness, productivity, quality and efficiency in the construction industry as well as facilitating future innovation and technological progress. In that respect, successful implementation of software tools and applications in practice will be crucial for architecture, engineering and construction (AEC) organizations to gain and maintain a competitive edge in the global construction market.

Figure 1 sketches the evolution of interest in building performance simulation for building and environmental engineering design and analysis. We are now at the point where it is important to try to raise the realistic level by increasing the usability of this technology for performance based building and systems design.

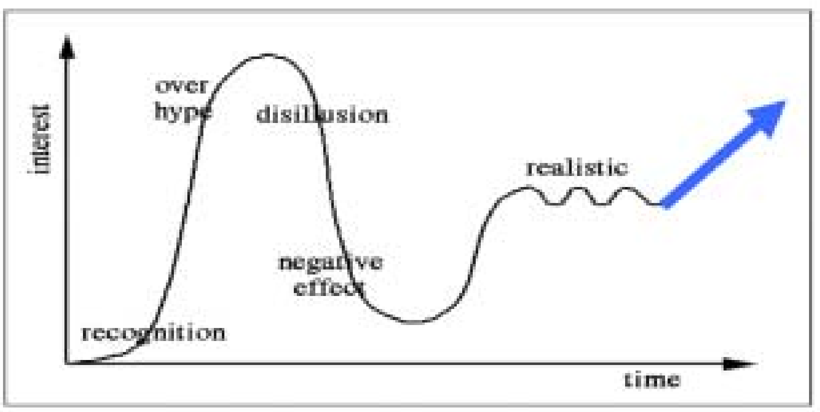

Figure 1 Schematic evolution of interest in - and uptake of – building performance simulation since approximately 1970 until the start of the 3rd millennium

The remainder of this paper highlights the work we are doing in this respect at the Environmental Engineering Department of the Czech Technical University in Prague. As implied by the authorship of this paper, this is done in close co-operation with the Center for Building & Systems TNO – TU/e at the Technische Universiteit Eindhoven in The Netherlands. We feel that these groups are very complementary on different levels. The Czech group is, for example, based in a Mechanical Engineering department, whereas the Dutch group is embedded in a building physics and building systems environment. The groups are also complementary in terms of research, with the Czech group more oriented towards practical application oriented scientific research, whereas the Dutch group more tends towards tool and process application oriented scientific research in this area.

INTEGRATION OF SIMULATION IN ENVIRONMENTAL ENGINEERING DESIGN

As implied by Figure 2, in practice there are actually many more professionals who use building performance simulation than is commonly realized. However, in most cases this is still indirectly. Of course the technology could be much more effectively applied through the direct route. In 1993 it was still expected that some sort of intelligent human-computer interface would be required for this. As will be elaborated in this paper, this idea has somewhat changed since those days.

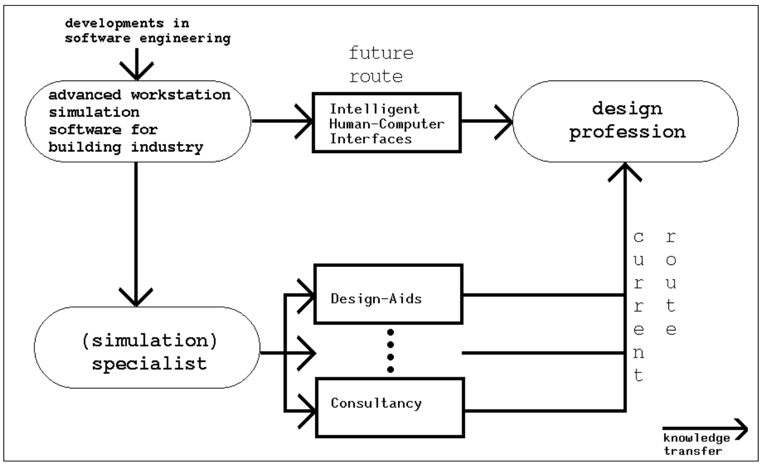

Figure 2 Direct and indirect usage of building performance simulation [5]

The main current issues in building performance simulation in terms of design support can be summarized as follows.

- The, until now, most common approach is detailed design confirmation, which is analysis (of a single solution) rather than (multiple variant) design oriented.
- Often this involves high-resolution (light and flow) modeling just to impress the client. If it is just "colors for directors" what is requested, why are current lower-resolution tools not able to provide these sorts of results?
- Many tools are not really used in design, probably because there is a mismatch between the anticipated user and the real user in terms of expectations, background knowledge, skills, and available resources.

- Many tools start from the same level and are (to be) used in a similar manner. There is an increasing awareness in design practice that there is no need for more of the same. However there is definitely a need for more effective and efficient design support applications.

Our current work in this area involves research that aims to find out (1) which designers would like to use simulation tools in the first place and (2) the requirements for these tools in terms of user-interface and design support features. We want to stress "support" so that future tools may help (not attempt to take over) the designer in his/her task at hand. Specific issues which will be considered in this research include the potential of data mining, design optimization, design analysis integration, use of component based systems templates, etc.

Current building simulation software is able to deliver an impressive array of performance assessments. However, there are many obstacles to their routine application in practice. Some of the main problems are as follows.

- Accuracy and confidence in the results.
- Technical promises are only partly achieved.
    - Simulation is mainly used for detailed design confirmation.
    - Most building and system models are limited in their capabilities.
    - System simulation is not very well developed yet.
    - Many building systems and components cannot be simulated yet.
- Simulation can be costly; especially in case of high resolution modeling

In terms of quality assurance, there have been – and still are – many efforts related to validation and verification of building performance simulation software itself. A perhaps even more important aspect, which received much less attention until now, is how to assure the quality of applying the software. This is very much related to knowledge and skills of the person who performs the simulation, and to the quality of performance assessment methodologies and procedures.

It was a rather naïve idea during the seventies and eighties that it would be possible to include sufficient "intelligence" in building performance simulation software so that "anyone" would be able to carry out relevant simulations. It is now commonly accepted that this will only be possible for a limited number of very specific, relatively simple, well-defined simulation tasks such as some code compliance checks, which can, for example, be driven from a CAD package. However, even in these cases the user needs to have sufficient domain knowledge in order to be able to interpret the results in a meaningful manner.
In the real world, simulation tools are "never" able to do exactly what a designer wants, because a professional usually wants to assess novel and innovative solutions that are commonly not yet featured in the software.

Simulation for environmental engineering is not merely software; it is an engineering discipline that, in summary, is critically dependent on the following user requirements.

- Sufficient domain knowledge and understanding of fundamentals and basic principles, which, as indicated in e.g. [6] , increases with modeling resolution level.
- The ability to creatively solve real world problems.
- Knowledge of which software tools to use, when, why and how.

Simulation quality assurance needs to incorporate the following aspects.

- Selection of appropriate level of modeling resolution and complexity.
- Calibration of validated software.
- Proper (design) application methodology taking into account uncertainty considerations applied to the input (design) parameters.

These principles are the foundation of our teaching activities and research interests as elaborated below.

TEACHING

Our teaching activities comprise both undergraduate and postgraduate formal classes and individual project work. The course material, which is used in the classes, is almost exclusively web based. Basically the same course material is used in Prague and in Eindhoven. All authors of this paper are involved in the teaching in Prague. The formal courses are as follows.

Introduction to Modeling and Simulation for Environmental Engineering. This class aims to give an introduction of the theoretical and operational principles underlying this new technology. By a series of (oral and self-study) lectures, the class introduces the concepts, assumptions and limitations that underlie the methods currently used to appraise the (energy) performance of buildings. The subjects are developed from basic principles assuming limited knowledge of computers and application software. Key concepts are: building performance analysis tools vs design tools; overview building performance simulation tools; hands-on experience web mining; hands-on experience integrated building simulation software; and hands-on experience Unix operating system.

Capita Selecta of Modeling and Simulation for Environmental Engineering. As a follow-up to the above, this (selected subjects) class aims to explore in greater depth some concepts of this new technology in terms of theory, assumptions, operation and limitations. Key concepts are: building performance modeling and simulation; theoretical principles and assumptions; hands-on experience by worked examples; and assignments.

Our teaching is based on the following premises and approaches.

- Teaching in higher education should be „fed" by research.
- All undergraduate students have to complete at least the above *Introduction* class before they attempt simulation based project work. All PhD students in our area have to take the *Capita Selecta* class as well.
- The real learning of modeling and simulation takes place by doing; i.e. by means of individual or group project work, which ranges in complexity from relatively simple (undergraduate), via state-of-the-art (e.g. consultancy projects) to very advanced levels (postgraduate research).
- PhD students are involved in supervising undergraduate work. Research fellows are involved in supervising PhD students. Senior staff is available to assist research fellows. This "stacked" approach is similar to practical training approaches in, for example, a medical school.

RESEARCH

Based on approaching the building as an integration of environmental systems as schematically indicated in Figure 3, our research basically aims to reduce fuel and power consumption, and associated emissions, while ensuring a good indoor environment.

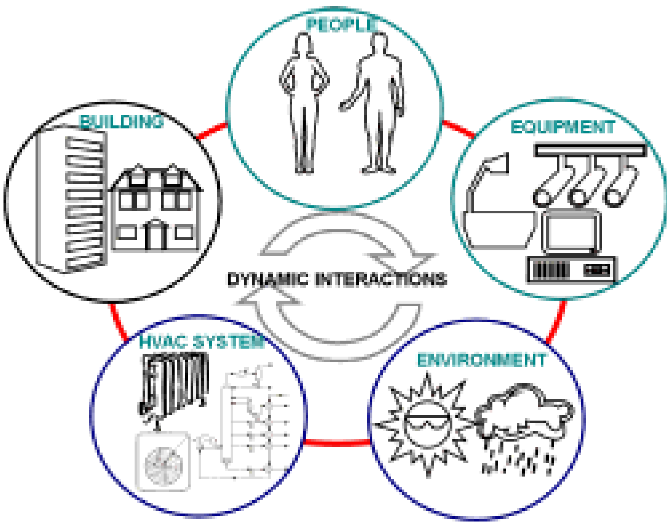

Figure 3 Dynamic interacting sub-systems in a building context

This work incorporates three main strands, as follows.

- General research on domain specific issues, such as integrated building energy performance appraisal, novel ventilation approaches, and low energy heating and cooling techniques and/or systems; e.g. [7].
- Application of this knowledge through consultancy for both the construction industry and the building energy modeling community, covering a range of building types and indoor environments in the Czech Republic (from offices, museums, supermarkets, factories to a zoo); e.g. [8-10].
- Advancement and validation of building energy modeling and simulation tools, guided by shortcomings encountered while pursuing the above; e.g. [11].

In all three cases, the focus point is the interaction between building structure, and other environmental systems such as: people, heating, ventilation, air-conditioning, lighting, and building integrated thermal and power generators (photovoltaic, combined heat and power, etc.). In our opinion this is a very interesting, inter-disciplinary (design) area where in practice many difficulties arise.

Most research is done in the context of national and international sponsored research, consultancy and PhD research. PhD research typically covers all three strands indicated above. In the context of the collaboration between Prague and Eindhoven, we aim to pair PhD student projects in terms of topics. In Prague, we also like to involve PhD students in consultancy work. This enables them to generate some additional funding while doing meaningful work for there PhD work.

CONCLUSIONS AND FUTURE WORK

Building performance simulation has come a long way since the early seventies. Instead of focus on the modeling aspects, there is now an increasing demand for better integration of the technology in the design, construction and operation processes of buildings and the systems which service them.
One of our main conclusion this respect is that simulation is much more than just software; it is an engineering discipline that can only be applied effectively if the user has sufficient domain knowledge.

Current software is able to deliver an impressive array of building performance assessments, but there are still many issues which must be resolved for routine application in practice, such as (1) accuracy and confidence in the results, (2) earlier technical promises have been achieved only partly, and (3) simulation can be costly.

This paper has indicated several possible solution approaches to resolve this including (1) better quality assurance, (2) research on how to make current tools more effective in building design, (3) sharing of software developments, and (4) routes for knowledge transfer such as teaching.

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