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The deployment-dependence of occupancy-related models in building performance simulation

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ABSTRACT

The relationship between the proper choice of occupancy-related models for building performance simulation and the pertinent purpose of the simulation-based query is not well understood. We thus address the necessary conditions for a better understanding of the context-dependence of occupancy-related model use in building performance simulation. First, given the multitude of application scenarios (involving different users, different phases of the building delivery process, different queries, etc.) in which building performance simulation can be deployed, we propose a conceptual framework in terms of a multi-dimensional simulation deployment space. To demonstrate the desirability and usability of such a framework, we provide two specific case studies, involving deployment instances of probabilistic and non-probabilistic occupancy models. One case study focuses on occupancy model deployment options in the context of simulation-based predictive building systems control. The second case study explores the implications of occupancy model selection in the context of simulation-based building design support.

1. Introduction

Performance simulation models can be generated with different levels of resolution with regard to the representation of the underlying (physical) phenomena, required (input) information, and produced results (output). Generally speaking, the choice of a specific level of resolution in these aspects is not independent of the types of queries, which the simulation model is expected to provide answers for. Most professionals are familiar with the query-dependence of modeling choices regarding representational methods of physical phenomena such as heat transfer. For example, it is generally understood that queries regarding buildings' dynamic behavior (e.g. their thermal inertia) cannot be supported using steady-state heat transfer models. However, such familiarity cannot be taken for granted in all aspects of model generation.

In this context, an important case in point pertains to possible choices in the type and resolution of representations of people's presence and behavior in building performance simulation models. The relationship between these choices and the purpose of the simulation-assisted analyses is not well understood. This, however, represents a practical problem, as it implies that adopted methods in capturing people's presence and behavior in a simulation process may in fact be inappropriate with regard to specific simulation use scenario at hand. Likewise, it can be argued that the criteria for the evaluation of the representational fidelity of people's presence and behavior in buildings are not independent of the types of the studies undertaken in the course of simulation tool deployment.

As such, there are a considerable number of scientific efforts toward quantifying the impact of occupants on building performance. For instance, Azar and Menassa [1] observed that energy models of office buildings' in different climatic zones in USA are highly sensitive to occupancy-related behavioral parameters. More specifically, Yang and Becerik-Gerber [2] showed that application of HVAC schedules that use observation-based personalized occupancy profiles in a three-story office building test bed could save up to 9% energy compared to the conventional (default) schedules. More recently, researchers have tried to classify and critically review different modeling approaches (see, for example, [3] with regard to presence models and [4], which addresses the adaptive occupant behaviors). General criteria for the evaluation of the fidelity and fitness of occupancy-related models were outlined as part of a recent review paper [5].

Many more instances of studies on occupants' behavior in buildings and respective modeling techniques could be mentioned. However, there are arguably very few studies that have explicitly addressed the fitness of occupancy-related models with regard to different simulation queries. Gupta and Mahdavi [6] first proposed

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– in a different context – a perspective to view and structure the performance queries in terms of a multidimensional query space. The classification of the queries was intended to render them more suitable for analysis, resulting in enhanced responses through selection and execution of appropriate computational tools and techniques. Specific to the deployment of occupancy models, Hoes et al. [7] used sensitivity analysis to arrive at the minimal required user model resolution with regard to a number of building performance indicators and design parameters. That is, when for example a performance indicator is determined to be more sensitive to the occupancy-related assumptions, the simulation effort should start with a more sophisticated model of occupancy (and if the performance indicator still does not fall within the required target value range, a higher resolution level should be applied). However, the focus of the study is on the design stage and it does not involve empirical data to confirm the conjecture that using more sophisticated models would necessarily provide more accurate results.

Given this background, we must conclude that the relationship between the proper choice of occupancy-related input data models for building performance simulation and the pertinent purpose of the simulation-based query is still not well understood. Hence, the need for further explorations in this area was recognized, amongst other instances, by the IEA Annex 66 [8], an international forum working on the advancement of the state of the art in the area of occupancy-related model development and evaluation.

Specifically, the present contribution addresses the necessary conditions for a better understanding of the context-dependence of occupancy-related model use in building performance simulation. Given the multitude of scenarios (i.e., use cases involving different users, different phases of the building delivery process, different queries, etc.) in which building performance simulation can be deployed, a respective well-structured conceptual framework in terms of a multi-dimensional simulation deployment space is of utmost importance. Such a framework is not only a prerequisite for establishing a solid basis for the suitability evaluation of alternative modeling techniques and resolutions with regard to people's presence and behavior in buildings, but also contributes to substantiating the evaluation process of such modeling techniques.

To demonstrate and elaborate on the desirability and usability of such a framework, we provide two specific case studies, involving probabilistic and non-probabilistic occupancy models. One case study focuses on occupancy model deployment options in the context of simulation-based predictive building systems control. The second case study explores the implications of occupancy model selection in the context of simulation-based building design support.

Note that the purpose of these case studies is not to argue for the superiority of any specific modeling approaches, be those probabilistic or non-probabilistic. In our view, it is of fundamental importance that research in developing occupancy-related models is not hampered by a priori or arbitrary fixation on specific techniques or tools. Rather, our objective is to emphasize that models cannot be meaningfully evaluated without a backdrop of the deployment scenarios.

2. The conceptual space of simulation-based deployment scenarios

In order to discuss the relationship between performance simulation deployment scenarios and the corresponding occupancy-related models, a structured overview of the former is needed. As a possible vehicle for such a structured overview, a multi-dimensional simulation deployment space can be highly expedient (see [6], as an instance of early work in this area). The idea is to locate a specific simulation-based analysis activity concerning building design and operation in a conceptual space of all theoretically possible simulation deployment scenarios.

Table 1
Dimensions of the proposed simulation deployment space.

	Dimension	Remarks/examples
i	Phase in the building delivery process	Early design, detail design, HVAC systems design, building operation
ii	Purpose (or nature) of the study	Parametric study of design options, generation of energy compliance documents, HVAC system sizing, HVAC controls
iii	Domain (discipline)	Energy, thermal comfort, lighting, acoustics, fire safety
iv	Building type	Dominant function of the building (residential, commercial, educational, mixed use)
v	Indoor climate control strategy	Passive, hybrid (mixed mode), fully air-conditioned
vi	Physical destination	Building details, whole buildings, campus, district, urban
vii	Zonal destination (resolution)	Whole building, individual floors, orientations, micro-zoning
viii	Performance indicator (results)	Annual heating/cooling demand, peak heating/cooling loads, PMV
ix	Temporal resolution (horizon)	Entire life-cycle, annual, monthly, daily, hourly, sub-hourly

A first step toward establishing such a framework would be the specification of the multiple dimensions of such a simulation tool deployment scenarios. In the following, we briefly outline nine such dimensions (see Table 1) that may be considered to be directly relevant for the selection of appropriate occupancy-related models. These dimensions specifically address: (i) relevant phase in the building delivery process; (ii) purpose (or nature) of the simulation-based study; (iii) disciplinary domain of the study; (iv) building type; (v) indoor climate control approach; (vi) physical destination (object) of the study; (vii) zone-level destination of the study; (viii) relevant building performance indicator; (ix) relevant time-resolution (or time horizon) of performance results.

From a broader perspective that is not specifically targeted at occupancy-related models, further considerations pertaining to users' professional background, users' experience, and the client type may also play a role in the identification of desirable tool attributes with respect to various simulation use scenarios. For instance, the proper and robust use of any kind of an analysis tool requires that the user can cope with the complexity of the modeled phenomena. Proper compilation of model input data, correct selection of simulation settings, and sensible interpretation of the results are parts of that process. It is thus not unreasonable to require that in general the sophistication of modeling tools and processes are commensurate with the user's professional background. Moreover, depending on their experience, even users with similar backgrounds may still display very different levels of comprehension and skills regarding constructing building models and conducting simulation-based performance analyses. Finally, the addressees of the outcome of simulation studies have implications not only for the scope and resolution of the analyses, but also for the way they are processed and presented: The clients' concerns can thus influence the choices regarding the representation of internal processes in building modeling.

2.1. Phase in the building delivery process

A simulation-based study can be conducted at different stages of the building delivery process. The implications for occupancy-related model selection is evident, as the resolution of available