Automation in Construction 54 (2015) 39–53

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Review

Building performance simulation in the early design stage: An introduction to integrated dynamic models

Kristoffer Negendahl *

Technical University of Denmark, Department of Structural and Civil Engineering, DTU Byg Brovej, Bygning 118 2800 Kgs. Lyngby, Denmark

ARTICLE INFO

Article history:
Received 6 November 2013
Received in revised form 21 February 2015
Accepted 4 March 2015
Available online 27 March 2015

Keywords:
Integrated dynamic model
Parametric
Dynamic
BIM
BPS
Building performance
Building energy
Collaboration
Early design stages

ABSTRACT

Designing with building performance simulation feedback in the early design stage has existed since the early days of computational modeling. However, as a consequence of a fragmented building industry building performance simulations (BPSs) in the early design stage are closely related to who is creating and operating the BPS models. This paper critically reviews the different ways designers and analysts use BPS in the early design stage. One of the key findings is that most tools and methods used in the early design stages are insufficient to provide valid feedback while in the same time being flexible enough to accommodate a rapid changing design process. The main concern points to the way geometrical models and analytical models are combined and how this affects the way the buildings are designed and perform. This paper concludes that integrated dynamic models may combine a design tool, a visual programming language and a BPS to provide better support for the designer during the early stages of design as opposed to alternatives such as the current implementation of IFC or gbXML or the unaccompanied use of simulation packages.

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Contents

* Tel.: +45 45251700.
E-mail addresses: kristoffer.negendahl@gmail.com, krnj@byg.dtu.dk.

http://dx.doi.org/10.1016/j.autcon.2015.03.002
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1. Introduction

Designing energy efficient buildings with good indoor environment involves elements of expertise deriving from multiple disciplines such as architects, civil, mechanical and electrical engineers. With current emphasis on sustainability, including building energy and indoor environment, design requirements from the involved disciplines have become more important in the early design stages.

As a consequence building performance simulations (BPSs) are increasingly used to design buildings.

While numerous unified tools that act both as a design tool and BPS tool exist, building designers still seem to prefer to create and explore design options in dedicated design tools such as ArchiCad, Sketchup, Revit, Rhino, and Maya, as they support the concept of a sketch and the freedoms associated with design tools [1]. As a result the most prevalent method of receiving performance feedback in the early design stages is associated with either manually (re)modeling the designs in dedicated BPS tools or with a manual import and export task of the geometry. The import/export process works with proprietary formats or common data schemes such as IFC (Industry Foundation Classes [2]).

During the last few years new ways of integrating design tools and BPS tools at runtime-level have been developed. These new methods provide performance feedback directly in the native design tool and opens up for new design scenarios previously inaccessible for architects and engineers during early design stages.

The integration of a design tool and a BPS tools is fundamentally changing building design into a faster, performance-aware and more flexible process, which eases the production of multiple design alternatives. The posing question is, how do these coupled models fit into the design process of the early design stages?

To answer this one must first deduct the ways design tools and BPS tools can be coupled, however before one can assess the coupling choices, it is necessary to define the users and their requirements for these tools. Acknowledging that requirements of building design are comprised of quantitative elements (i.e. yearly consumed energy, amount of daylight, cost etc.) and qualitative elements (i.e. social impact, spatial planning, esthetics, etc.), building design aims to satisfy multiple criteria beside measurable performances. This implies that building design is evidently connected to role-definitions and collaborative processes, and it also implies that the utilization of building performance has to respect the broad extent of both quantitative and qualitative elements of building design. This article reviews current interdisciplinary collaboration in the early design stages and specifically reviews, how building performance simulations are used by architects and engineers in designing buildings. The second part of the review addresses the main developments in which a design tool and a BPS tool are combined. Under these circumstances using BPS environments in the early stages of design propagates in two main questions:

1) Who operates geometric models and building calculation models?
2) What is the best way to couple geometric models and building calculation models in the early design stages?

These questions are explored in two dedicated parts in the article.

2. Model operation — the users, the geometry and building performance

Operating a geometric model[1] implies both the creational process of making geometry and the direct effect on building performance. Operation of a geometric model infers a) creating unambiguous geometry that represents a building, and b) any changes, modifications and manipulation during the design process is performed by the model operator. The typical user or model operator consists of an architect creating and manipulating a geometric model in a design tool. The term design tool covers any tool that is able to represent building geometry. Another typical model operator is the engineer, who in similar ways creates and controls a calculation model in a BPS tool. The amount and quality of human and machine interaction between different model operators form convergence between the operated models.

Separated but correlated models have been the standard procedure, when architects and engineers have designed and later constructed buildings. Separated geometric and calculation models is one of the many symptoms of a disciplinary fragmented building industry. Souza [3] prefers to describe the disciplinary division by the qualification of a person, rather than the background of the person, thus classifying two main roles in building design as the building designer and the simulationist. It may be appropriate to let the building designer operate design tool and simulationist operate the BPS tool, but in many cases the roles and the operations of the models are less clearly defined.

The introduction of building information modeling, BIM (specifically referring to the gbXML [4] and IFC [2] standards), sought improvement, when teams are working with separated models. Even though the concept of a common reference model makes sense in all stages of building design, the early stages are often detached from any form of building information model. Seen from a technical point of view this is mainly due to the fact that many of the tools (both design tools and BPS tools are yet to implement resilient tool integration).

This article examines, to what extent building performance simulation software is integrated in the early design stage, thus touching upon two domains of integration: user integration (Fig. 1.1) — concerning human collaborative interactions, and model integration (Fig. 1.3) — concerning higher levels of computational automations between design tools and BPS environments. The third domain; tool integration (Fig. 1.2), mainly concerns technical details of specific tool interoperability and is omitted in this article.

2.1. The users — model operation

Model operation is today primarily a collaborative concern, which refers to 'whom' and 'what' is to be manipulated, rather than 'how' the model is manipulated.

Different collaborative partnerships have been suggested, examined and documented over the past years. Researchers such as Attia [5], Banke [6] and Hermund [1] have documented the current relationship and effect of using design tools linked to BPS through interviews and surveys among architects and engineers. Some of their results on

[1] Geometric models refer explicit to building geometry in computational geometry and topology in geometric modeling and graphics.

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