Performative Design in Architecture

Employment of Virtual Prototyping as a Simulation Environment in Design Generation

Rivka Oxman¹, Roey Hammer, Shoham Ben Ari
¹Technion Israel Institute of Technology, Haifa, Israel
¹http://tx.technion.ac.il/rivkao
¹rivkao@gmail.com

In view of current developments in the theory and technology of digital design, certain potential for novel direction in virtual prototyping is beginning to emerge. In this paper an approach for the employment of virtual prototyping as a generative environment for performance-based design is proposed. The term combines both the concepts of performance and digital generation. In creating digital design environments for design the generative capabilities are incorporated within performance-based simulations. The potential of performance-based simulation as a digital design methodology in architectural design is explored. Experiments in digital architectural design illustrate this approach. Works in a framework of an ‘experimental digital design’ are presented and illustrated.

Keywords: Digital design; performance-based design; design generation.

Introduction

In a survey of current approaches to virtual prototyping in the fields of architecture, engineering and construction in the built environment, it is clear that there is significant potential for the employment of virtual prototyping in digital architectural design.

Virtual prototyping in the literature has various definitions (Oxman, 2007). In this work, virtual prototyping is considered as the exploitation of simulation processes for the test, evaluation and modification of prototypes in virtual design environments. Virtual prototyping originated in manufacturing industries where industrial products such as cars and airplanes were tested before manufacturing. Virtual prototyping exploits simulation processes and is carried out on a CAD model, by performing the same tests in computational environments for virtual prototyping as those formerly undertaken on physical prototypes. The role of simulations here is to obtain quick design feedback and to help make expedient and well-founded judgments in order to support efficient design modification processes.

Virtual prototyping and current simulation technologies are used for evaluating the performance of the design prototype mainly in product development, manufacturing and construction purposes. Such simulations are based on quantitative and
analytical results and can vary from visual analysis to various engineering analysis simulations such as testing temperature; acoustics; behavior under physical conditions etc.

Design is conventionally viewed as a process of repetitive cycles of generation/evaluation/Modification until convergence is reached by satisfying the design objectives. The need to modify and re-design the model by modification and manipulation on a CAD model are key issues in developing applications in virtual prototyping environments for design.

Most virtual simulations today are employed in the evaluation phase. Current applications in virtual prototyping in architecture, engineering and construction are focusing on the development of models and simulation techniques for evaluation and prediction tasks of STATIC designs. For example, certain techniques are employed in design for modeling visual impact others are employed for testing structural stability etc. These types of works are related to the traditional iterative design model in which environmental feedback is essential to check a final STATIC design. Issues such as interactivity and control are also essential for developing the iterative model (Kieferle et al., 2006).

Recent work in the construction industry demonstrated applications of virtual prototyping for the evaluation of complex construction processes (Baldwin, 2006). Recent works in architectural design demonstrated interesting evaluation methods related to environmental design. For example, an evaluation method of airflow (Kieferle et al., 2006), or an evaluation method of environmental conditions and their impact on human behavior (Wei and Kalay, 2003) and a method for close-range view representation of natural elements in a real time simulation for environmental design (Fukuda et al., 2006).

However, there currently appear to be fewer works that support virtual prototyping design generation in which the design object can be DYNAMIC. In most applications in which simulations are used for the evaluation phase they are not integrated in the generative process. In contrast to simulations that evaluate performance processes we present an approach that combines both the concepts of performance and generation. In creating digital design environments for digital design the generative characteristics such as dynamic parameters are incorporated within performance-based simulations.

This paper proposes a transition in applying virtual prototyping techniques in architectural design. In the following section, key concepts of important technologies in virtual prototyping for design are presented. Following this, we present methodologies in digital design (Oxman, 2006) focusing on design methods and techniques. We then propose and discuss how performative considerations can be formulated as simulations and become an integral part of performance-based generative models. Finally, we present and illustrate experiments in digital architectural design and demonstrate how virtual simulations can support performance-based design generation. Works in a research framework of the digital design studio are presented to illustrate this approach.

**Performance-based design and the Design Prototype**

Currently simulation processes in virtual prototyping remain within the boundaries of the conventional formulations of the design prototype. There is a wide range of digital tools for analysis and evaluation of performance aspects. However, none of them currently provide generative capabilities. Contemporary digital theories and technologies suggest a shift from analysis simulations to synthesis and generation. This distinction is very significant. Instead of analyzing the performance of a design, and modifying it accordingly, we propose using performance-based simulations to directly generate and modify the digital prototype. In such an approach the desired performance can be selected and activated as a performative-mechanism that can generate and modify designs.
A typical simulation process can illustrate this distinction. A frequently applied simulation that characterizes testing and evaluation in conventional structural prototyping process is the Finite Elements Method (FEM). This type of simulation typically presents the traditional iterative approach. In such a design mode, only after analyzing the structural stability is the design re-generated. In this approach evaluations provide feedback for iterative design modifications. By contrast, the proposed approach suggests that on the basis of such analytical procedures modifications can be automatically modified by generative operations controlled by the analytical findings. Performance here is defined as the ability to directly manipulate the variable properties of a digital prototype (Oxman N, 2005).

The implications of such approach can be broadened and include simulations of both quantitative and qualitative aspects such as spatial, social and cultural factors (Rahim, 2005), in addition to technical simulations such as structural and acoustical performance. Such advanced applications require the formulation of generative types of simulation models that can be oriented towards the generation of designs.

In the following section we introduce and discuss concepts and works related to performance-based design and analyze their potential relevance for design generation in a virtual prototyping environment for design.

**Performance-based architectural design**

Architecture as a design discipline has become rich in concepts that are transforming the design methodological, as well as the formal, content of the architectural artifact. Among the methodological developments that are emerging, performance-based design offers significant design models all of which are essentially meta-formal in their intentionality.

Performance-based design is currently recognized as one of the most significant and productive design models in digital design. In performance-based design, building performance is regarded as a guiding design principle and one which is morpho-genetic while being essentially formally neutral in the sense that form generation is the result of performative simulation processes (Shea, K., Aish, R., Gourtovaia, M., 2003; Kolarevic and Malkawi, 2005).

Many recent designs associated today with digital architecture are the products of performative design methods. The list of recent projects that have incorporated performative methods in the design process are now well-known. They include among others: the Greater London Authority Headquarters, (2002) and the Swiss RE building (2004) designed by Foster & Partners and Arup Associates, the ZED project by Future Systems (1995); the Kunsthaus in Graz by Peter Cook, Colin Fournier; Bollinger and Grohmann (2000-2003).

In spite of the complex geometries and free-form that characterized digital designs, in most of these projects performance-based systems and simulations were based on traditional iterative design models.

Understanding how performative design can methodologically influence the generation of designs while supporting the potentially complex formal and geometrical character of designs is a question of relevance for the future development of performative design systems. In the next section we suggest and illustrate how the employment of performance-based simulation can dynamically generate and modify designs.

**The ‘Performative Design Prototype’**

Performative prototyping is fundamentally different from conventional CAD simulation processes. Traditional CAD tools are based on performance evaluation of the object itself. Existing CAD prototypes are not programmed to integrate formation processes informed by performative simulations. Future directions for development are digital techniques that couple principles of performance with principles of generation (see Shea et al., 2003).
In our approach in a performative-based simulation the prototype is dynamically modified. For example, desired effects of physical context, such as effects of light or effects of behavior, can be formulated as formal systems which include formative transformations as well as evaluative simulations.

In the following section we present an experimental project done in the research framework of the digital design studio that illustrate our suggested method and show how animated simulations can be employed to generate designs. We discuss and demonstrate how performative considerations can be formulated as simulations and become an integral part of design models.

The two layered wall
The following experiment in performative modeling involved the design of responsive building skins that might protect a building from excessive wind loads, solar penetration and contextual acoustical problems such as urban noise.

The structural pattern is adaptable and designed to respond to changing conditions of wind and light. The responsive wall is a project that integrates a constructive skeleton (see figure 1) that supports an external layer composed of a dynamic surface structure (see figure 2). This skeleton is being designed in such a way that built-in sensors will inform and modulate the dynamic motion of the external skin.
which is designed as a system of operable scales. The sensors activate the mechanism embedded in the skeleton that modulates the openings of the scales (see figure 3).

The skin design itself has been generated by a digital performative simulation of wind force and light penetration. These forces produce dynamic effects on the skin. Animated techniques were employed to study these dynamic simulations and performative effects. This work was generated by scripting in 3D Studio Max (see figure 4).

The objective in this model is that the formation of the skin/structure assembly will be generated by multiple performative conditions, all of which are dynamic. This condition of design models that support multiple performative analyses in their componentized assembly is highly representative of complex wall assemblies. In this case, the design objective is to support dynamic behavior in the various components in response to the dynamic nature of wind and light loadings of the building surface. Animation studies in 3D Max were employed to model the formation process in which form generation was controlled according to types of simulations.

**Future research**

Developments in virtual prototyping will be based upon such integration possibilities of generation and evaluation in performative-based generation. One of the outcomes of these studies is the need to research the formulation and design of such integrated performative-based generation systems.

*Figure 2*
The animated skin
Future directions for development are digital techniques that couple principles of performance with principles of generation.

However, much of the problem of future research in the design of performative architectural systems for virtual prototyping lies in the need for new conceptualizations of the architectural prototype. What's in a prototype? What is the content that will make both generation and evaluation possible?

The “Performative Wall” project has illustrated how simulations were employed as “design tools” in the hands of the designer. These simulations of the dynamic behavior of architectural systems in response to performative factors are an experimental medium for designing prototype systems. This direction can potentially promote the development of prototype-based user interfaces for performative-based digital design. If the new conceptualization of such architectural prototype systems is the first prerequisite for research and development, then the model of the “designer as a tool maker”, must find expression in this important design space that we refer to as virtual architectural prototyping.

Here we have considered the dynamic properties of prototypical architectural models and how their dynamic evolution can support a performative process in virtual prototyping. Beyond such simulations, what then might be the generative limits of design creativity of the virtual prototype? If performative design takes us beyond the formal into a territory in which form and formal preferences are not
dominant considerations, is the “formlessness” of performative about to generate a world of “natural” forms that are predetermined only by their response to physical context? Where then is the dividing line between architect as form giver and tool maker as form receiver? When and how does one intervene through physical laws?

**Summary and conclusions**

Performative-based generative design potentially introduces directions in architectural digital design that have important implications for future developments through the concept of virtual prototyping for architecture. In performative-based generative design approaches to simulation models are employed that integrate form modeling, performance evaluation, and generative procedures into a virtual environment. Instead of using simulations for testing and evaluation, design generation and design evaluation are integrated in digital technologies for modeling the physical qualities of design systems, simulations of their performance, and redesigning their form according to findings of performance evaluations.

In this paper we discussed and demonstrated how performative-based considerations can be formulated as simulations and become an integral part
of design models. An experimental project illustrated the conceptual content of this approach.

New developments in virtual prototyping will be based upon such integration possibilities of generation and evaluation in performative-based generation. One of the outcomes of these studies is the need to research the formulation and design of such integrated performative-based generation systems. Future directions for development are digital techniques that couple principles of performance with principles of generation.

However, much of the problem of future research in the design of performative architectural systems for virtual prototyping lies in the need for the new conceptualization of the architectural prototype. What’s in a prototype? What is the content that will make both generation and evaluation possible?

Furthermore, simulations might be employed as “design tools” in the hands of the designer. This is a novel direction that will promote the development of user interfaces for the future digital architectural designer. If the conceptualization of the new architectural prototype is the first prerequisite for research and development, then the model of the “designer as a tool maker”, must find expression in that design space that we call virtual prototyping.

Acknowledgements

Work presented was carried out in the framework of the Experimental Digital Design Studio, Faculty of Architecture and Town Planning, Technion, ITT headed by Professor Rivka Oxman. The following students are highly acknowledged Shoham Ben Ari and Roey Hamer.

References


