DDNET: THE CONCEPTUAL STRUCTURE OF DIGITAL DESIGN
Emerging Body of Concepts of Digital Architecture

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ABSTRACT: The ability to define novel body of concepts related to digital design media is becoming a central issue in the attempt to establish the theoretical foundations of Digital Architecture. The aim of this research is to identify and map the design concepts and relevant methodologies of digital design in architecture. In making the survey, analysis and the categorization of relevant concepts and emerging precedents we formulize a theoretical basis for the conceptual mapping of this field which is termed DDNET: Digital Design Network. The DDNET is a semantic system divided into 4 levels: key-concepts; sub-concepts; system level and precedent level.

KEYWORDS: Digital Design, digital architecture, design thinking, conceptual structure

RÉSUMÉ: Définir un nouvel ensemble de concepts liés aux médias numériques de design est un problème central dans l’établissement d’une base théorique pour l’architecture numérique. Le but de cette recherche est d’identifier et de structurer les concepts et méthodologies relatives au design numérique en architecture. En faisant le recensement, l’analyse et la catégorisation des concepts pertinents et de précédents émergents, nous formulons une base théorique pour la structure conceptuelle de ce champ appelé DDNET: Digital Design Network. Le DDNET est un système sémantique divisé en quatre niveaux: concepts-clés, sous-concepts, niveau du système et niveau précédent.

MOTS-CLÉS: Design numérique, architecture numérique, pensée de design, structure conceptuelle

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1. INTRODUCTION: ACCESSING THE THEORY AND PRAXIS OF DIGITAL DESIGN

New media and methodologies are being employed in changing our conceptual understanding of what digital design is and may become. The ability to define the novel body of concepts related to digital design media is becoming a central issue in the attempt to establish the theoretical foundations of the field. The clarification and meanings of conceptual relationships between concepts, models, systems, and their applications in precedents, appears to provide various advantages in the formulization of novel bodies of knowledge and procedures in both theory and praxis. These are accompanied by a high level of theoretical content in the field of Digital Design which is currently developing its own discourse.

Theories and methods of digital design can no longer be conceptualized as the merging of computational tools with conventional formulations of design methods and processes (Oxman, R., 2006; Liu 2006). The present dynamic condition of the absorption of new media in both theory and design praxis in an age of pervasive media has resulted in the need to pioneer an understanding of the nature of designing and design thinking in relation to digital design media. Such a level of understanding of digital design might emerge as a theoretical formulation through the theory-based knowledge generated in academic research; an alternative source might be the praxis-gained knowledge gained in practice, or the way in which theory is actually applied is applied. Such a combination of sources can contribute to a theoretical formulation of ways in which digital designs are generated, modeled and materialized. It is to the symbiosis of this dual orientation of both theory and practice that we have turned in our research.

Among the significant impacts of digital media for the design theoretical community is the way that this form of mediated design is beginning to evolve original and characteristic conceptual content (Oxman, R., and Rotenstreich;2005, Oxman, R., 2008a). The evolution of digital architectural design as a unique field of design has been motivated by its own body of theoretical sources and its own design discourse. Having created a body of novel precedents in emerging practices, new methods and processes of mediated design have reached the point of maturity in conception and practice that now demands a broad and general theoretical formulation. Our approach to this task has been to access and attempt to structure a mapping of the concepts of the field. Such an interpretation of the methods, media and design technology requires a definition of new concepts and a formulation of their realization in design.
2. NEW DOMAIN: DIGITAL DESIGN

Early attempts to deal with digital design as an important theoretical threshold in architecture were realized by various theoreticians. *Folding in Architecture,* the special issue of the journal *AD* (Lynn 1993) created an influential body of early theoretical sources and had an important impact in determining the constituents of an incipient digital design theory. Early contributions by Lynn (1993, 1999) and Kipnis (1993) provided introductions to potential philosophical sources, to studies of technological innovations, to descriptions of experimental projects, and to identity of their relevance in the formulation of a theory of the digital in design. This combination of diverse theoretical, philosophical, methodological, technical and professional sources has characterized the discourse of digital architectural design in its first decade. In parallel, emerging technologies began to influence central issues in design theory. From the mid 1990’s digital architectural design became engaged with the exploration of complex geometries (Rashid and Couture 2002), with so called, ‘free forms’ (Zellner 1999) as well as with related materialization processes of fabrication and manufacturing technologies (Schodek *et al.* 2005; Sass and Oxman 2006). These developments have begun to broadly exert significant influence on the theoretical, conceptual and methodological contents of design.

In parallel to the formulation and publication of a theoretical discourse, novel precedents were starting to challenge designers of to formulate the new knowledge and understanding associated with *practice gained theory.* Among such significant monographs on *digital theoretical practice* are UN-Studio, van Berkel and Bos (1999), Rashid and Couture (2002), Oosterhuis (2002), Zaero-Polo and Moussavi (2003), and Spruybroek (2004) each of which is a significant theoretical work promoting digital design as a unique set of processes. Works such as Kolarevic, ed. (2003) and Kolarevic and Malkawi (2005) provided a base of methodological and technological content. Furthermore, there was a growing impact of innovative experimentation in design and construction. In architecture, the Bilbao Guggenheim by Frank Gehry (1992-1997) was the most prominent catalyst of theorizing new formal directions and postulating new design methods (Lindsey 2002). Other formative works that helped to generate theoretical discourse include the Greater London Authority Headquarters, (2002) and the Swiss RE building (2004) designed by Foster & Partners and Arup Associates etc.

Praxis and theory evolved simultaneously. New approaches and technologies were accompanied by new directions in design methodology. Since these first generation developments the field, the profession, now more confident in its understanding of the theoretical implication of emerging media technologies and design practices, has produced a wave of new writings and experimental projects (Reiser and Umemoto 2006). We are now at the threshold of
the need to pioneer a theoretical understanding of the nature of designing in relation to digital media.

The objective of the research presented in this paper has been to address this evolving synergy and its theoretical imperative. In the following section we present the basis for the conceptual mapping employing a semantic network formalism (Sowa, and illustrate its application in making knowledge formulations.

3. A NETWORK CONCEPTUAL STRUCTURE IN DIGITAL DESIGN THEORY

One of the distinctive problems in representing practice-based design precedents is the richness and complexity of their descriptive content. Each design contains many related chunks of information that are difficult to decompose. ICF is based on the cognitive theory of CBR. It was the first application to apply this theory to design precedents (Oxman, R. 1994). ICF was developed as a formalism composed of a tri-partite representational formalism to represent Precedent Knowledge Similar approaches were employed in applications ranging from the construction of libraries to pedagogy and didactics (Oxman, R. 2003; Iordanova and Tidafi 2005). This formalism maps the relations between associated concepts in precedents in a way which captures the conceptual significance of the design precedent. This method for formulating knowledge derives from the analysis of precedents and the structuring of knowledge into a semantic net. Conceptual links in the semantic network can connect different precedents. This resulting structured representation of conceptual knowledge can later be accessed and expanded in the analysis of other media such as theoretical content in forms of discourse, or content, analysis.

The resulting network of concepts represents design knowledge as a conceptual network. Thus the semantic network structure, incrementally constructed, tends towards the characterization of the conceptual constructs of the body of works along with their associated discourse.

The goal of this work has been to expand this formalism and make a conceptual mapping of digital architectural thinking today and to identify the emerging body of novel design concepts of digital architectural design.

4. TOWARD A NETWORKED STRUCTURE OF DIGITAL DESIGN CONCEPTS

4.1. introduction

Each historical period creates a distinctive focus in identifying the relations between theory and practice. In order to explore the particular theoretical implications and knowledge related to digital architecture we define and analyze the terminology which is associated with a particular precedent. While a selected body of theoretical and research writings provided the initial set of concepts, case studies in practice were employed for the analytical process of relating
concepts to components of actual design precedents; and thus testing and restructuring the original assumptions of the initial conceptual vocabulary.

4.2. Construction process

In this section we describe the theoretical assumptions, the methods of knowledge acquisition and the process of network construction underlying DDNET. Following this, we provide an exegesis of selected examples of the key, or seminal, concepts of digital design that were identified. These key concepts provided the content for the analysis of precedents, and through this, the expansion and construction of the semantic networks. In the scope of this introductory article we provide an introduction to the idea of constructing a conceptual network as a basis for defining the theoretical foundations of a design discipline.

Theory formation is a dynamic and developmental phenomenon. The interpretation of theory as a body of knowledge in an evolutionary process of change and reformulation appears particularly relevant to the formalization of an emerging field of knowledge such as digital design. Given that one of our underlying assumptions is that designing in digital media is a new and unique class of design, we have attempted to identify the processes of conceptual structuring and their intellectual sources that have contributed to the formation of the field and its theoretical and methodological practices.

A broad literature survey of leading sources was selected from the body of general publication, the research literature (publications and conference proceedings), and the small number of journals that support publication of material in the field. The period studied was from the early 1990s to the present. A large body of publications were selected and analyzed according to taxonomical contributions. On the basis of this extraction of a body characteristic and important textual material, we attempted to identify key, or seminal, concepts. Key concepts, such as morphogenesis, appeared to be those concepts that formed a sub-discourse. As such, it was possible to identify their body of related concepts and to graphically describe discourse as a constellation of concepts.

The theory of semantic networks (Sowa 1991) is a method that supports the graphical representation of knowledge structures and cognitive processes. We have applied this method to define the conceptual network of digital design particularly from the point of view of the conceptual structure of its body of theory. In addition we are attempting to address in current work two additional and essential characteristics of the contents of the field: design models and methods. Eventually we will graphically plot the relationship of the three conceptual levels of conceptual structures in digital design: theory, models and methods.

The original experiment underlying the knowledge acquisition and network construction process was carried on in an educational situation in which a team of student-researchers collaboratively constructed a generic knowledge base for the conceptual and methodological applications in a specific design
library of theoretical material and case studies. The initial stage of the research was based upon the collection of theoretical materials as well as a systematic survey of relevant precedents. The work is now being advanced by the principal researcher and is being prepared for publication. It will contain the expanded listing of key texts in digital design, a selection of texts of the past fifteen years that were determined to be the canonical texts of the field, and an expanded graphical version of the conceptual network, the DDNET (Oxman R, in process; projected for publication in 2010).

5. KEY CONCEPTS

As proposed above, *key concepts* are those concepts which have emerged as central to a sub-discourse in digital design. We have proposed that in design there is a highly conventionalized acceptance of the constituents of theories, models (important models of digital design such as “performance-based models”), and methods (important methodological/technological foundations for system development such as “parametric systems”) and illustrative precedents. These levels interact in a conceptual structuring of the field. DDNET attempts to represent the conceptual complexity as well as the dynamism of the theoretical and knowledge foundations of the field.

Selected illustrations of the concept formation process and of the formulation of the 4 conceptual levels are presented below (see Figure 1).

**Figure 1. Conceptual Levels: Key Concept, Sub-Concept, Digital System, Precedent.**

Each key concept is linked to one or more sub-concepts that define the meaning of a key-concept and may provide an underlying computational model for system implementation. Sub-concepts are linked to one or more computational systems which are implemented on the basis of underlying computational model.
5.1. Free Form

The term, *free-form*, constituted what was in the early 1990’s the new promise of an architecture freed from the constraints of orthogonal geometry and rational standardized construction. Inexact as it is from both a geometrical and descriptive point of view, the term symbolized the relationship between architectural theoretical positions regarding form and the formal potential of new productive possibilities in *non-standard architecture* and through *mass-customization* and *fabrication*. Free Form thus illustrates the complexity of constructing a coherent approach to conceptual structuring. On the one hand it relates both to its means of modeling (e.g. *MESH systems* or *NURBS system*) and production methods as well as to its knowledge sources (e.g. *complex geometry*) (see Figure 2). The term and the set of relationships have become an ideological position now, replaced by new and more exact terminology. The next related concept is deriving from conceptual associations with terms such as *Topology*.

*Figure 2. Free Form.*
5.2. Performance

Performance or Performance-based Design is driven by simulations. Performance here is defined as the ability to directly act upon the physical properties of a specific design. In addition to quantitative properties, these classes of properties could eventually be broadened to include qualitative aspects such as spatial factors in addition to technical simulations such as structural and acoustical performance. Today, there exist a wide range of digital tools for simulation, analysis and evaluation of performance aspects (Kolarevic and Malkawi 2005). Current theories and technologies of digital design suggest a shift from analytical simulation for evaluation to simulation for synthesis and generation (Oxman, R., 2008).

*Figure 3. Performance.*

SWISS RE, Norman Foster
These approaches attempt to integrate generative processes with performance as *integrative processes*. This distinction is very significant. Instead of analyzing the performance of a design, and modifying it according to results, generative aspects of performance-based can directly modify designs. In such approaches the desired performance can be activated as a performative mechanism to generate and modify designs digitally (Oxman N. 2007).

The next related concept is deriving from conceptual associations with terms such as *Parametrics*.

### 5.3. Parametrics

As an example of the dynamics of theoretical discourse, *Parametrics* and *Parametric Design* have now emerged as two key contemporary terms.

*FIGURE 4. PARAMETRICS.*

Various designers and researchers (Burry and Murray 1997) view parametrics and the related body of theoretical, modeling and methodological concepts as the seminal concept of current digital design and a distinguishing characteristic...
of a digital architecture Parametrics (Burry and Murray 1997) is essentially a design enabling technology. Coupled with other concepts such as *associative design*, it enables the exploitation of *topological diversity* and transformations. Furthermore, parametric design supports the existence of design models such as *generative components* that are among the foundation of important contemporary design technologies (see Figure 4).

On the other hand, parametrics also underlies advanced engineering design practices and methods (e.g. flux structures, Sasaki 2007). Thus the conceptual constellations of this term are both complex to represent and rich in interpretative potential.

Figure 4 illustrates a well-know precedent, the Segrada Familia by Antoni Gaudi. The remodeling of the Segrada Familia is associated with parametric systems (Burry and Murray 1997). The next related concept is deriving from conceptual associations with terms such as *Morphogenesis*.

### 5.4. Morphogenesis

We have seen that the terms *free form* and *parametrics* are characterized by diverse meanings and connotations that have developed and evolved historically. The presence of theoretical, design models and methodological/technical content makes the visual characterization of conceptual relationships difficult. Certainly, in addition to scientific and computational content, these concepts also contain ideological content.

The fourth term which we present is *morphogenesis*. This term further illustrates the rich body of discourse (or in other words, the complexity of the conceptual network) that canonic terms can generate. Morphogenesis essentially relates to processes of *form evolution* and particularly to modeling of “natural” processes of form generation (Hensel Menges and Weinstock 2004). In design, the term is strongly related to the historical tradition of *form-finding* and *self organization* in the work of designers such as Frei Otto. Furthermore, it is associated with the terminology of *performance-based design*, the methods of *performative analysis* and the potential of *performance driven generation* (Oxman, R. 2008b). The discourse of morphogenesis has become associated with studies of the principles of form generation in nature and their exploitation in design (*biomimicry*) and with the associated contemporary discourse on material in design (Oxman, N. 2008).

This term is proposed as a key term in an emerging body of key concepts that contribute to generative models, methods and techniques related to emergence in design. This term thus exemplifies a highly complex level of discourse in which multiple key terms are interrelated in new processes of conceptual development.
6. DDNET: SIGNIFICANCE, DEVELOPMENT AND FUTURE POTENTIAL

We have identified the significance of conceptual structuring as a method of discourse analysis. The clarification of meanings and conceptual relationships in the creation of complex semantic networks appears to provide various advantages in the formulization of emerging bodies of knowledge and procedures that are accompanied by a high level of theoretical discourse as is the new field of Digital Design.

Semantic networks and our proposal of enriching this formalism through describing the meaning of conceptual clustering and multiple levels of clusters have proven relevant as a tool of discourse analysis. They help to clarify important semantic relationships as well as identifying scientifically meaningful,
as compared to the purely descriptive, terminology that is associated with ideology.

DDNET approaches the building of a foundation for a theory of digital design by attempting to relate the body of theoretical constructs with the models, methods and technologies of the field. Once the mapping of the levels of conceptualization is completed, we believe that the theoretical foundations of the field will emerge as a distinct body of theory and related design practices. Such clarified terminological and conceptual distinctions should also serve to ameliorate the effects of an ideologically charged interpretation that has characterized much of the design practice and not little of the research practice of this field.

Perhaps the most problematic of the obfuscations of the terminology of digital design is the term Digital Architecture. Whether distinct architectural phenomena actually exist and justify such a term is a question of some import. Given that such phenomena do exist and that they are simply stylistic indicators, it seems doubtful that they justify the claim of a “new architecture”. Certainly the meaning of the new digital presence in design is that we are able to at last, abandon the dinosaur sanctuary of form.

We hope that in the future this knowledge may become accessible by using a computational tool that will enable the construction and usage of DDNET. Furthermore, some of these topics will be a subject of future work publication which will contain a selection of readings from canonical texts, a comprehensive bibliography of the field as well as a final version of DDNET.

REFERENCES


