The Emergence and Impending of Digital Design in Architecture

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Abstract- The paper introduces and discusses current developments in architectural discourse, design theory, digital design models, techniques and their relations to design pedagogy. The evolution of design knowledge in architectural theory and praxis is explicated and its implications for required changes in design education are presented. The theoretical influence of architectural concepts is presented through historical references in digital architecture. This structure of design concepts is proposed as a medium of design education. An experimental design studio on: 'Design as research: the exploration of digital architectural concepts' is presented as a pedagogical framework for educating the digital architect and a series of research and design programs carried out in an experimental design studio demonstrates this framework. Digital architectures are profoundly changing the processes of design and construction. By integrating design, analysis, manufacture and assembly of buildings around digital technologies, architects, engineers, and builders have the opportunity to reinvent the role of a "master-builder" and reintegrate the currently separate disciplines of architecture, engineering and construction into a relatively seamless digital collaborative enterprise, thus bridging "the gap between designing and producing that opened up when designers began to make drawings.

Index Terms- digital architecture, digital design theory, digital design media, digital design knowledge, education and pedagogy

I. INTRODUCTION

Regardless of what might be the particular formal vocabulary, syntactical and formal knowledge is strongly accepted as a foundation of design pedagogy in architecture. Beyond the exploitation of digital media as tools, the relation between digital design and digital design models as a form of architectural knowledge has begun to emerge as a significant ideational resource for design and design education. Theoreticians have attempted to define paradigmatic approaches in architecture based on the ideational impact of digital technology. As a result of the growth of a new knowledge base beyond the skill set of the digital designer, architecture as a design discipline has become rich in ideas, changing and a unique body of conceptual content. A recent research reported on the cultural process of the emergence, migration, and crystallization of new conceptual structure over the past decade under the influence of digital design demonstrating how concepts whose theoretical source is digital design are beginning to occupy a central role in current architectural language and discourse. The explication and ideation of this conceptual content of digital design is another import agenda for digital design education in architecture. Certain of these concepts are in direct contradiction with formalist approaches of syntactical and formal knowledge. The search for new educational frameworks is due to the pedagogically unique impacts of digital design. Various researchers and educators have begun to address the need to integrate digital design in architectural design education investigating various forms of pedagogical agenda. Design computation and digital design had an influence on the development of theoretical; computational and cognitive approaches by various researchers as a foundation for design education and pedagogy.

Following this basic assumption that change in the professional culture of architecture is substantive in that it transcends stylistic agenda, it has now become important to re-consider certain of the existing theories of design and education. Concepts such as design thinking have in the recent past been part of a powerful cognitive model of design. The term designerly ways of knowing is particularly significant, since it also introduces the notion of knowledge in design and what this might imply with respect to new approaches of digital design education.

II. REPRESENTATION

A suitable working definition of what a representation is and what it does can be derived from Ref. w6x. According to this definition, a representation is a formal system for making explicit certain entities in a transparent manner, i.e., together with an explanation of how the explicitness is achieved. The product of a representation, as applied to a specific entity, is a description. Familiar examples of representations include Roman and Arabic numerals _decimal or binary.. Fig. 1 contains alternative descriptions of the number 17 produced by different representations. In each of these representations, a number is described on the basis of a finite set of symbols and a rule systems for composing a description from the symbols. Arabic decimal numerals use the following set:

S s_0,1,2,3,4,5,6,7,8,94 . These symbols are correlated to a number in the following manner of positional notation: *n) 10nqn) 10ny1q. . .qn) 101 n n*y1 1 q*n) 100´n, n . . . n n* . 0 *n n*y1 1 0

For example:
1)101q7)100´17.

Arabic binary numerals make use of a smaller set of symbols and corresponding decomposition rules:

S s_0, 14, B *n) 2nqn) 2ny1q*. . .q*n*)21 *n n*y1 1 q*n*)20´*n* ,*n* . . . *n n* . 0 *n n*y1 1 0

For example:
1)24q0)23q0)22q0)21q1)20s10, 001.

Architectural representations are essentially similar in structure. They consist of symbols for spaces andror building elements, relations between the symbols and correspondence rules for mapping the symbols and their relationships to the subject of the representation. Fig. 2 depicts the symbols of a basic set of building elements. The set is sufficient for

Fig. 1. Alternative representations of a number.

Fig. 2. A basic set of symbols for floor plans.

describing orthogonal floor plans, such as the one in Fig. 3, as two-dimensional arrays comprising generic building elements w5x. The choice of symbols relates to the constraints of the symbolized entities. These constraints are, in turn, reproduced in the representation. In the example of Figs. 2 and 3, there are specific expectations concerning the type of linked wall corners and junctions _the first nine symbols in Fig. 2. These expectations can be used to evaluate and control the syntactic correctness and integrity of a description. They can also be used to recognize the spaces in a floor plan w5, 7,8x. Computational representations of architectural designs generally concentrate on these two types of symbols, building elements and spaces, i.e., the 'solids' and 'voids' of architectural composition. Most generative systems concentrate initially on the relative arrangement of spaces and subsequently on the positioning of building elements which bound the spaces w9, 10x. Other systems have focused on the coordination of the resulting dual network of building elements and spaces w11, 12x.

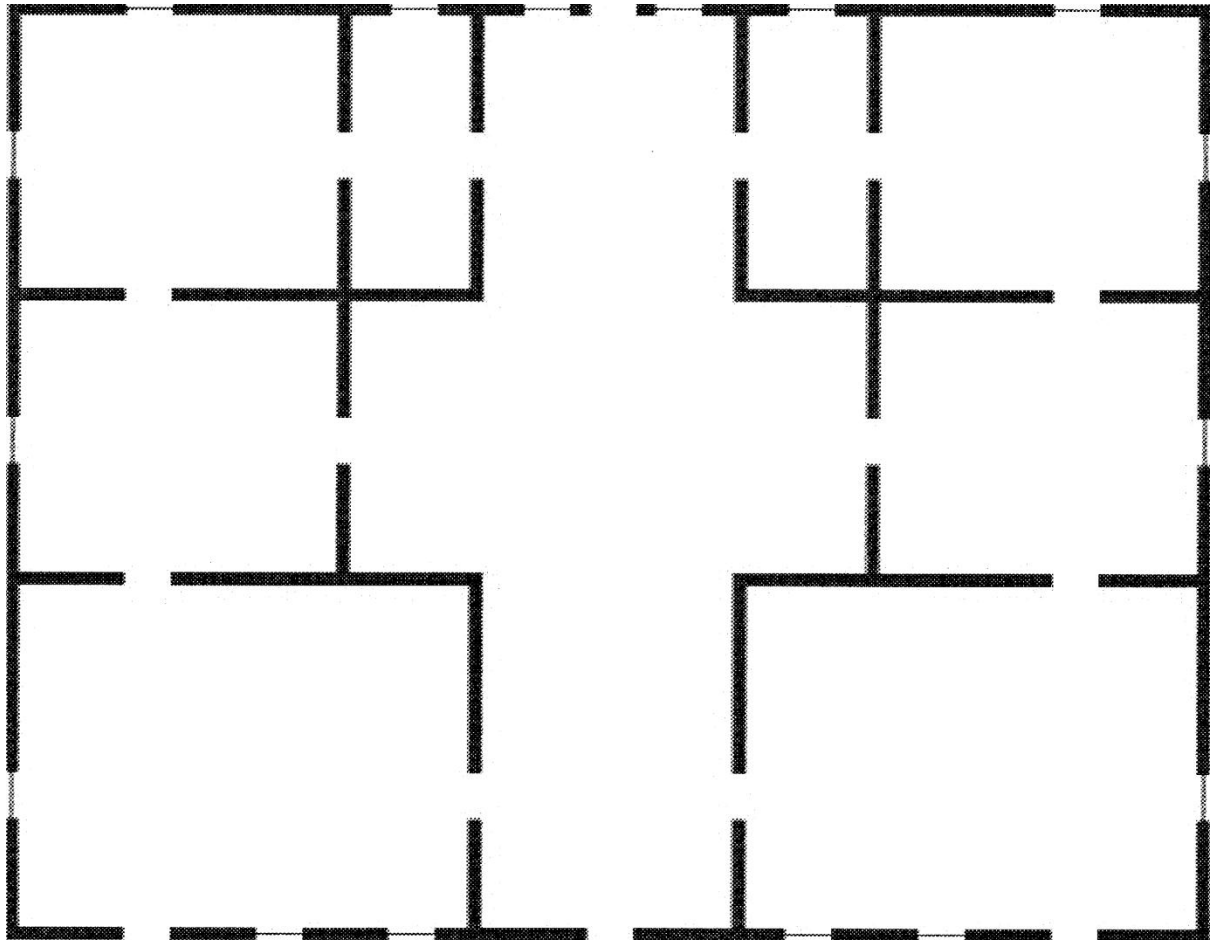

Fig. 3. Floor plan created with the symbols of Fig. 2.

III. DEVELOPMENTS IN DIGITAL DESIGN

One of the toughest exercises in design computing is predicting future developments. The race for more computational power, the availability of increasingly more worthwhile computer programs and improvements in operating systems are just a few of the factors which make the projection of current technical aspects rather futile. To a lesser degree, this also applies to approaches and methods, especially those aspects that are inescapably constrained by technical opportunity, such as human–computer interaction.

All that remains is fundamental issues that should guide technological development.

Probably the most significant fundamental issue for architectural visualization is representation. Current visualization problems are posing a wide spectrum of questions concerning our representational assumptions. Rather than adapting design representations to the requirements of these problems, we should attempt to arrive at a unifying theory of representation capable of dealing with such problems in a systematic, consistent manner. The main objective of this theory should be other than the current goal of increasingly higher levels of photorealism: the inclusion of modelling and analytical facilities that support and enhance the architect's intuitive creativity without prescriptive or proscriptive restrictions.

IV. EXPLORATION OF DIGITAL MODELS, METHODS AND DESIGN CONCEPTS

The digital design studio is experimental in the sense that it encourages research-oriented study. This is treated as a bottom-up process, one can explore processes that can organize a set of ideas and rules that can than modify the process by selecting alternative methods and techniques of exploration. Each of the following projects was developed by exploiting digital models and techniques that suited the theoretical and conceptual content of the project. In each a conceptualization of 'digital material' and a unique digital model or digital technique appropriate to the material concept was employed.

The didactic process consists of the following four basic steps: -

Conceptualize and define a specific type of 'digital material'. Digital material can be defined as an organizational structure, or pattern, of a certain material.

- Define a specific digital design model related to formation, generation, or performance, or relationships of such models.
- Select a context that can best demonstrate the behaviour and applicability of the 'design material' in relation to principles related to formation, generation or performance.
- Develop and present a taxonomy (related to digital architecture) that can be used to describe the digital architectural design thinking processes.

All work is in the form of multiple short exercises which are finally produced by each student as a research report including the conceptual vocabulary.

These experimental projects explore the intersections between methodologies techniques, representational modes, etc. underlying the integration between digital media and the conceptual. They also explore resulting new geometries related to particular forms such as topological surfaces and responsive network structures that are related to the given materials.

V. CONTINOUSLY EVLOVING TOPOLOGICAL VOCABULARIES

The following research explored the concept of hyper continuity as an expression, a linear evolving topological vocabulary of form. It accommodates the complexity of topology and attempts to apply topology that maintains the same relations along a linear development. The application involves the study of such design methods and techniques in order to develop a national boundary. In this case, the boundary is conceived of a continuous set of diverse functional spaces for collaborative activities of the neighbouring countries. Changing requirements along the boundary create a constantly changing condition of context and program along the otherwise continuous design of the boundary. Acting together, both performance-based technique and the definition of programmatic parameters produced a concept: a 'functional boundary', that is, hypercontinuity of surfaces and volumes, and heterogeneity. This approach relates to the generic problem of complex program and changing conditions. Heterogeneity has replaced the instantiation of a particular standardized, modular structure as is currently routinely applied irrespective of complex changes of program and conditions.

VI. A MOBIUS MODEL OF CONTINUITY

In comparison to the digital model of topological geometry studied in the first research, the following design project explored a topology of the Mobius Ring; named after August Fernando Mobius (1790e1868). It is characterized as an infinite spatial topology; without definition of inside and outside. In this project these characteristics are employed in order to create a blurring of the conditions of inside and outside, horizontal and vertical employed as an architectural space. These studies were then utilized to be explored in an architectural project.

VII. GENERATIVE DESIGN BASED ON MORPHOLOGICAL PRINCIPLES

The conceptualization here is based on a study and analysis of the morphological principles of woven textiles. This woven material created an indeterminate range of heterogeneous folded profiles that were versions of folding and weaving principles. The formation principles of the woven materials were exploited to generate the structure. These profiles evolved to enable spatial, structural and environmental envelope functions within the woven matrix.

The design transformations are defined by a set of syntactic rules related to morphological principles. The diverse matrices were transformed with respect to their solar protective (sun-shading) potential.

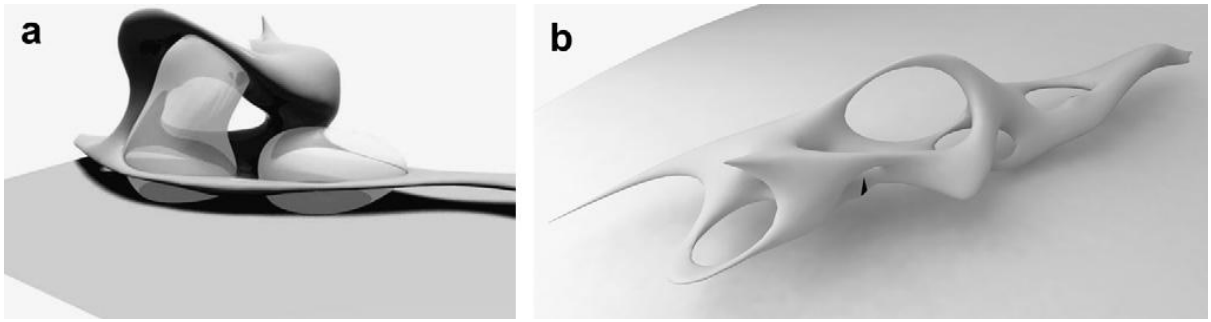

Figure 4. Topological design of a continuously evolving boundary

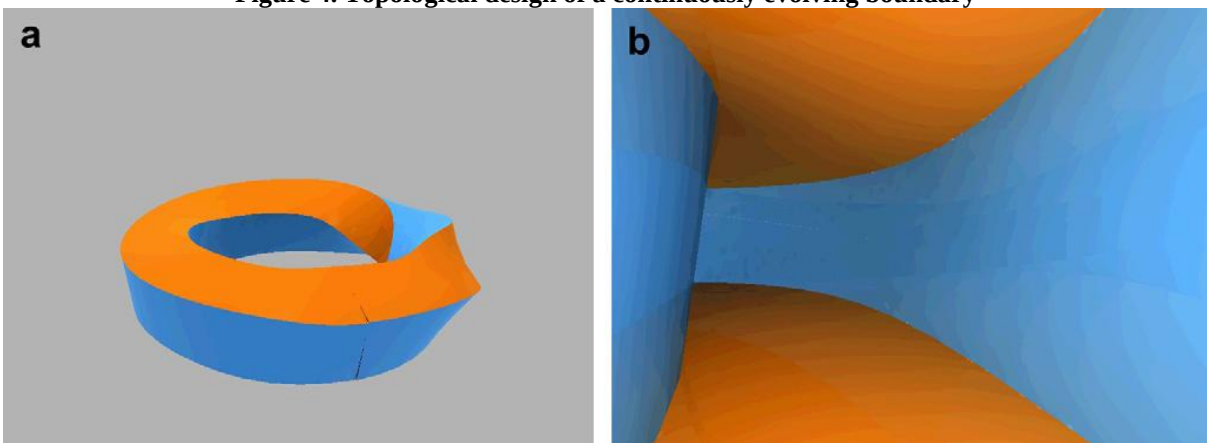

Figure 5. Spatial explorations of Mobius-based digital models

VIII. DIGITAL ARCHITECTURE AND THE CHALLENGE OF A NEW PEDAGOGY

As a result of these experiences we have encountered new orientations to the explication of the judgmental aspects of design as per formative and generative factors. The student has become adept at juggling the multiple forms of data and images that are represented in digital design environments. Far beyond Scho¨ n's characterization of visual reasoning as a 'dialogue with the materials of the problem' and 'backtalk' from visual images, the digital and compound processes of formation, generation and performance of 'digital material' creates a completely novel view of design that may even justify the uniqueness of the term, digital design thinking.

Architectural thinking has been presented as non-typological and nondeterministic in supporting and preferring the differentiated over the generic and the typological. We have explored new forms and relationships between the designer, process and information establishing new approaches to design. Integration of techniques, such as parametric formation, etc. has provided novel venues for design exploration. These models have demonstrated the growing impact of digital design media as a mediator between content and skill. With respect to certain of the root concepts of conventional design theories, the implications of these transformations of traditional didactic principles, as we believe, have demonstrated significant implications for the field of architecture and design education.

Root concepts in design theory such as representation, typologies, and other principles of the visual literacy school of design pedagogy are transformed. Instead concepts such as morphogenesis, generative and performance-based design, materialization and production are introduced. A schema of four paradigmatic models presents an interpretation of digital design in which the methodological characteristics of these paradigms have been formulated relative to theoretical concepts of design and design thinking. These models include formation, generation, performance, and performance-based generation. These four processes become the underlying logic of digital architectural design in which digital models can be applied to architectural content and design tasks.

IX. CONCLUSION

As digital design media become more multifaceted and more demanding with respect to knowledge of many types of software, knowledge of scripting languages, and the management and maintenance of complex data models, there will be a need to educate a new generation of digital design experts. The thought of the designer as digital tool-maker reflects both the potential for modifying digital design media as it does the necessity for specialist knowledge needed to operate such media. So presently the idea of a class of 'digerati', or digital literati as advanced digital systems designers appears to be an accurate description of the contemporary situation.

Beyond any doubt digital design appears to be a mainstream marvel, and the theory of digital design appears to be one of the most active and significant subjects of theoretical discourse today. Our approach to fitting the digital and the theoretical has dealt with the problem of any new instruction: beginning with a new classification for digital architectural theory. This has occurred in order to create the theoretical foundations of new

processes of design that, in turn, are transforming our accepted traditional models and logic of design.

Together with the accompanying technological and media developments, the foundations of architectural education appear to be in need of a make-over from the bottom-up.

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