DIGITAL FABRICATION - FROM TOOL TO A WAY OF THINKING

Toward redefining architectural design methodology

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Abstract. The digital design appears as an integrated process from conceptualization to materialization and fabrication. The main question is: How the new medium changed the workflow in architecture from a linear model to a cyclic model and the role of new materialization as a form of design thinking? This paper is part of a study that investigates the architectural design process and starts from the premise that we should expand the study of design methods to include other approaches. It considers digital fabrication not as a tool, but as an integrated strategy in collaborative digital processes that can allow a better communication along the design process. It presents the development of design methodologies in order to contribute to a greater understanding of the methodology for design projects with caution to the fact that each one reflects the period in which it was developed.

Keywords. Digital Fabrication; Computational design; Architectural design.

1. INTRODUCTION

"(...) What can this medium do? (...) What do I wish to do with this medium?" [McCullough, 1998].

The rapid development of computational design methods has a huge impact on contemporary architectural design practice. Design methods have always changed, considering that design thinking is bound to the representational medium [Leach & Yaun, 2017] [Menges & Ahlquist, 2011]. Thus, its scope can be expanded by the enlarged possibilities offered by the new media and techniques [Carpo, 2017] [Kieran & Timberlake, 2004].

Today, most of the buildings are both designed and fabricated with computational methods. The use of digital tools and manufacturing processes and their synthesis through the use of novel technologies is significantly changing the future of architecture and construction [Kolarevic, 2003]. With the introduction of in-house rapid prototyping machines, the architectural design process within the practice has changed [Peters, 2008]. Currently, computational techniques have enabled new design methods, casting a revaluation of theories related to design

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[Ostwald, 2012] [Booth, 2009]. Digital design emerges as a holistic integrated process from conceptualization to materialization to fabrication [Oxman, 2014].

In this context, is necessary to offer an informed overview of the development of design methodologies in architectural practice, from computerization to computing and the role of advanced digital fabrication in the design process [Burry & Burry, 2016]. The main question is: How the new medium changed the workflow in architecture from a linear model to a cyclic model (Figure 1 and 3) and the role of new materialization as a form of design thinking?

The thesis of this article is that the assimilation and synthesis of digital communications among architects, engineers, fabricators and builders is dramatically altering how we work and our relationship to the tools we use. New digital capacities are restructuring the organization and hierarchy of design from autonomous processes to collective workflows. The historical role of the designer as an author, a sole creator, is being replaced with semi-autonomous, algorithmically driven design workflows deeply embedded in a collective digital communication infrastructure [Picon, 2010]. This is creating a number of pressures on the discipline of architecture to reorganize around the opportunities, and risks, of these changes. One of these changes is the role that design itself might play.

The logics of digital fabrication in architecture have begun to structure the way that architects design, the way that builders build, and the way that industry is reorganizing.

2. BACKGROUND

Starting in the 1950's, the study of design methods evoked the perception of the increased complexity in industrial products. The first models presented in a linear paradigm, evolved to more integral representations of the design process in a way that affects the entire system.

During the end of the 1950s and beginning of the 1960s, researchers were trying to describe the creative problem-solving process at work in design by way of the logical structure of apparent activities that appeared to take place. In this context design was seen as a series of stages defined by dominant forms of activity, such as analysis, synthesis, evaluation and so on.

Bruce Archer (an industrial designer from Hochschule fur Gesttaltung at Ulm and the Royal College of Art in London) proposed a more "operational" model of design. In a simple way, Archer's model is schematically showed in Figure 1. The design process model that he proposed predicts the necessity for different approaches in different moments of the process: systematic observation and inductive reasoning in the analytical phase, and subjective and deductive reasoning in the creative phase. Design is then seen as a sequence of activities defined by their orientation and by the type of task involved, and the lineage of tasks can be easily recognized. Additionally, the process can be described in a general form, regardless of specific circumstances. Feedback loops of relationships between activities are clearer in this case than in previous models, resulting in an organization of activities less quietly set. With the reference to

three interrelated domains for the process, particularly the external representation, process of activities, and the problem solver, a distinction begins to be made between overt behavior and the cognitive realm - a departure from the behaviorist position [Rauterberg, 2008] [Pallasmaa, 2009]. The focus is still on the sequence of activities and on the behavioral domain.

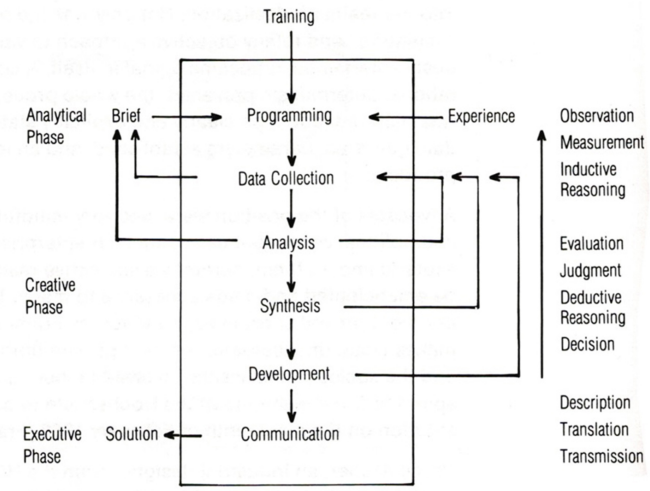

Figure 1. Bruce Archer's model of the design process [Rowe, 1987].

Looking at the first representations, linearity was a common characteristic. Many authors considered the existence of loops and feedbacks in their research, but it was seen as a problem or an opportunity to correct errors and not as part of the design activity and its nature of uncertainty. The process was no longer linear because successive iterations are needed to define both problem and solution. To this concept of parallel evolution between problem and solution is given the name co-evolution. This concept is deeply analyzed by Nigel Cross [2008].

March's [1984] (Figure 2) broke with the linear representation of design process, based on the assumption that the problem is dependent on the solution and that the inductive-deductive thinking is inadequate for the production of synthesis in the design process. March defends the idea of abductive thinking, which is linked to the production (synthesis), while induction and deduction are related to research (analysis). In other words, "deduction proves that something must be; induction shows that something actually is operative; abduction suggests that something may be" [Cross, 2008]. March's representation for design process (Figure 2) is a cyclic model that starts with production (preliminary requirements and assumptions about solution types to describe a design concept), followed by deduction (to predict solutions performance) and goes through a moment of induction (indicating changes and refinements in the concept).

The IDEO's design process introduces us to a nonlinearity, described by Brown [Brown, 2008, pp. 88] as "a system of spaces rather than a predefined series of orderly steps". Figure 3 demonstrate a system that goes beyond the classic models.

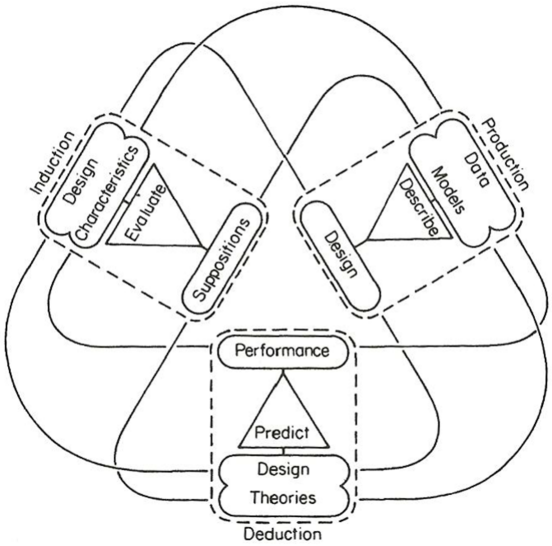

Figure 2. March's diagram [Cross, 2008].

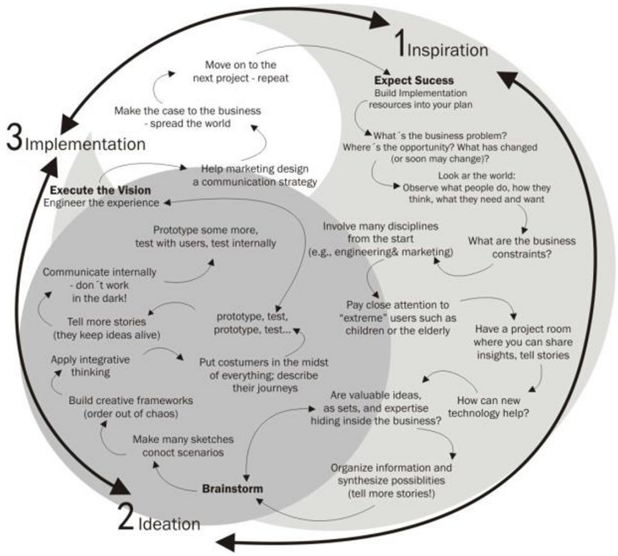

Figure 3. The IDEO process [Cross, 1984].

The process works around three areas: inspiration, ideation and implementation. Inspiration is linked with the motivation behind the search for a solution (a problem, an observation or both). Ideation associates generation, development and testing of an idea that could drive to a solution. Implementation in the other hand is directly related with the product launch. While developing a project, all three

phases can be explored, in particular inspiration and ideation, in order to clarify ideas and enroll in new paths. It's important to refer that the design in IDEO has a competent group of multidisciplinary professionals with different backgrounds. This allows that different activities can be done simultaneously, saving time in comparison with linear processes.

Professionally divided design processes are being redefined as integrated design systems. Vast amounts of information, both descriptive and analytical, are now instantaneously available to help define and assess design options. Much, if not all, of this information is filtered through software that, by extension, structures the digital environment in which architects design. Architectural design has become a complex workflow in which geometric, spatial and technical information is filtered through simulation, analysis and optimization processes, with the aim to form integrated, parametric building information models that can generate an array of output ranging from energy usage to manufacturing instructions. With the introduction of parametric and algorithmic design processes, the reliance on the visual as the primary source of design production and evaluation gets supplemented by rules, numbers and other forms of quantitative logic. This logic is placed between creative thinking and foregrounds the way in which architects are engaging with the broader cultural and technological debate between the open nature of scripting and the closed nature of applications as they begin to define the design space in which they work.

3. METHODOLOGICAL PROCEDURES

Based on the understanding of design methodologies taxonomies, a framework for design thinking has been generated, by observing the models as a manifestation of the design discourse. Clearly, there is a gap between the complexity of practice and the simplicity of a theoretical model [Schön, 1983]. However, the models cannot be neglected due to its main function as an element able to structure a complex activity to allow the detachment of the professional, which enables him to examine critically the process.

This article presents a brief overview of design models in order to contribute to a greater understanding of the methodology for design projects with caution to the fact that each one reflects the period in which it was developed.

The three diagrams presented in this paper (Figure 1, 2 and 3) attempt to summarize the workflow changes in architecture from a linear to a cyclic model. The identification of these tree moments in the design methodology practice helps us to understand the evolution of the methodologies of thinking along the design process.

4. RESULTS

This paper presents the preliminary research results that attempt to understand the role of digital fabrication on design process in architectural practice along with a discussion of their capacity to question the basis of education and the conceptualization of architecture.

The emergence of complex technological and environmental problems, challenge the professionals to seek novel practices of collaboration and exchange

that deliberately overcome and dissolve traditional disciplinary boundaries. This collective approach to working with technology is not only revolutionizing how things are designed and made, but is fundamentally transforming the culture, politics and economics of the creative industries as a whole.

If the first robotic age - the age of industrial automation - vastly improved our physical productivity, the second robotic age will surely come to distinguish itself as a driver of creative capacity.

The present moment is ripe for connecting technology with imagination and materialization, inspiring new fundamental discoveries and opening new scientific frontiers.

Looking at the presented models as a reflection of the design methodology and development, it's clear that during the half century occurred a notable evolution between the linear model of Bruce Archer and the cyclic model of IDEO. When comparing these models, we must consider the context as well: they arise from different eras and the evolution of technology during this period certainly has an important role in their characteristics. We move from the era of mass production to the era of mass customization and clearly the second has become the reference. There is a gap between the complexity of practice and the simplicity of a theoretical model that the studies around methods for design can't ignore. Nonetheless, the models cannot be ignored due to its essential function as a component that has the ability to structure a complex activity but with a detachment of the professional, which facilitates the critical analyses of the process. Also one important function of these models is to standardize the language adopted by a team of product development, allowing communication between different teams.

Considering the current state of architecture practice, it is clear that the IDEO model (Figure 3) is still relevant to the current context of practice. Depending on each studio practice, other denominations could be applied, but the workflow has as a common ground the one presented in Figure 3. New digital capacities have restructured the organization and hierarchy of design from autonomous processes to collective workflows, making a new dialogue between design and making. In this sense, digital fabrication has reinforced the idea of a flexible and permeable system for design thinking process. The multidisciplinary nature of integrating digital processes remains a key challenge to establishing a digital building culture. Traditionally separated disciplines such as: architecture, structural design, computer science, materials science, control systems engineering, and robotics now need to form strong research connections.

5. DISCUSSION

This paper is part of a study that investigates the architectural design process and starts from the premise that we should expand the study of design methods to include other approaches. It considers digital fabrication not as a tool, but as an integrated strategy in collaborative digital processes that can allow a better communication along the design process. It presents the development of design methodologies in order to contribute to a greater understanding of the methodology for design projects with caution to the fact that each one reflects the period in which it was developed.

The Architecture, Engineering and Construction industry is in a state of flux fueled by transformative shifts in technology and design. Financial incentives around new economics of production, increased efficiencies afforded by streamlined communication and the automation of labour-intensive processes are already underway. The suggestion of this article is that there is a momentary opportunity to give a direction to this shift that will set the foundation for the next generation of architects.

Technology research should not be bound by constricting disciplinary standards, constrains or ideologies lest we limit its potential. Yet to explore this unprecedented potential requires not only a technical grasp of digital fabrications' capabilities and limitations but also an in-depth understanding of the disciplinary consequences of technology research.

There is no doubt that the profession is expanding traditions of making towards new techniques that integrate manual craft, computational design, digital fabrication and advanced robotic technologies, often in hybrid relationships.

The identity of the architect is largely built upon the ability to author design solutions that satisfy pragmatic concerns while also capturing the imagination by producing unique visual and spatial experiences. Pragmatic concerns are usually well defined and therefore can be solved with a high degree of certainty - the respective design space is relatively narrow, more quantitative, and possible to define algorithmically. The creation of unique experiences, by contrast, is ambiguous, it relies on inference and an indirect connection between an architect's knowledge and own lived experiences and how well they can anticipate responses from users. The result is never fully known of predictable. In this case, the design space is difficult, if not impossible to define algorithmically; it is highly qualitative and therefore better suited to human judgment.

While this portrayal of design space as either quantitative or qualitative is perhaps oversimplified, as these two threads are more typically intertwined, it serves to highlight the challenge of capturing the full range of architectural design intent within digital workflows. With more and more steps in these workflows being driven by design, analysis and performance algorithms authored by anonymous programmers, the identity and authorship of the architect come into question. If the architect has been increasingly displaced by technologically mediated processes over a long time, the expanded realm of digital workflows transforms this in historically new ways.

6. CONCLUSION

Digital technologies have handed architecture a very powerful tool, which has led to an explosion of experimentation in the last two decades. This technology has shaped an entire generation of architects. Current research on digital fabrication in architecture indicates that the development and integration of innovative digital technologies within architectural and construction processes are transforming the building industry.

Questioning the importance and impact of design thinking methodologies in the architectural design studios is a backbone of architectural education in the twenty-first century. 3D printing and digital manufacturing are disruptive

technologies that are changing architects and designers daily lives. These trends require new skills, based on a deep understanding of digital continuum from design to production, from generation to fabrication. This continuity transcends the merely instrumental contributions of a person-machine relationship to praxis, has begun to evolve as a medium that supports a continuous logic of design thinking and making.

If we may speculate on the future of design thinking and its influence on architecture, we can say that it's becoming a hybrid model of practice with manufacturing.

Design thinking methodologies associated with digital fabrication emerged as a leading technological and design issue of digital research and design. As designers, we are witnessing a no frontier between computational design and digital fabrication.

With digital fabrication, we turn our attention to the physical nature of architecture. We open up new aesthetic and functional perspectives and address the digital in architecture as a radically contemporary building culture. Through not only digital designed but also digitally materialized architectures, it becomes possible to engage with both the fundamental issues of our digital age and the purpose of architecture itself, that is, its concrete physical realization.

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