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Prototypes, models and challenges to architectural education: An examination of the role of computer assisted fabrication in the design process

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Abstract

It is a well-documented fact that the effects of the information age are felt across the whole spectrum of the architectural field, from theory to construction. Among the trends that have emerged one can cite the increased interest in digital fabrication methods, utilized in the creation of architectural models using numerically controlled tools. These approaches are commonly - albeit inaccurately- associated with the term prototype. Nevertheless, the implications of this phenomenon are numerous, ranging from practical considerations regarding the expedience of the new methodologies to theoretical ones, such as to how does "prototyping" affect the architectural model and by extension the design process in general. Computer Assisted Fabrication can be viewed as part of the general trend towards digital media in design and also presents new challenges and potential risks for contemporary architecture. This paper, which is part of a Doctoral research on the impact of digital media on architectural education, will attempt to explore some salient issues of computer assisted fabrication in architectural design, focusing on the educational aspect. Certain implication of these issues as well as proposed frameworks for contextualizing them will also be briefly discussed.

Keywords

Prototyping; Digital Fabrication; Model Representation; Design Process; Architectural Education.

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Introduction

The Oxford English Dictionary defines "prototype" as:

- The first or preliminary version of a device or vehicle from which other forms are developed.
- The first, original, or typical form of something; an archetype.

Alternatively, in the Merriam Webster Dictionary "prototype" is defined as:

- An original model on which something is patterned (ARCHETYPE)
- An individual that exhibits the essential features of a latter type
- A standard or typical example
- A first full scale and usually functional form of a new type of design of construction (such as an airplane)

It is of certain interest to examine the definition and application of the term "prototyping" in contemporary architectural discourse and the effects it has on the architectural field. Both in the sense of a new technology utilized in the design process as well as in the context of conceptual model of architectural praxis. It is argued that this examination can lead to the identification of certain challenges facing contemporary architecture as well the risks inherent in these challenges, Furthermore, it is contended that the phenomenon of "prototyping" in architecture and the questions it raises can be approached in the context of a broader theoretical framework. Finally, the utility of such a framework in the articulation of architectural culture as well as the questions raised by "computer assisted fabrication", especially in a pedagogical setting will be briefly discussed.

In order to highlight certain salient issues in this direction, this article will attempt to:

- Explore how the concept of "prototype" affects architectural thinking and praxis
- What do we mean by "prototyping" in an architectural context?
- Do "prototypes" influence the design process?
- What are the challenges and risks posed by the adoption of the new technologies?
- Interpret the role of "prototyping" in architectural methodologies in a theoretical context

Defining Prototypes

William Mitchell wrote that the modernist motto "form follows function" lacks meaning if we cannot specify what form, function or even follows means [Mitchell 1990]. Bearing this in mind, it is of interest to examine what we mean when we utilize the term "prototype" in an architectural context. Such an inquiry is of additional use in order to avoid the pitfall, all too common in architectural discourse, of utilizing terms and concepts that originated in other fields, without properly translating and internalizing them. This process of interpretation is conceived along the lines of a "transcoding" process as proposed by Frederic Jameson [Jameson 1981].

When one speaks of prototypes, one of the first images that come to mind is an experimental construct, usually a machine that, as the definition cited above states "exhibits the essential features of a latter type". For example we could imagine a prototype airplane that precedes the full scale mass production based on this test model.

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In the case of architecture, one would be hard pressed to state that prototyping plays a similar role to the one described above. With the exception of parts that are mass produced to construct a whole architectural element (e.g. panels for a facade) there are few occasion on which design has use of mass production.

Nevertheless, the terms "prototype" and "prototyping" are common in architectural discourse, spawning multiple approaches that mostly structure design methodologies around computer assisted fabrication in some form or another. One could argue that in the vast majority of the cases, the process described is not actually "prototyping" according to the definitions described above, but rather a form of model making, or representation, in the sense of a method, or design world [Mitchell 1990] that aids in the articulation of the design.

For the purposes of this paper, the term "computer assisted fabrication" will be utilized to refer to the approaches described above. This is in order to avoid confusion regarding the difference between "prototype" and "model". Although admittedly as has been already mentioned, there is little true prototyping involved in architecture at least in the industrial sense, it is valid to point out that there is widespread use of modeling as a means to test architectural design proposals. Computer assisted fabrication effects in this regard are twofold.

On the one hand it affects the modeling process described above, on the other hand it could be contended that digital tools could allow for the introduction of "prototyping" in the design process along the lines by which the term is used in other fields.

It is argued that regardless of the semantics of the term, it is a fact that the introduction of "computer assisted fabrication" in contemporary architectural discourse is viewed as a new design process paradigm [Kolarevic 2001].

Prototypes and Models

Computer Assisted Fabrication arguably falls under the domain of model making, i.e. the physical scale models architects produce during the course of a design project. Although it escapes the scope of the present paper, it is interesting to note the differences between "model" and prototype" and the risks involved with their misuse in current architectural discourse.

In any case, as a model making method, Computer Assisted Fabrication can be categorized in three distinct groups. Conceptual models, used to articulate a design idea, exploratory models, utilized in the testing and judge design concepts and presentation models, and finally presentation models which are part of the final demonstration of the design product to others [Kvan et al 2001]. The different roles these models are called upon to fulfill result in different characteristics in each group. As a result, conceptual models may be more abstract and their making process more ad hoc. Similarly, exploratory models may incorporate material considerations and precise dimension in order to evaluate a specific aspect of the design, such as morphological, structural or functional considerations. Finally, presentation models usually contain a high level of detail and similitude to the final project in order to be understood by the broader public [Kvan & Thilakaratne 2003].

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The role and importance of model making is well documented in architectural theory [Tsou et al 2001]. The physical model allows an unmediated inspection of the design, and is especially useful to examine spatial sequences and geometric form [Sass 2004]. These aspects of the design are usually difficult to discern in architectural images such as sketches, layouts, 3d models etc [Stavric et al 2007]. Therefore the physical model retains its importance in the design process despite the proliferation of digital media that have subsumed almost the totality of drawing representations.

Contemporary approaches to modeling as described above focus on the utilization of digital tools in the fabrication process [Valdés et al 2013]. This allows for the representation in physical form of the complex geometries that usually accompany the use of computational media in architectural design [Klinger 2001]. Beyond this ability to realize the new forms of digital design, these tools also allow for greater precision and speed in the creation of models [Kenzari 2005]. Therefore it might be argued that modeling using digital fabrication tools has the effect of returning to physicality the architectural forms of the digital age that display an alarming tendency to drift into disembodied forms in cyberspace [Lynn 1999] and create an emancipated reality in place of the holistic representation required to conceptualize the totality of the architectural project [Vesely 2005].

At this point it must also be mentioned that Computer Assisted Fabrication is not limited to scale models of the kind described above. The existence of an uninterrupted flow between design and construction through the use of CAD-CAM systems allows architects to have immediate access to the building site itself, creating the tantalizing vision of a designer – fabricator that is present in all stages of design from conception to construction [Clarke 2004]. It is worth noting that this could be a paradigm shift comparable to the evolution of architects from master builders to creators of representations, that all drawings and models ultimately are [Vesely 2005].

The Technology and Risks of Computer Assisted Fabrication

As has already been stated, contemporary modeling methods are closely connected to the introduction of digital tools in architectural design. Beyond the existence of computational design media capable of creating and manipulating complex forms, Computer Assisted Fabrication requires a series of numerically controlled machines, such as CNC routers, laser cutters, 3D printers and the like [Pupo et al 2009].

It has been often noted that the whole concept of Computer Assisted Fabrication is approached from a technical standpoint rather than as a design issue [Streich 1991]. In other words, many approaches focus on the details of the manufacturing process rather than examining the architectural aspect of the project. Therefore there is a risk of not addressing purely architectural consideration such as aesthetic or design intent and limiting the methodology to a how to" manual of prototyping.

It is also interesting to note that older approaches focus more on the technical descriptions of the digital tools used in prototyping. As a result one can read a detailed description of e.g. stereo lithography [Streich 1991], whereas more contemporary approaches take 3D printing for granted and focus on the actual manufacturing process [Marcus et al 2014]. One can argue that this evolution indicates a shift from the "how to do" to the "what to do" [Cabrinha 2006] in prototyping and at the same time that this signifies a certain lack of authorship. In other words, by no longer finding and describing the processes that fit our design intent but rather adapting our projects to fit the available tools. One can conceivably argue that this presents the risk of tethering design intent to technological elements that is doubtful can act as the generators of architectural meaning [Vesely 2005].

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In any case, as has been mentioned above, information technologies allow the creation of a continuum in the design process from drawing to realization, although it remains an open question if the architect can retain a holistic supervision of all different aspects or there if there is a need for specialization and one cannot expect a designer to be proficient in all stages of this CAD – CAM process. Therefore, one can pose the question if Computer Assisted Fabrication favors a holistic approach to design or risks further fragmenting the design discipline into autonomous specialist fields.

It is obvious that these challenges and potential risks go beyond a narrow technical approach. Furthermore, there are obvious risks in ignoring this aspect of Computer Assisted Fabrication. It can be theorized that it is the role of architectural culture, to address these issues, in the light of the parallel discussion regarding the use of digital design media. Furthermore, I believe that contemporary architectural education frameworks must address the questions raised by the new design paradigm.

Designing as Computer Assisted Fabrication

Beyond the aspects of Computer Assisted Fabrication briefly analyzed above, an important issue is how these methodologies affect the design process itself. In other words, do they affect the resulting architectural product in the same way that digital design media does [Kolarevic 2000]? Or do digital fabrication methods offer little more than a practical expedience to the slower and less precise analog methods of model creation?

First of all we must mention that these tools remain comparatively expensive and therefore are not readily available [Lara et al 2009] in the same way that design software packages are. To put it simply, architects are much more likely to have access to a computer than to a CNC router and as a result the computer – and therefore the digital design software is more likely to affect the design than the digital fabrication tools. This hypothesis is supported by studies examining the behavior of students with regards to fabrication labs, where the most extensive use is observed during the final presentations [Rügemer 2008] which means that the project has been all but finalized, and there is no opportunity for the digital fabrication of the "prototype" to offer any feedback or insights to the design. One can argue that dedicated workshops centering on prototyping might offer an alternative educational method [Hemsath et al 2009], but this runs into the problem of being separate from the design studio that is the linchpin of architectural education strategies [Kvan 2003]. What is more the limited time of such workshops doesn't allow for a thorough articulation of a design proposal, a fact exacerbated from the need to also introduce prototyping tools and their use to the students.

In any case, it must be admitted that even in today's limited fashion, Computer Assisted Fabrication tools are affecting design [Diniz 2015], either through the realization of complex forms of digital software, either by creating a loop between drawing and modeling [Arpak et al 2009]. What is needed is an introduction of the fabrication processes in the design studio as well as a larger number of machines to allow better access to students. And while the hardware aspect is harder to tackle given the realities of academic budgets, it can be argued that a better integration of Computer Assisted Fabrication methodologies during the course of design studios can benefit the educational process significantly by increasing the exposure of students to such methods in the context of their own design projects, offering feedback that informs the designs' evolution instead of merely actualizing the final product and lastly maximize the efficiency of the limited resources available to architectural schools [Pupo et al 2008].

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Representation and Computer Assisted Fabrication

Thus far we have described the relation of Computer Assisted Fabrication to architectural models, mentioned the technical focus of design modeling methods and briefly analyzed the impact of fabrication on design process especially in an educational context. In order to outline a possible holistic conceptual model regarding the use of Computer Assisted Fabrication in design, it will be attempted to examine the implications of the previous observations in a non-deterministic manner in contrast to a technological approach common in relevant discourse. To that end, concepts drawn from the field of hermeneutics will be utilized.

It has been argued that the design process is in essence a hermeneutic process [Schon 1987], in other words, that the architect enters into a dialogue with the project. This process cannot be examined solely through the lens of deterministic logic, since its workings include elements and mechanisms of a hermeneutic nature [Snodgrass and Coyne 1997].It is not possible in the context of this paper to further analyze this position, suffice to say that methods and processes that focus exclusively on the quantifiable part of the design process, such as computational design media or arguably digital fabrication techniques ignore crucial elements of the architectural project [Gu et al 2010] [Davis et al 2011].

But how does this reflect on the use of Computer Assisted Fabrication in architectural design?

On the one hand, as has already been mentioned, the focus on such approaches is on the technical aspect, i.e. the "what" and the "how" of design [Sommer & Palz 2009]. This leaves the important question of why, which is of crucial importance to a design project as well as an educational process, [Kastoriadis 1991]. Current Computer Assisted Fabrication approaches share this issue with the broader field of digital design theory and praxis, i.e. the lack of a critical view of the various design methodologies. It is useful to cite Mies van der Rohe's statement, that the how we build is not as important as the spiritual issue of why we build [Neumeyer 1991]. In light of this, it can be argued that there are benefits to approaching fabrication as a design world [Mitchell 1990] in which they can enter into a dialogue with the design project and within which prototypes are considered arguments in this dialectical procedure rather than finalized products. This view is corroborated by studies indicating the importance of feedback from Computer Assisted Fabrication that informs the design process, as has already been mentioned [Yazici & Gerber 2016].

On the other hand, the fact that Computer Assisted Fabrication methodologies succeed in rendering in physical form the complex geometries and multiple alternatives associated with computational design can be seen as a positive factor inasmuch as it aids in the tethering of architectural space in physical reality [Kvan et al 2001]. All too often digital media lures designers into the digital exploration of abstract geometric spaces that retain little or no link to the physical reality into which architecture must conceivably exist. The ability to rapidly translate these complex forms into tangible objects aids in the better appreciation of various aspects that the -ultimately two dimensional- nature of an image can obscure [Stavric et al 2007]. Furthermore the physical aspect afforded by Computer Assisted Fabrication methodologies allows the appreciation of architectural objects with other senses other than vision, senses that are equally important in the way we perceive space [Pallasmaa 1996]. It is interesting to speculate if current developments in virtual or augmented reality will affect the need for tangible models in design process, but that discussion is beyond the scope of the current article [Coomans & Oxman 1996].

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Conclusion

An attempt has been made to examine certain aspects of the architectural discourse in the field of Computer Assisted Fabrication. Although the nuances and particularities of the numerous methodologies cannot be adequate addressed within the limits of such an approach an effort has been made to identify a number of salient issues and analyze them in the context of the design process per se as well as part of contemporary architectural culture and pedagogy.

In order to further analyze these themes, it is suggested that they must be viewed under the lens of a broader conceptual framework. This framework can aid in conceptualizing Computer Assisted Fabrication as means of representation according to Gadamerian hermeneutics, i.e. of the object of representation being present in the only way available to it, not as an inferior simulacrum [Vesely 2005].

In this sense, Computer Assisted Fabrication is approached as part of a broader dialogue in which the "how" and the "what" do not risk eclipsing the "why" of architectural design.

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