Framing Digital Fabrication in the Architectural Research Practice through a Taxonomy

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Abstract. This paper examines the integration of digital tools in architecture, exploring their transformative effects on the design process. Despite the increased control and innovative possibilities these tools provide, their impact on research-driven architectural design studios remains underexplored. The research focuses on the role of digital fabrication, a method that has revolutionized design and construction, but also brings several misperceptions about its role in architectural practice. By analyzing selected architecture offices, the investigation uncovers new modes of design thinking, highlighting the architect's role in solving complex processes and expanding architectural vocabulary. A taxonomy approach is utilized to categorize methods and identify interrelationships within the design process. Ultimately, the study contributes to a deeper understanding of digital tools in project-based research methodologies in architecture, offering insights that challenge traditional practices and pave the way for innovative design mechanisms.

Keywords: Digital Fabrication, Processes, Methodologies, Design Studio.

1 Introduction

Technical change does not happen in a vacuum (Carpo, 2016). In fields ranging from design and manufacturing to education and architecture, the integration of digital technologies has granted architects an unparalleled mastery over the design process. Yet, the depth of this transformation's impact, especially on research-driven architectural design studios, remains to be fully explored. By unraveling these complexities, we can illuminate the vital role of digital tools, accentuate opportunities to refine digital fabrication methods, and develop methodologies more attuned to architectural design's nuanced demands.

Within this scope, architectural research emerges as a form of applied research. Designed for specific applications, it translates fresh insights into practice, a pioneering approach with the potential for revolutionary outcomes.

Moving beyond the Computer Aided Design (CAD) era, where computers merely replicated manual tasks, today's computational capabilities are far more nuanced. With digital fabrication as the cornerstone of this study, computers are now involved in sophisticated processes (Aish and Bredella, 2017), transforming them from passive tools to active participants in creation.

This paper aims to navigate and dissect design studio methodologies anchored in digital fabrication. Rather than focusing on automating or distancing architectural processes, it underscores the importance of reinvigorating the architect's role. This involves serving as a critical catalyst for resolving intricate challenges and extending the architectural vernacular. Such an alignment recognizes digital fabrication's integrative role in both architectural research and practice, as evidenced by the exemplary studios scrutinized in this study.

Highlighting three avant-garde architecture studios, all distinguished by their innovative use of digital technology and unique proficiency in contemporary techniques, this paper serves as a focal lens. Through their work, we can glimpse groundbreaking design trajectories catalyzed by digital technology's evolution. Further, this exploration sets the stage for discovering novel design thinking paradigms, fueled by the burgeoning field of digital fabrication.

The study's findings coalesce into a taxonomy that not only reimagines the design-thinking process but also sketches a future landscape. Inspired by the methods embraced by the participant architecture studios, this innovative classification system paints a compelling picture where digital fabrication transcends mere support, morphing into an integral facet of the design process. In doing so, it signals a promising horizon where technology and creativity effortlessly intermingle, opening doors to unprecedented architectural possibilities.

1.1 Background

In the early 90s, computer-aided design (CAD) was perceived merely as a creative aide, not as a generator of creativity. The visionary Richard Buckminster Fuller, however, hinted at technology's extraordinary potential back in the 1920s. It was only in the late 1990s and early 2000s that these tools began to pervade architectural design. They transitioned from mere creative assistants to essential components in processes, protocols, and fabrication. Architects were no longer simply using computation; they were thinking with and through it.

Digital fabrication has caught the attention of architects and designers by unlocking innovative solutions to complex construction challenges. This method allows for a more integrated design process, enriching architects' skills and broadening their vocabulary.

However, misperceptions abound. Digital fabrication is often misunderstood as an automation tool that might alienate architects from their craft. Contrarily, it can serve as a bridge to traditional craftsmanship. Custom elements created through digital fabrication add a personalized touch to projects, unattainable with conventional means.

Architectural design is a process (Burry 2016) that continually evolves. Digital design and fabrication empower designers to immerse themselves in the design and receive feedback. Many architects now prototype components of their designs, progressing further in the design process, and integrating form generation and 3D printing.

Additive manufacturing, or 3D printing, emerged in 1983 with stereolithography (SLA), which solidifies photopolymers with an ultraviolet laser beam. Now, processes have evolved, and materials range from plastics to metals, glass, clay, and nanocomposites.

Digital fabrication is revolutionizing many industrial manufacturing processes. Though relatively unexplored in construction, interest from architects and academics suggests it won't be long before it becomes a design workflow staple.

The introduction of digital fabrication marks significant shifts in architectural practices, hinting at a future ripe with untapped possibilities. Research, experiments, and dedication from architects and universities have opened a realm of opportunities for architectural expression. This paper seeks to reframe the potential that architecture holds through these emerging technologies, acknowledging its rapid evolution and the need for the profession to adapt and reinvent.

2 Methodology

Since digital fabrication made it possible for new design mechanisms, the chosen methodology for this study encourages an overview of current office practices, leading to a re-evaluation of design-related theories.

Digital fabrication has revolutionized design mechanisms, prompting this study to explore current office practices and reassess design-related theories. The methodology focuses on examining the output of three distinct architecture studios to uncover new design thinking techniques fueled by digital fabrication.

Two of the selected studios, HANNAH Office and Studio RAP (figure 1), are young and were chosen for the innovative way they combine computational design and digital fabrication—a complementary relationship driving creativity.

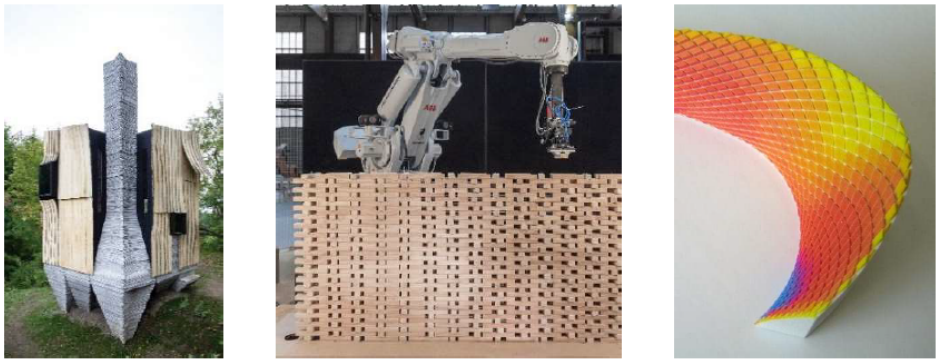

Figure 1. Left - Ashen Cabin. Source: HANNAH Office, 2019. Middle – Circular Experience. Source: Studio RAP, 2019. Right – a colour 3D print of a structure within the Duisburg Harbour Masterplan representing solar exposure throughout the day. Source: Foster + Partner, 2007.

An experimental design and research studio, HANNAH Office, based in Ithaca, New York, delves into the intrinsic connection between digital design and fabrication technologies. They pioneer new material methods, environmental practices, and technological affordances. By controlling building processes, they reconcile mechanical means with architectural goals, influencing future creative pursuits (hannah-office, 2022).

Based in Rotterdam, and a leader in marrying computational design and cutting-edge digital fabrication methods, Studio RAP's robotic fabrication challenges traditional building methods. Their approach results in expressive architecture and a practical, innovative solution to construction challenges. By rethinking the architectural profession, they contribute to a radically contemporary building culture (studiorap, 2022).

Unlike the digitally-native practices of HANNAH Office and Studio RAP, Foster + Partners began investing in digital fabrication tools in 2003. This world-renowned firm employs computational design to enhance the material efficiency of building components and construction methods.

The Specialist Modelling Group (SMG) at Foster + Partners leads the exploration into efficient shapes and materials across design levels. They were quick to exploit 3D printers and rapid prototyping facilities, unlocking a faster creation process and near-limitless prototyping opportunities. This marked a significant shift in their design methodologies, further assisted by computational tools that allowed for infinite variations in shape and form (fosterandpartners, 2022).

The architectural and construction industries are amidst transformation, thanks to computational design and digital production. The chosen studios for this study represent the spectrum of these changes—from the novel approach of young studios like HANNAH Office and Studio RAP to the adaptive evolution of an established firm like Foster + Partners. These cases illuminate the dynamic ways digital fabrication is shaping the future of design.

3 Results

The taxonomy design in this study unfolds in two distinct stages: (1) Analyzing Key Processes: This includes a comprehensive analysis of the Design Thinking Process (Gibbons, 2016), the Architectural Design Process Work Flow (hmh, 2022), and the Digital Design and Fabrication Process (Hensel, 2016), focusing on their interrelations; (2) Project Analysis: This stage involves detailed analysis of a group of projects from each studio, highlighting their unique approaches and techniques.

The first analysis builds upon the Design Thinking Process, comprised of three phases and six sub-phases, as proposed by Nielsen Norman Group (Gibbons, 2016). It correlates this with the Architectural Design Process Work Flow by HMH Modern Architecture, further enhanced with the Digital Design and Fabrication Process by Perkins + Will.

An Operations and Maintenance stage was added, typically ascribed to the BIM construction process (ventures, 2022). This resulted in a three-level taxonomy that connects Design Thinking with architectural practice and Digital Fabrication Process (Figure 2).

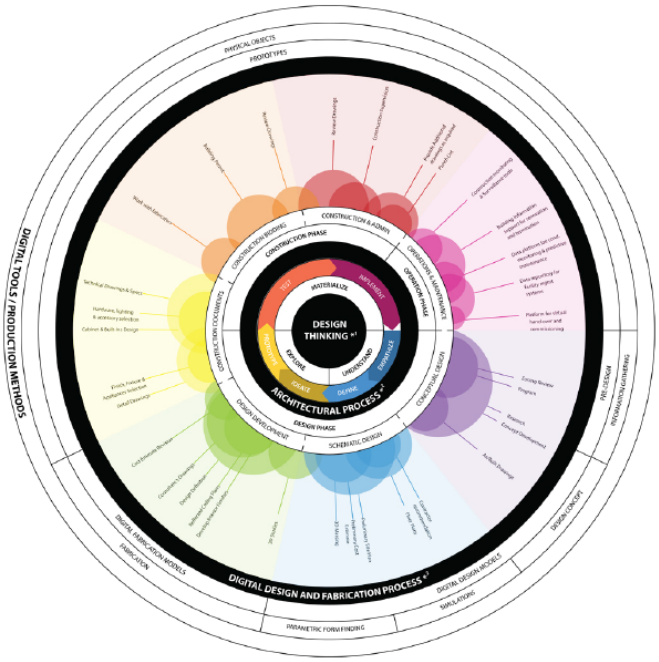

Figure 2. Preliminary taxonomy relating Design Thinking, the Design Process Work Flow and Digital Design and Fabrication Process.

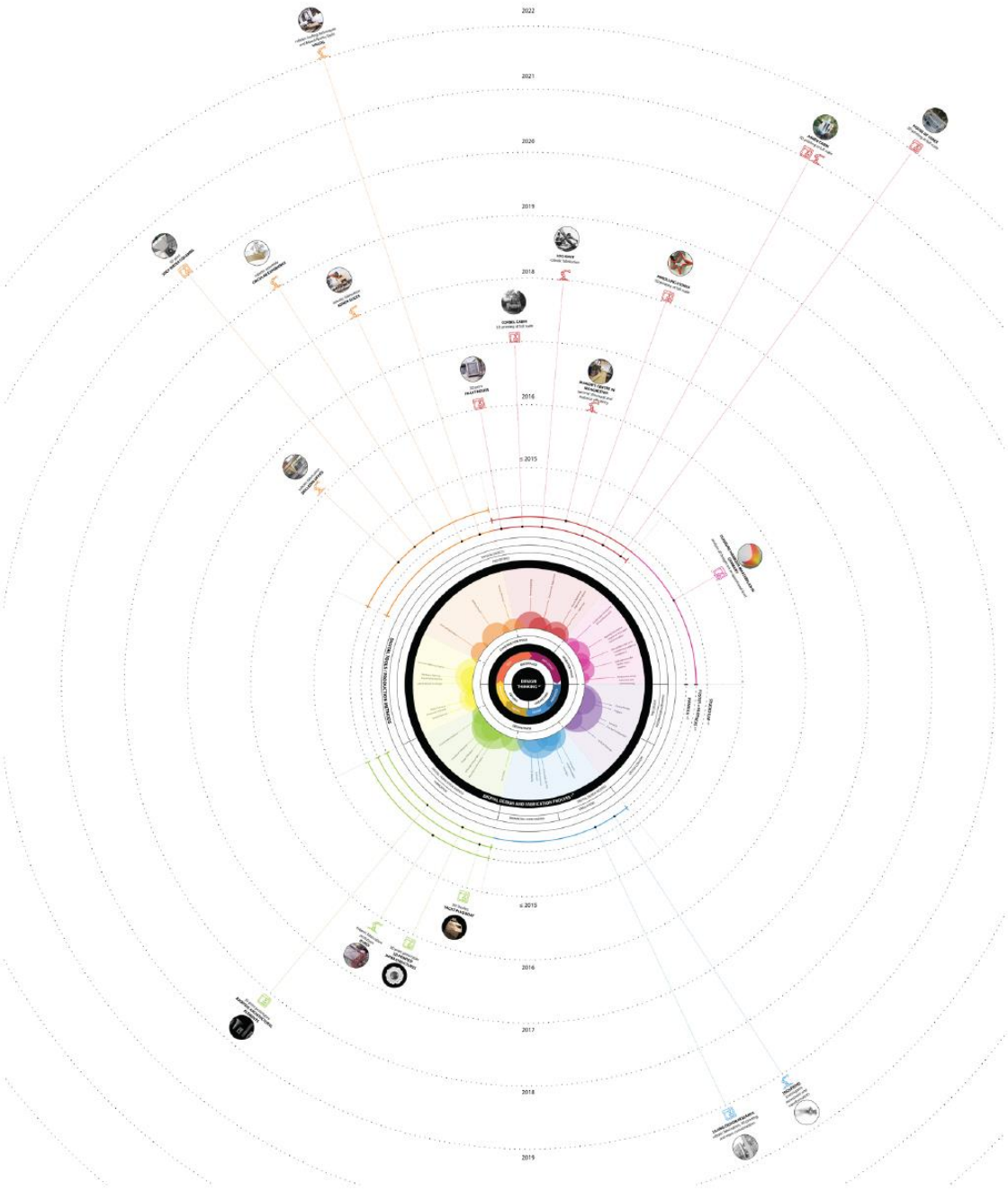

Figure 3. Preliminary taxonomy relating HANNAH Office, Studio RAP, and Foster + Partners group of projects

This novel approach frames digital fabrication as both an augmentative tool and a core component of the design process.

The taxonomy adopts a radial structure, and the second analysis organizes projects from the selected offices on a timeline. Positioned within concentric circles, the projects are arranged by year, with more recent projects located farther from the center. Every project included in this classification represents a completed construction and is categorized based on the type of digital fabrication technique used, such as drones, 3D printing, or robotic arms. Furthermore, each project is aligned with the specific design phase in which the digital fabrication was applied, and a unique color has been assigned to each phase to provide a visual indication of the corresponding design stage.

When analyzing the data, it is evident that the studios view digital fabrication as a way to expand their research and enhance their craft's potential. The variety of projects included in the studies demonstrates their ability to operate at many scales, and through time, they have figured out how to make design profitable.

They have come to understand that by combining symbiotic techniques and pushing the boundaries of their practice, diversity is where they truly add value or contribute. For this investigation, data from the three architecture offices selected for case studies were collected online, based on their wide work published online and their own websites from the offices. This collection method provided an extensive overview of their different approaches to utilizing digital tools and fabrication techniques.

The case studies demonstrate a development process that depends equally on knowledge of physical characteristics and manufacturing procedures as it does on design intent, allowing more elements to be directly incorporated into the suggested outcome. Instead of merely replacing traditional sketching or modelling techniques, computation is directly integrated into the form-generation process. The techniques allow for the use of novel vocabularies that are not really feasible with conventional techniques. Through detailed modelling and testing of physical models, it would be difficult to attain the complexity in form variation associated with structural and material attributes. As a result, the project not only shows how differentiating building components may be to a great extent, but also how fabrication limitations and material qualities can be included into form generation.

The case studies show potentials that could be improved upon and modified for use in further projects. The possibilities should become clear when more realized instances of these kinds of architectural projects appear. We can already observe a number of outstanding projects, like the House of Cores (2022) and Ashen Cabin (2019) by the Hannah Office, and the SkilledIn Office (2016) by the Studio RAP (figure 3), that clearly rely on digital manufacturing. However, a more comprehensive and integrated approach will enable the concepts to have a greater overall influence on the built environment.

4 Discussion

The taxonomy formulated in this study reaffirms the core hypothesis that digital fabrication goes beyond being a mere tool; it represents an integrated approach within collaborative digital processes that enhances communication throughout the design journey.

By scrutinizing and assessing the works of three independent studios, we comprehend how each has utilized digital technologies to forge their unique modes of operation and cognitive frameworks. It's evident that the industry is not only adopting fresh methodologies but also evolving traditional manufacturing practices. Digital fabrication emerges not solely as a tool for the end product but as a technology that supports the entire design thinking continuum.

In this paper, we assert that digital fabrication can amplify design thinking within architectural studios, thereby fostering a more profound understanding among architects. Digital fabrication is converging with conventional workflows, simply evolving current practices rather than entirely supplanting existing tools.

This research is part of a broader examination into the architectural design process, predicated on the notion that additional methodologies ought to be integrated into design techniques. It envisages digital fabrication as a strategic part of collaborative digital processes, enhancing communication throughout design methodologies. This perspective sketches the evolution of design principles to enable a richer comprehension of project approaches, recognizing each as a product of its era.

The rise of complex technological and ecological challenges compels professionals to explore novel forms of exchange and partnership, intentionally breaking and transcending traditional disciplinary barriers. This collective technological utilization is not only transforming how products are conceived and fabricated but is also profoundly altering the culture, politics, and economics of the creative sectors.

If the first robotic era marked a surge in physical production, the impending second robotic era promises to be a catalyst for creative capacity. The alignment of technology, creativity, and materialization encourages unique scientific inquiries and uncovers new possibilities.

Drawing on the works of HANNAH Office, Studio RAP, and Foster + Partners, it's apparent that the confluence of computing and fabrication has already enabled a dynamic interaction between design and digital fabrication, orchestrating production from file to factory to site.

The preliminary taxonomy crafted within this research framework sheds light on digital fabrication's role within architectural design practice. It challenges conventional architectural education and the foundational conceptualization of architecture itself.

5 Conclusion

This paper embarks on a nuanced exploration of how the fusion of design thinking methodologies with digital fabrication is reshaping the landscape of architectural practice.

The integration of digital fabrication into design thinking contexts isn't merely a technological advancement; it's a convergence of creativity and precision that has become a critical aspect of contemporary research and design. This intersection isn't a straightforward one; it's a complex, evolving synergy that challenges conventional methods.

As elucidated through practical examples in this research, the incorporation of digital fabrication into design studio workflows acts as a catalyst. It not only enhances design thinking but also amplifies the material efficiency of building elements and refines the construction methodologies. Digital fabrication transcends its role as a tool and becomes an integrative part of the creative process.

Design thinking emerges as a supportive structure in studio work. It embraces failure as a learning opportunity, advocates iterative procedures, and encourages continual reflection on the materials and processes utilized in manufacturing. These aren't mere stages but vital components that breathe life into the entire creative cycle.

Our observational research, engagement with design thinking theory, and the research experiments conducted in this study have not only illuminated existing practices but also laid out a roadmap for future exploration. There's a rich terrain to be investigated in how design thinking might be further woven into reflective and innovative digital fabrication processes within the design studio environment.

The melding of digital fabrication with design thinking is far more than a trend; it's a transformative shift that holds the promise of redefining architectural practice. It is a movement that transcends boundaries, bringing a fresh perspective to design, and holds a mirror to an evolving architectural landscape that demands agility, innovation, and reflection.

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