Phygital Fabrication and the Evolution of Traditional Handicraft

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ABSTRACT: This paper untangles the emerging need for a critical understanding of phygital design and phygital material by exploring its most definitive qualities in the context of a quasi-autonomous collaboration between human agency and the computer, here explored through the digital reinterpretation of traditional handicrafts belonging to the ethnic Chinese minority Bai from the northwestern province of Yunnan. A phygital fabrication workflow challenges experience-based standardized fabrication techniques by creating atypical results from a constant exchange between physical fabrication and digital simulation, consciously acknowledging the contributions of the machine. It suggests, moreover, a new way to inherit indigenous design as a deliberate collaboration with non-human agencies, reflects the anxiety of designers seeking new positions around digital design tools, and describes a workflow not wholly defined but nonetheless integral to contemporary design practice.

KEYWORDS: Phygital, Materiality, Fabrication, Indigenous, Quasi-autonomy

INTRODUCTION

In her book, *Lo-TEK: Design by Radical Indigenism*, Julia Watson maintains that the mythology of technology, as a confluence of humanistic, colonialist, and racist tendencies, has historically disregarded local wisdom and indigenous innovation (Watson 2022). To resist the qualification of indigenous innovation as primitive and existing apart from "technology," designers must be conscious of the impact of modern tools on the cultural landscapes to which they are applied.

Ongoing advances in machine learning technologies continue to make artificial intelligence tools extremely accessible. The level of accuracy and sophistication generated by machines can now be easily confused with content created by humans. Established workflows from the artificial intelligence chatbot to text-to-image generators suggest that emerging digital tools are capable of autonomous design. The anxiety surrounding intelligent digital tools is palpable in the design industry today. Indeed, what is the value of human agency to a creative process informed by artificially intelligent machines whose processing power and memory are a billion times more advanced? Renowned American literary critic Harold Bloom once stated that artists must be aware of this anxiety of influence but must also strive to create something new and unique that advances and transforms it (Bloom 1997). We concur, maintaining that the new human-machine relationship must be critically examined.

Digital design tools have been used in various industries for several decades, prompting the constant re-evaluation of the human-machine relationship. The introduction of Computer-Aided Design (CAD) tools in the 1960s and 1970s marked the beginning of the digital design revolution. CAD tools allowed designers to create and modify designs using computer software, increasing productivity and accuracy. The computer was considered a powerful tool, a buffed-up drafting table (without autonomy) that could create optimized and efficient drawings. The machine output being a direct response to human input meant that it could be easily evaluated by its user. In the early 21st century, the advent of cloud-based software and collaborative design tools with BIM (Building Information Modelling) technology enabled designers to work remotely. BIM models rely on accurate input data and designers' skilled interpretation, which require additional expertise and training to avoid errors or oversights. Now, working with AI, the bar should be even higher for designers to interact with the machine consciously. However, designers are not trained as computer science engineers. For most, the computer is a black box, a mechanism of mystery, when engaging with automated tools. Consequently, it can produce many unintentional outputs that are exceptionally difficult, if not impossible, to evaluate and control.

How can designers be more conscious about working with the engaged tool? Creating a quasi-autonomous workflow could be an answer to this question. In his article, "Quasi Autonomy in Architecture," Stanford Anderson maintains that a collaborative approach to the design process is required to avoid complete autonomy. There is no imperative that we must use any given technique (Anderson 2002). Friction between humans and machines is needed to create such a collaboration. When human agencies apply experience-based knowledge to a workflow, machines can output with optimized, automated, and limitless possibilities waiting to be curated. Phygital design incubates this collaboration by engaging both the physical understanding of material, fabrication, and construction from human agencies and the digital non-rectilinear translation from machines (Figure 1).

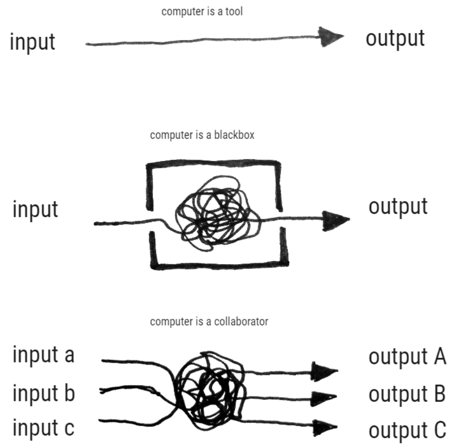


Figure 1: Diagram of three types of human-machine relationships. Source: (Nero Chenxuan He 2022)

1.0 METHODS

An example of phygital material fabrication, created in collaboration with a Chinese artist, is introduced here to evaluate the phygital design process. The artist samples traditional handcrafted tie-dye artwork from the Bai nationality of China. Bai tie-dye is a coloring technique representing various symbols, patterns, and meanings. The representation of the tie-dye requires a complex process handed down from one generation to another by word of mouth. Locals stitch fabrics in different manners, which allows fabrics to have different contact areas when dyed in a large container. After the fabric is dyed and dried, the stitches are removed to reveal the stained patterns. It requires 17 unique steps to finish a traditional Bai tie-dye work (Figure 2).

Figure 2: Indigenous Bai tie-dye process. Source: (Unknown 2019, Shuying 2017, Zhiqiang Liang 2021)

The phygital fabrication process begins by inheriting the stitched sculpture-like fabrication techniques of the local community; it samples identifiable patterns of the material artifacts and simulates their behavior in a digitally enhanced but physically consistent way. In so doing, the phygital workflow not only translates but transforms traditional knowledge through the vision of a machine (Figure 3). Translating from physical fabrication to digital simulation (and vice versa), phygital material fabrication provides an ongoing process to present atypical fabrication possibilities.

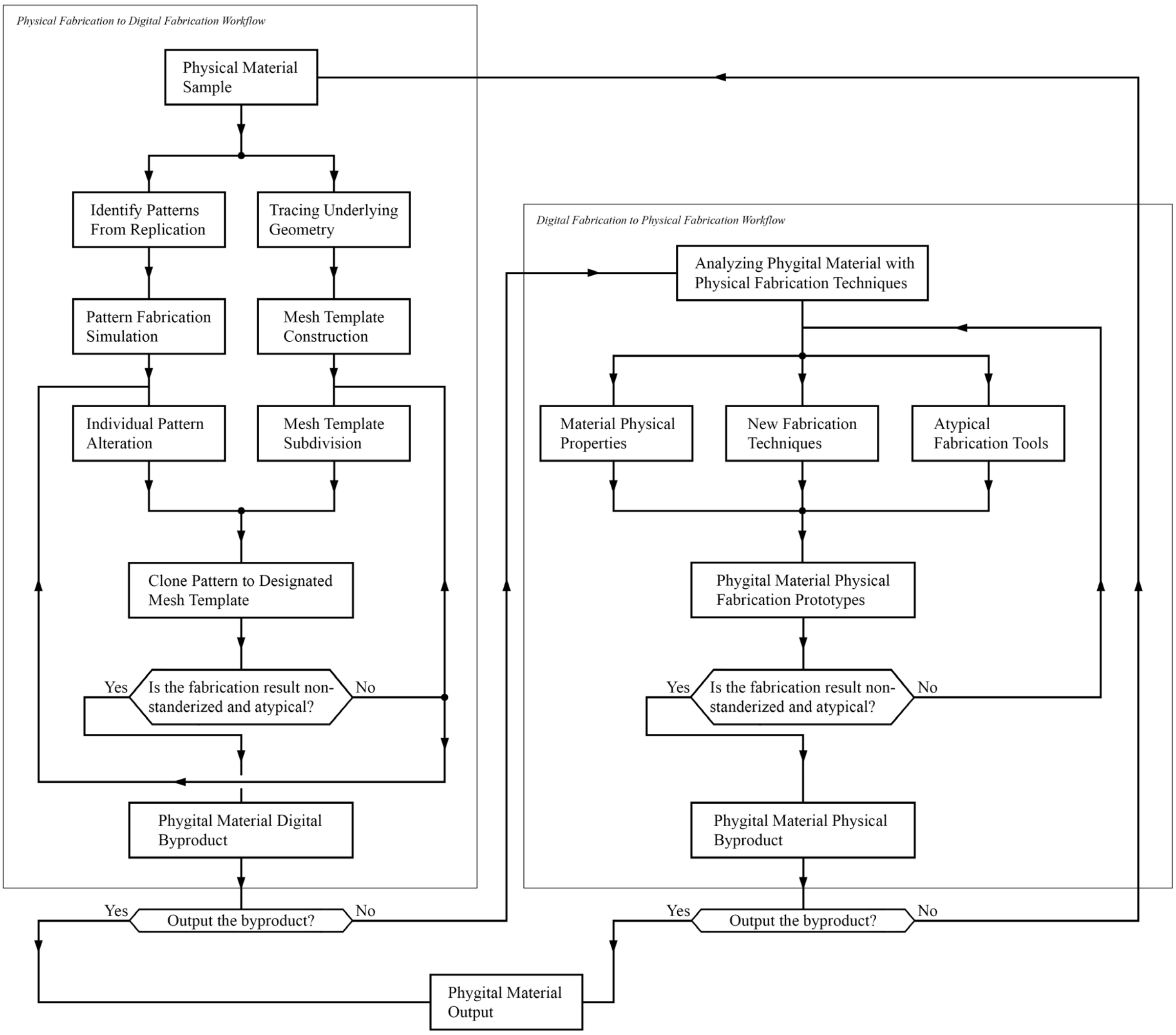


Figure 3: Phygital fabrication workflow chart. Source: (Nero Chenxuan He 2023)

1.1 Physical-to-digital fabrication workflow

To simulate the fabrication digitally in an efficient and automated manner, the translation from physical to digital must engage the proficiency of a computer for outputting consistent results. A new application logic, a template, should be designed for the computer to follow, attaching each replication to form a structural result consistent with the physicality of the artifact.

Identifying the replication in patterns is the first step to sampling from the physical fabrication. *In The Art of Manipulating Fabric*, Colette Wolff categorizes various fabric manipulation techniques, including pleating, gathering, smocking, quilting, and applique (Wolff 2003). These techniques can be rationalized by a computer with simulation forces mix-and-matched (Figure 4). The simulation is “fluid, responsive, and time-based,” as Greg Lynn observes in *Animate Form* (Lynn 1997). It creates a range of results sharing the same logic but formally altered from one another.

The difference in fabric patterns leads to a curation operation for the designer to evaluate and then selectively attach patterns to templates in order to diffuse the cloning and tiling nature of the process (Figure 5). This procedure artfully engages with the UV structure of a mesh surface and computational coning operation to maximize the power of the computer as a design agency. The simulation also implies a direction for material behavior in the fabrication, which will be discussed in the digital-to-physical fabrication workflow.

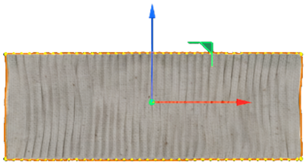


Figure 4: Single pattern fabrication simulation. Source: (Nero Chenxuan He 2023)

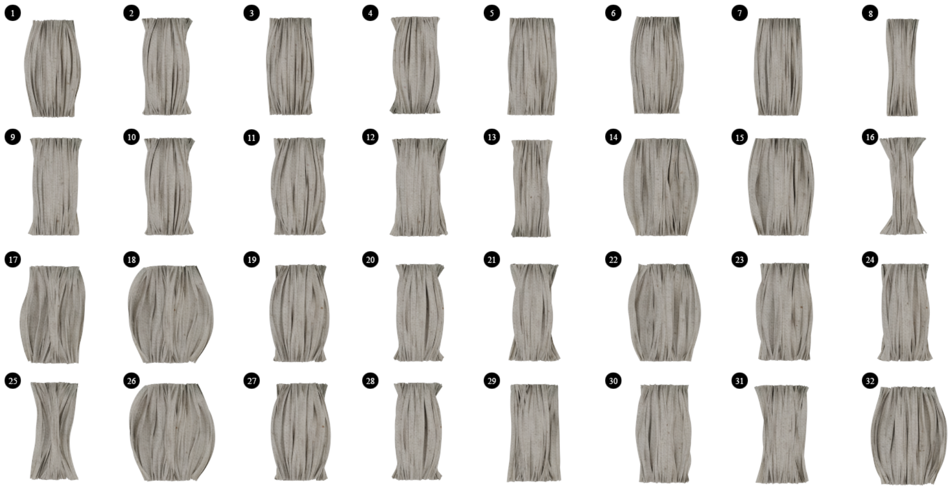


Figure 5: Curated results of single animated simulation. Source: (Nero Chenxuan He 2023)

The workflow is created to necessitate interference from human design agencies. Besides curating simulated patterns, the designer engages with the construction of fabrics by adjusting the scale, orientation, density, or materiality of the sampled pattern and the correlated template (Figure 6). If the result is excessively standardized, more alterations are needed.

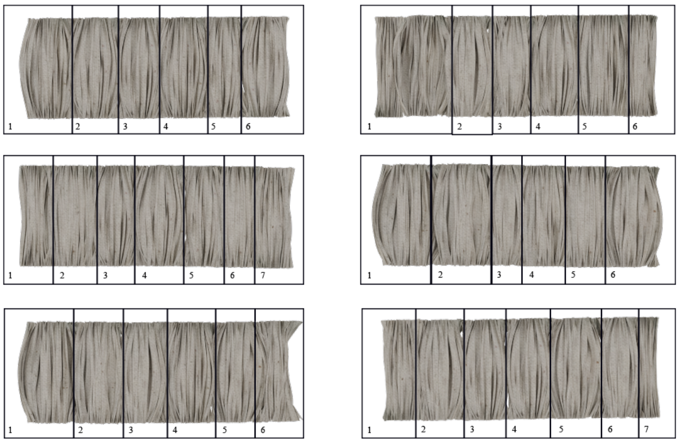


Figure 6: Pattern curation on templates. Source: (Nero Chenxuan He 2023)

Due to the abundance and complexity of the simulation, the simulated fabric is difficult to make visible in the design interface without crashing the computer. The process is bounded by the limitation of operated software and machinic hardware. Only by rendering out temporary results in real-time can the digitally fabricated product be critically evaluated (Figure 7). In this way, the limitation of conventional computer hardware necessitates another layer of digital perspective.

Figure 7: Phygital fabrication interface and real-time render result. Source: (Nero Chenxuan He 2023)

1.2. Digital-to-physical fabrication workflow

In this step, a collaborative process employs experience-based knowledge to identify atypical artifacts from the digital simulation (Figure 8). Each artifact challenges the designer's understanding of the behavior of physical materials and the capabilities of traditional fabrication techniques and tools.

In the digital domain, rendered material can be detached from its material behavior. When a digital material does not follow physical rules, it calls into question the nature of established fabrication techniques and tools (used for mass production and standardization) and generates an impetus for innovation and customization. The physical fabrication of this digital artifact should not, then, aim to recreate it as a physical clone. It should, instead, embrace the technological limitations of fabrication and make further alterations (to the digital) with consideration (of the physical) (Figure 9).

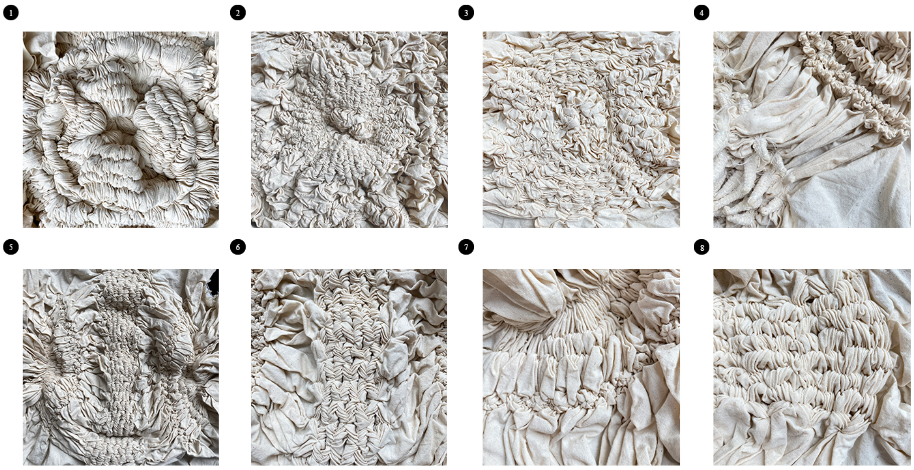


Figure 8: Physical pattern fabrication studies. Source: (Fanglu Lin 2023)

Figure 9: Phygital fabrication: digital byproduct (left) and physical byproduct (right). Source: (Nero Chenxuan He and Fanglu Lin 2023)

2.0 RESULTS

Phygital design is the last line of defense claimed by designers who fear losing agency in an industry that continues to contend with advances in automation. Design is a cultural practice. An intelligent machine, without guidance, can only sort and recombine information. The machine needs inferior human agencies to mediate its relationship with a physical world that (for now) it has a limited understanding of. When introducing the replica of Gordon Pask's 1968 "Colloquy of Mobiles," Paul Pangaro questioned the future of the machine by asking whether it should:

> predetermine everything for us, make the calculation in advance, and be the smartest AI in the cloud that tells us what we want to see every moment in the world? Or it should create "something playful, sometimes random and unexpected, something special? (Pangaro 2018).

While digital creation uses logic to simulate an optimized / automated / limitless possibility, human agencies assess, curate, and fabricate work by assigning physical concepts. Without interference or interpretation, the digital result is nothing but representations from calculated numbers. Just as the design of the pencil was informed by the dialogue between technological capability and human intention, the tools of phygital design must be continuously re-examined through the lens of contemporary contexts and conditions.

2.1. Not all digital is phygital

Phygital is conflicted. It seeks exchange but not synthesis. To understand how phygital design works, designers must accept that not all digital is phygital.

A phygital design establishes a two-way exchange from physical to digital and the other way around. In the simulation, there is no physics until a person with a physical understanding projects physics onto the representation of the performance of objects calculated with mathematical concepts. Material behaviors and material appearances can be mismatched but must ultimately be post-rationalized with knowledge of fabrication and construction.

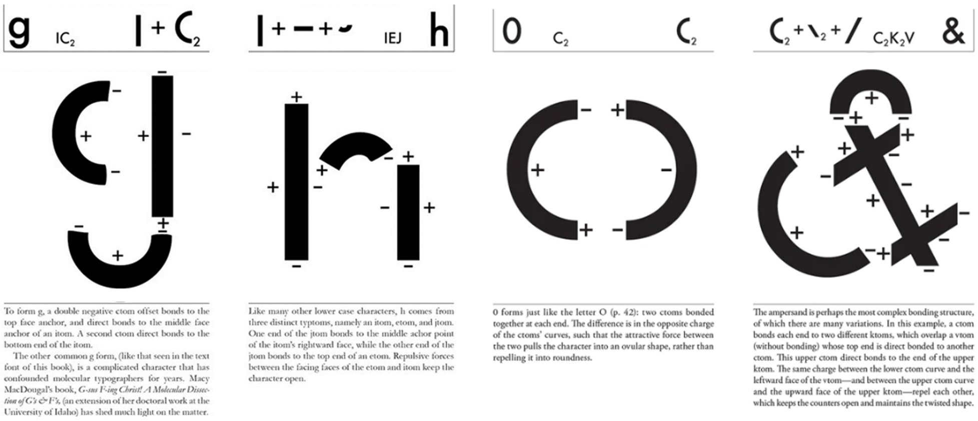
2.2. Phygital has no finite result

Phygital is an endless physical and digital seesaw. There is no finite result, only byproducts and fractures of this push and pull. A phygital object carries a fabrication logic of how a physical piece comes to be. Thus, its result could always be reanalyzed by an optimized digital representation which drives a new type of physical fabrication. Residues from both physical and digital processes are welcomed to create friction and challenge established knowledge.

2.3. The friction from translation

Phygital exists as friction between the physical and digital. The goal of each translation is not to create an identical double from another medium. Instead, a logical reconfiguration is needed with the accessible procedure in the medium to which the product is translated. The information exchange will inevitably produce friction, which is preferred over the homogenized representation attempted by projects like the Cornell Box.

In the elaborate para-fiction, *Understanding Molecular Typography*, by H.F. Henderson, artist protagonist Woody Leslie forces the logic of shaping and structuring molecules onto the visual representation of typography (Leslie 2019). He presents the result as an artifact that is as critical to document as the recognized waypoints of "correct" schools of thought. By introducing an alternative logic to existing information, this sophistry explores the possibilities of creating atypical results from translational friction (Figure 10). When an input is effectively finite, therefore – e.g. bounded/defined by the parameters of traditional knowledge, the computer as an intermediary performs the historical operation of cultivating variations by outputting mistranslations.



To form g, a double negative ctom offset bonds to the top face anchor, and direct bonds to the middle face anchor of an itom. A second ctom direct bonds to the bottom end of the itom.

The other common g form, (like that seen in the text font of this book), is a complicated character that has confounded molecular typographers for years. Macy MacDougal's book, *G-sus F-ing Christ! A Molecular Dissection of G's & F's*, (an extension of her doctoral work at the University of Idaho) has shed much light on the matter.

Like many other lower case characters, h comes from three distinct typtoms, namely an itom, etom, and jtom. One end of the jtom bonds to the middle achor point of the itom's rightward face, while the other end of the jtom bonds to the top end of an etom. Repulsive forces between the facing faces of the etom and itom keep the character open.

0 forms just like the letter O (p. 42): two ctoms bonded together at each end. The difference is in the opposite charge of the ctoms' curves, such that the attractive force between the two pulls the character into an ovular shape, rather than repelling it into roundness.

The ampersand is perhaps the most complex bonding structure, of which there are many variations. In this example, a ctom bonds each end to two different ktoms, which overlap a vtom (without bonding) whose top end is direct bonded to another ctom. This upper ctom direct bonds to the end of the upper ktom. The same charge between the lower ctom curve and the leftward face of the vtom—and between the upper ctom curve and the upward face of the upper ktom—repel each other, which keeps the counters open and maintains the twisted shape.

Figure 10: Understanding Molecular Typography. Source: (Woody Leslie 2019).

3.0 APPLICATIONS

Phygital fabrication techniques can be applied to any fabrication process that contains a traditional, linear design workflow (architecture included). Each sequence of fabrication events can be challenged by engaging with the computer simulation (the imitation of the operation of a real-world process or system over time), combined with the designer's curation (the process of receiving or giving systematic instructions).

Resistance to standardization is not a new phenomenon. The Arts and Crafts movement of the late 19 and early 20 centuries emerged in response to the perceived detriments of standardization linked to industrial machines and factory production. William Morris, one of the figureheads of this movement, designed the Red House to emphasize the designer's curation – the totality of craftsmanship – by exposing and exaggerating hand-crafted interior elements. This approach denied the benefits of engaging with non-human agencies.

The application of phygital fabrication celebrates craft *over* craftsmanship. The end goal is not the digital appropriation of human crafting techniques; it is, rather, the creation of an atypical craft that acknowledges and engages both agencies. In an alternative example of non-phygital design, the creative aggregation undertaken by Dennis Maher presents the results of accumulated labor over time in the absence of craftsmanship / design curation. The labor of phygital fabrication, however, is still meant to involve curation, so that the outcome evidences a deliberate awareness of the tools and techniques which have been applied to the work.

Despite also demonstrating digital residue (like the phygital fabrication process), parametric design is substantially a form-making workflow dissociated from material fabrication. By shifting forms, orientations, and/or colors, the physical index of material curation which is inherent to phygital design inherits traces of its digital counterpart, which may manifest as the result of an executable/economical fabrication solution. Parametric design, however, has not generally given priority to challenging design through crafting; rather, it has celebrated the formal (micro and macro) results of scripting language.

Phygital fabrication is a design-oriented methodology engaged as a deliberate curation of computer simulation. It is an exchange between physical fabrication techniques and digital simulation workflows. It unabashedly extols the collaboration of the human designer and the machine. Designers need to apply experience-based knowledge to the simulation process and then directly manipulate relevant variables. Computer simulation, when compared to 3D modelling tools, allows for an alternative approach to fabrication, particularly through the metric of time. The notion of time within simulation software is an abstraction; it is an elastic number which can be slid, stretched, paused, and reversed. Digitally simulated time is neither true time nor absolute time; it is a physical input (like gravity, illumination, and materiality) which is dependent on the understanding and curation of human designers. Without deliberate human engagement, the outcome of simulation (the nature of its relationship to time and space) presents as a meaningless visualization of calculated binary numbers.

Within the back and forth of translations from the physical to the digital, due to the limitations of software and hardware, the simulated design is inevitably 'optimized' to a legible digital standard, which is different from the absolute standard for material fabrications or constructions. Through the process of documenting, dismantling, simulating, restructuring, and making, phygital fabrication enables the atypical exploration of architectural tectonics, proposing new possibilities for formulaic materials, tools, and means of evaluation.

CONCLUSION

Phygital fabrication is an exchange between physical fabrication techniques and digital simulations. Due to the limitation of software and hardware, the simulated design is inevitably 'optimized' to digital standards, leading to an atypical outcome (when compared to a standardized physical precedent). After curating different sets of outcomes, the digitally fabricated piece becomes physical through an idiosyncratic exchange with fabricators or fabrication machines. Thus, phygital fabrication compels an endless physical and digital translational seesaw averse to synthesis. There are no procedural results from this push and pull, only byproducts. The physical project has a digital residue, and the digital project has a physical residue.

Phygital fabrication, in its digital presence, is not an image slapped on a digital surface; it has volume, weight, and material behavior. Since the energy required to produce material is a substantial factor in the raw material cost, the value of the phygital material has its own economy. The digital waste from the process is negligible. In its physical presence, phygital fabrication, while inheriting the tradition of the indigenous artifact, challenges the standards of fabrication techniques and used tools.

Phygital fabrication, physically manifested, carries deliberate traces of the digital workflow. The storefront presents the output of the aforementioned material exploration as a speculative consequence of digital optimization and limited hardware capacity, calling into question how the phygital workflow may influence the development of building materials and fabrication technologies as a speculative expression of the ever-changing interrelationship between people and machines (Figure 11).

Figure 11: Phygital fabrication exhibited at a storefront. Source: (Nero Chenxuan He and Fanglu Lin 2023)

Phygital design introduces new design possibilities through the exchange of digital and physical design mediums. The consistent and mutual interference by human and machine agencies is an established (albeit primarily unconscious) dynamic. Phygital design is neither the exclusive application of human intelligence nor total digital autonomy; it is the creative exchange of both agencies culminating in a deliberately unsynthesized design. It represents the spirit of an age before the synthesis of the virtual and the real, before VR glasses become VR eyeballs, before cyborgs or biomechatronics, or the augmented person.

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