Cyborg Craftsmanship
A Human-Machine Collaboration Future in Architecture

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Abstract

This paper begins with an analysis of "craftsman" and "tools." On the one hand, it explores computer algorithms as the core technology of simulation, iteration, optimization, and fabrication, which was significantly involved in and changed architectural design, research, and practice. Meanwhile, it also points out that the intelligent design and construction tools are continually enhancing the thinking, building, and organizational capabilities of the human body, further developing into various fabrication techniques under the human-machine collaboration in the future. It is where the concept of "cyborg craftsmanship" comes. The human-machine collaboration system will empower architects and the whole industry, liberating greater creativity and accelerating the architecture production system upgrading.

The digitalization process has dramatically promoted the comprehensive and accelerated evolution of human knowledge systems such as science, technology, and culture. Similarly, in the field of architecture, digital tools are fully integrated into the process of contemporary social production in the architecture field, including the continued expansion of the designer's thinking ability, and also involved in all production links from design to construction. When intelligent technology meets and merges with traditional culture, it is very urgent to rethink and imagine the future of architecture. On the one hand, starting from the historical context, reviewing the development of an architecture that once gave birth to the perspective of the historical view of technology, on the other hand, discussing the shifts of design and construction paradigms from the perspective of the relationship of artisans, tools, to name a few in material craftsmanship.

The Division of Architects and Craftsmen

During the Renaissance, Leon Battista Alberti (1404 ~ 1472) observed the emergence of "free-lance architects" in large cities like Florence. These phenomena prompted Alberti to summarize and theorize "Architecture" as a discipline. Architecture is, first of all, an idea shaped in mind, expressed by drawing, marking, and annotation, and then executed by the builders according to the picture. Alberti sees himself as the archetype of the architect, and this idea started to shape in *On the Art of Building in Ten Books*. The demand for architectural drawing also means an architect's career shifts from craftsman to draftsman. In the early Renaissance, Italian humanists realized the value of copyright attached to this intellectual

labor became apparent. On the one hand, the work model advocated by Alberti can be taken as a stereotype of the fundamental division of labor in the construction industry: unlike the role of the medieval craftsman, since the Renaissance, the thinker does not build, the builder does not think; on the other hand, the rise of the architects brings the corresponding degradation of the craftsman, then becomes a subordinate and downstream process of the design. The separation of design and construction also brings the separation of mind and hands.

Figure 1. Illustration by John Ruskin, The Seven Lamps of Architecture [M]. London: Smith, Elder & Co, 1849.

The division of labor and trivial work in the construction industry easily replaced by an industrial assembly line and a social industry situation in which deskilling appeared. In the late 19th century, The Arts & Crafts Movement led by John Ruskin (1819-1900), William Morris (1834-1896) and others started. In their view, the decline of handicrafts and the opposition of classes have caused social degradation. Industrialization and the large-scale use of machinery must be held accountable for this. Only retrospecting the traditions before the Renaissance can effectively resist the problems. However, Ruskin did not think that the medieval master-slave social relationship was worth emulating. The handicraft movement was proposed that "artists and craftsmen have the same interest in the quality of life and work." [1]

When machines are put into capitalist production on a large scale, "humans cannot do highly specialized work in a mechanized, automated, tireless, and inexpensive way. Sometimes machines do better." [2] We will find that industrialization has significantly changed architecture, because they redefine the purpose of the design and the process of construction, forcing architects to think differently than before. One of the essential characteristics is the adaptation to the logic of industrial production. It means operating with linear from design to construction as the standard, then the overall acceptance of the principles of material standardization. Design and construction must face limitations. It means that as people use machines, they integrate them into our physical behavior diagrams, which in turn shape our thoughts.

Despite more than a century, Ruskin's writing has always been the most thorough and critical reflection of the labor division and the relationship between man and machine. Now we are more and more aware that intelligent production follows the opposite production logic-not only large-scale batch production, but also differentiated customization. With the addition of parametric design tools and construction robot technology, the long-lost differences, deformability, and uniqueness of industrial standardization can be recalled to the perspective of mass production of buildings. The relationship between architects and construction is once again tight. Thinking from this, the digital design and intelligent construction technologies emerging in the

architectural disciplines today foreshadow a series of possible changes. They have many analogies with the transformations experienced in historical development, especially during the industrial revolution. How to define "craftsmanship" at the moment? How has the role of artisans changed in the digital living environment? It is also possible to rewrite the long-term separation between design and construction, which is the most crucial change facing the architecture discipline since Alberti.

Cyborg Craftsmanship

A Post-humanistic Perspectice of Technology Culture

Why bring up the topic of "craftsmanship" now? Because today's architecture seems to be standing again in fear of technology and division of labor similar to the late 19th and early 20th centuries. The difference is that this time, the discipline of architecture has experienced a crisis of highly differentiated and gradually isolated industries, and issues related to design subjects, methods, and tools worth rethinking. It is true that information integration tools such as BIM, which have become popular in recent years, can become an efficient working platform for designers, contractors, and agents of various parties. Besides, non-standard component construction can also be achieved through CNC tools. These characteristics are also Ruskin "the thinking hands" raised cherish. Nevertheless, can these technologies ultimately be called "digital craftsmanship"? It should say that these tools improve the efficiency of the communication of instructions between the design and construction division of labor. However, they do not provide more possibilities for creation. Machines are not only a tool of making but also a tool of thinking. From geometric and performance parameterization to construction parameterization, the overall deployment of design methods and processes the current digital environment tends to integrate the human brain with new tools such as construction robots to form an entirely new relationship. The improvement of human thinking, construction, and organizational abilities are different from the role envisaged by Alberti during the humanist period. The subject of design no longer confined to humans; machines have also become part of the subject. This characteristic of mixing organisms with machines commonly defined as "cyborg."

We might as well put forward the concept of "craftsmanship" under the condition of human-

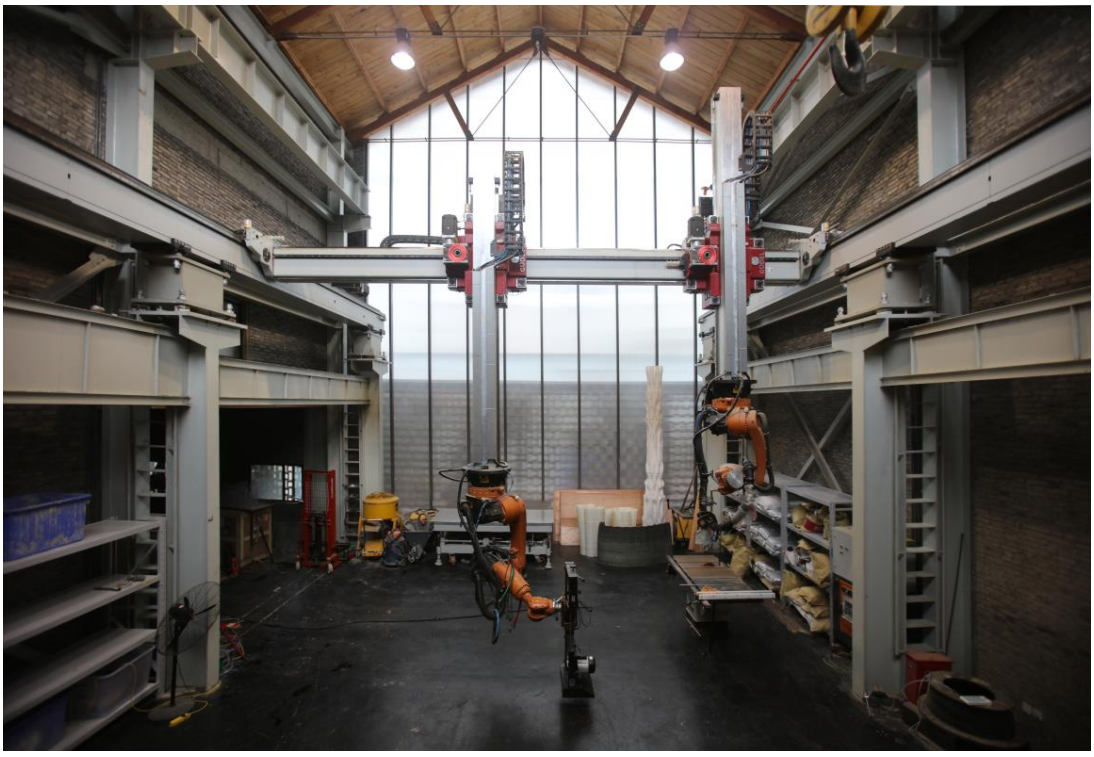

Figure 2. Robotic Construction Platform in Fab-Union, Shanghai.

machine symbiosis, and its premise is the parameterized cooperative relationship between humans and machines. This time we realized that the design subject had changed radically. The design method is different from the "design -drawing-build" process. The new relationship between human and machine determines the new "cyborg craftsmanship" mode. Through this collaboration, the object-centric and work-oriented working mode has undergone a fundamental change, with the parametric design and construction process itself become the source of creation. The application of digital tools is not limited to the integration of information and even directly extends to the creative work of construction robots. Through the organization of geometric parameterization, performance parameterization, and construction parameterization design processes, architects and small-scale architectural firms seem to be able to work more independently. The collaborative production model under the Internet of Things can allow them to compete with those large-scale design institutions or commercial cooperations. Of course, this view does not mean that we will retreat to the era of craftsmanship advocated by Ruskin. On the contrary, we hope that the "digital craftsman" can surpass the simple analogy of the hand and digital tools mentioned by the former and promote us in the present — the role of the architect in post-humanistic thinking a digital environment.

A New Working Model of Cyborg Craftsmanship

Architectural historian Robin Evans (1944-1993) once wrote, "Architects do not build buildings, architects only draw drawings of buildings."[3] For a long time, architectural drawings were the design intent. The most critical step between implementation and the subsequent notational system and drawing paradigm gradually evolved into a space design productivity. The architect's brain-synchronous thinking has become the core content of the representation. The role of architectural drawing is also questioned: there is a difference between the action of drawing and the cognitive mechanism of creative thinking. The latter emphasizes the creation of spatial relationships, rather than superimposing different information as in the drawing process. Second, although computer-aided drawing software has dramatically improved drawing's efficiency, it has not made any substantial impact on the design method, and its effect is limited to the digital communication of design intent.

One of the crucial reasons for this limitation is that the traditional design is object-centric. With the advent of the era of algorithms as the core language tools, parameterized tools can seamlessly connect the entire process of design to space construction. The evolution of this organizational form will become an entirely new type of productivity. It is also different from the earlier design intention-drafting-reproducing-building “process, using human-machine collaboration achieved through parametric design methods, re-establishing a new connection from” design intent to” building.” The final results are not predetermined. It starts from the design goals and is deduced step by step according to logic. Among them, Formation, Simulation, Iteration, Optimization, and Fabrication form an integrated workflow. For example, in 2017 and 2018, Digital Design Research Center of Tongji University and Fab-Union designed and constructed two robotic 3D printed pedestrian bridges. The optimal curve shape of the bridge outline firstly generated by the structural shape finding algorithm used in the forming phase; then in the simulation phase, according to the material properties (respectively modified plastics and metal), structural form and robotic printing process, the cross-section of the modified plastic footbridge are developed into the form of interlocking shaped units, and the metal footbridge designed into a continuous gradual space grid form; then, in the iteration and optimization phase, the introduction of more design determinants form a multi-objective design model, and then continuously feedback the prototyping process through simulation; finally, during the construction phase, the physical data of the 3D printing results reflected continuously in the digital model for comparison and detection, and then adjusting the unprocessed parts form, in order to keep the construction of error is always at an acceptable threshold.

In the integration process from design to construction, the data transmission between machines constitutes a networked feedback relationship between the various stages. At the same time, as the main body of design and construction, humans always maintain a symbiotic state with the machine.

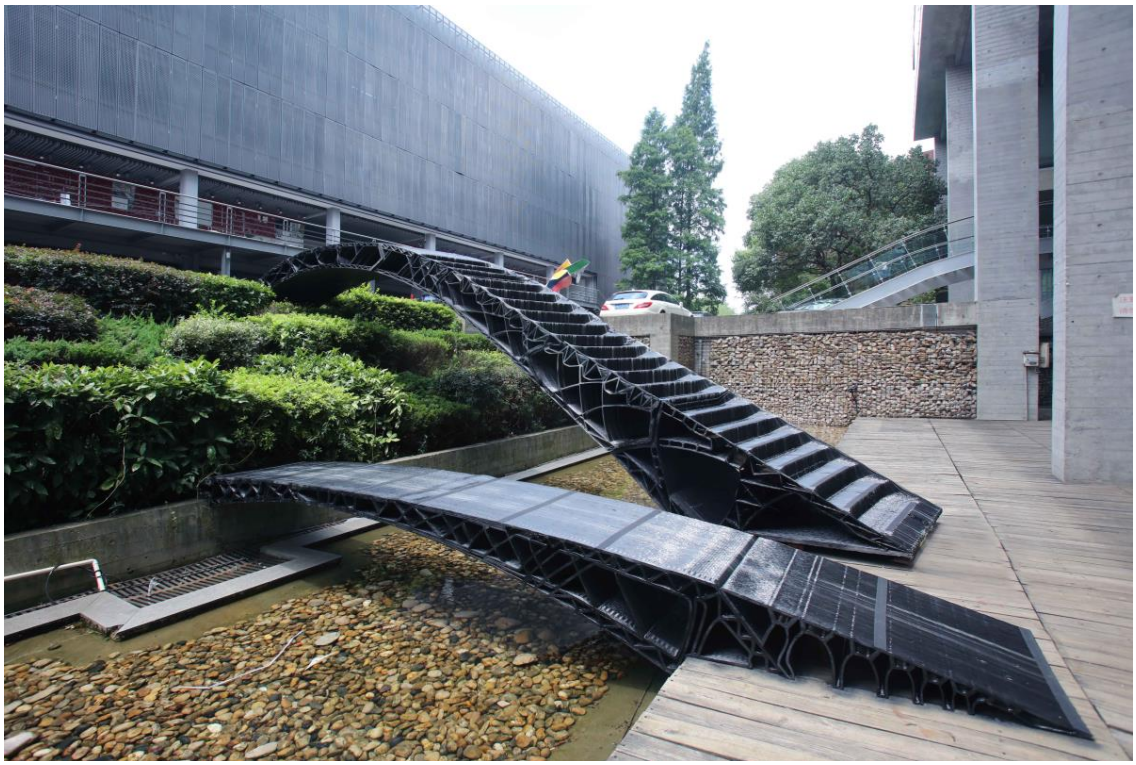

Figure 3. 3D Printed (Modified Plastics) Footbridge in Tongji University by DDRC&FabUnion in 2017.

Figure 4. Printed(Metal) Footbridge in Tongji University by DDRC&FabUnion in 2018.

Conclusion

Reducing or eliminating the steps of translation associated with the transition from design to fabrication allows the designer to embed intent into the process and, more significantly, dissolves the hierarchical chains of labor divisions prescribed by prevailing modes of production. The serial and highly compartmentalized processes and responsibilities that have calcified around the professional divisions of labor — architects, shop-drawers, fabricators, and builders with contractually distinct roles — serve only to reduce the possibility of innovation and invention through productive overlaps and feedback. Together with machines, individuals can engage from the start of the design process to realization with the aid of small-scale production of non-standard components, marking architecture's departure from repetitive, industrialized, and orthogonal design, which is also despised by John Ruskin at the dawn of industrialization. By taking this further, a utopian perspective can be deducted from this argument, that digital fabrication is associated with the idea of empowerment and even democratization. It is shaping not only the future of design but also the type of society that we eventually build and live. It again constitutes a contemporary critique of industrial production, only without a looking back attitude.

Back to the topic of "cyborg craftsmanship", when facing a comprehensive upgrade of the construction industry, man-machine collaboration opens up new possibilities for design and construction. This possibility is not limited to the high degree of synchronization between design and construction. It determines the starting point of architectural creation. "Cyborg craftsmanship" shows not only the improvement of design rationality and construction efficiency but also the attention to diverse and dialectical topics, including tools, labor, collaboration, material materials, traditional culture, so it is particularly urgent at the moment.

However, the future of architecture created by human-computer symbiosis is not without problems, and it shows no less complex than the hope it brings. Today, architecture has become a common practice. There is continuous participation in the design process from design software toolkits to specialized processes. The copyright attribute accompanying human-machine collaboration cannot be ignored. More importantly, when we focus on the new concept of "cyborg craftsman," the attention to designers is often accompanied by the neglect of the vast labor involved in the construction. At least in the construction mentioned above cases, there is still a considerable amount of workforce. It is invested in the construction process and forms a more elaborate production relationship. Should we equate the transformation of disciplines with the exchange of information between architects, computers, and robotics? The labor force has never disappeared from the real construction, but in the view of neo-Russianism, the designer often obsessed with the illusion of absolute control of the designer. The designer will occupy the position of the former craftsman, but this time will use numbers Enhanced "hands" to shape the world. Have we forgotten that human labor needs to fill the gap left by the machine for a long time? As philosopher Bernard Stigler once commented after observing the impact of technology on human beings: "Technology is the antidote to humankind, and it is also the poison of humanity. We need to be wary of the high level of technological development. We need to create a New technology culture to cope with the age of technology."

Endnotes

1. Isabell ANSCOMBE, Charlotte GERE, Arts and Crafts in Britain and America[M]. London: Academy Editions, 1978, 110.
2. Frank L WRIGHT, "In the Cause of Architecture," The Architecture Record, no.5, 1927: 394.
3. Evans ROBIN, "Architectural Projection", in Architecture and its Image: Four Centuries of Architectural Representation: Works from the Collection of the Canadian Centre for Architecture, ed. BLAU E, KAUFMAN E, EVANS R. Montreal, QC: Canadian Centre for Architecture, 1989 : 369.