Paradoxical Territories of Traditional and Digital Crafts in Japanese Joinery

While one can argue that a certain traditional craft such as Japanese Joinery should remain adhered to its processes, materials and methods, others could see potential possibilities that might be explored through applying contemporary technological advancements such as digital fabrication and engineered timber. This can only leave us with more questions than answers; what are the advantages and the possibilities? Does technology offer a "one size fits all" solution to any building material, or are there profound limitations? Where do we draw the line between traditional and contemporary craftsmanship?

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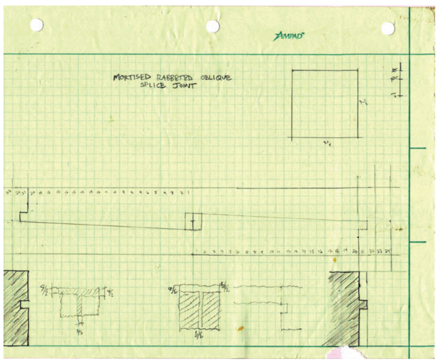
INTRODUCTION

When Torashichi Sumiyoshi and Gengo Matsui wrote their 1989 book titled *Wood Joints in Classical Japanese Architecture*, Computer Numerically Controlled technology (CNC) and digital fabrication methods as we know it today were still in its infancy. While Japanese joinery has traditionally been reserved for solid heavy timber, the increased use of both CNC and engineered timber (CLT, Glulam, LVL,..etc) as a sustainable material and an alternative to concrete and steel gives rise to number of interesting questions. While one can argue that a certain traditional craft such as Japanese Joinery should remain adhered to its processes, materials and methods, others could see potential possibilities that might be explored through applying contemporary technological advancements such as digital fabrication and engineered timber. This can only leave us with more questions than answers; what are the advantages and the possibilities? Where do we draw the line between traditional and contemporary craftsmanship? Two accounts may profoundly frame these questions; first Renzo Piano often refers to technology in architecture—and the term "techne"—as *the art of joining or the art of making things*.[1] Second, In his famous 1954 essay on technology, Heidegger explored the meaning of the word "technology," tracing it to the ancient Greek *technikon*, meaning that which belongs to techne (art, skill, craft in work). With reference to Piano and the fabricatore idea, Heidegger also makes two observations about techne: First, the word is applicable not only to the talents and skills of the craftsman but also to the world of the intellect and of the fine arts. Secondly, Heidegger says: "techne belongs to the bringing-forth, to poesis; it is something poetic."[2]

In this paper we attempt a contribution to the open-ended dialogue between traditional and digital fabrication through an experimental study investigated by students of architecture. Students were asked to study traditional Japanese joinery, in particular the work of Sumiyoshi and Matsui, and to select two wood joints: a splice joint and a connecting joint. The task was to recreate the same joints in full-scale with real wood materials and CNC technology. Instead of heavy timber, however, the students were to use laminated engineered wood composite. Through the process of understanding how a traditional handmade joinery could be created using digital fabrication, the students came to a deeper understanding of manufacturing processes and were also asked to record their experience through drawings and photography.

CHALLANGING TRADITION

In traditional Japanese architecture, it is common to use solid dry timbers to make structural members of major buildings and shrines. Through generations of expertise, the Japanese craftsmen became incredibly adept in building with timber construction and finding ways to establish a solid system of timbers without the use of nails or adhesives. The result of this tradition is an innumerable amount of wood joining techniques and connecting methods that were created in order to make their buildings stand even in areas of frequent seismic activity. The craftsmanship and skill of the Japanese in creating wood joints used in building construction surmounts almost any other culture today. In our experiment, we asked students to study traditional Japanese joinery methods and techniques, in particular the work of Sumiyoshi and Matsui,[3] in order to design new interpretations of the same joints that were used to connect large timbers within the construction of their buildings. Each student was asked to choose one splice joint and one connecting joint and recreate them with laminated engineered timber, but utilizing a CNC router to take the place of the skilled craftsmanship that students most likely would not have at the start at the experiment (Figure 1,2). This exercise was a provocative attempt to understand how using "computer numerical controlled" processes could have positive or negative impacts on creating wood joints as complex as those of traditional Japanese ones. While there were clear positive outcomes that resulted from the experiment, students were also given the opportunity to reflect on the conflicts that could potentially arise from trying to utilize CNC fabrication methods to create these joints along with the use of dimensional lumber as the base material.



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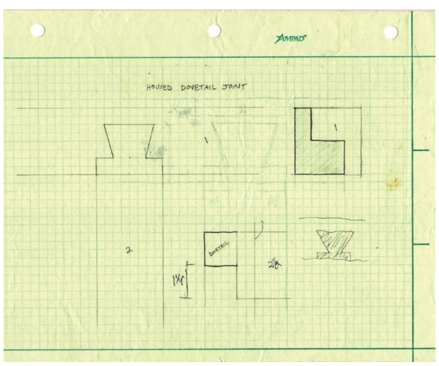

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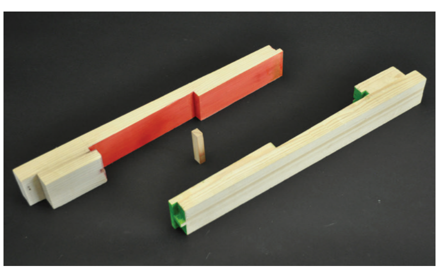

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Figure 1: Full scale drawings of a Mortised Rabbeted Oblique Splice joint *Kanawa Tsugi*

Figure 2: Full scale drawings of a Housed Dovetail joint *Ari Otoshi*

Figure 3: Final Mortised Rabbeted Oblique Splice joint *Kanawa Tsugi*

DIGITAL PRACTICE BETWEEN MATERIAL PROPERTIES AND INDUSTRIAL PROCESSES

It is invitable that once the mechanical technology driving computer numerically controlled tooling was able to mimic an uninterrupted Cartesian movement path, the standard of control and consistency became reliable. Mechanical reliability allowed the user to focus on what the tool was doing, instead of how it was doing it. Inevitably, the inventive focus on "what" ends with asking the question of "how." This two-fold relationship between conception and execution will never cease to exist. As the case with traditional practice, digital practice processes can be influenced by specific material properties and industrial manufacturing processes. These processes, relationships, qualities, and restrictions, along with time and mass, can be categorized as characters that attempt to understand what is and what could be. Typically, a theoretically infinite numbering system is utilized to quantify each part and how it influences the whole. This universal language of numbers, and how it is interpreted, is the foundation of the "what" and "how". Through numbers, anything can influence something.

Contemporary digital practice has inevitably allowed for greater capabilities of the manipulation of various materials. For example, wood and metal can be cut quickly and precisely through a CNC machines, and plastic particles can now be used to print in three-dimensions. It is important that designers test their ideas when working with industrial manufacturing processes to understand the limits of a specific material. Pushing the limits of materials ultimately open up new opprtunities in a way that has not been investigated before. The digital practice has certain limits, as technology must accommodate for material properties, which our students found in the experiment of making a traditional Japanese joinery using a digitized process. However, it is these limits that often encourage designers, engineers and manufacturers to explore further development in the field of digital practice. The physical properties of building materials have consistently influenced the practice of architecture during times of traditional production as well as in our own "digital age." Each material we use demonstrates specific properties that influence how they are manufactured, which in turn corresponds directly to the information we use for computer fabrication (Figure 3). For example, wood has appearance-type properties that include texture, grain, pattern, and color that influence characteristics such as machinability, dimensional stability, and decay resistance. Weight, shrinkage, strength, and other properties depend on the moisture content of wood, therefore influencing the industrial processes associated with manufacturing wood framing in standard sizes. It is clear that these engineering processes take into account the material properties. If this were not the case, timber construction would lack the structural strength required. Hypothetically, digital manufacturing allows for fewer deficiencies in materials, more precise material alterations, and easier, quicker production. While there are several benefits to employing digital practice in the support of industrial processes, our students found that computer controlled processes only have the ability to go as far as applying certain data input. CNC machines lack the ability to investigate and test materials and their physical properties further, which can hinder design by limiting it to systematic manufacturing. The research required to expand on our knowledge of these physical properties comes from working more directly with materials.

While experimenting with a 3-axis CNC machine, students quickly discovered its limitations. One, for example, is the depth at which the router can cut a block of wood. This limitation brought about two options in one of the experiments: create a shorter right angle tenon and mortise splice (kaneori mechiire) (Figure 4), or dissect the joint in multiple layers (using laminated process). This finding could help improve the digital practice by making it corresponds to advancement in laminated timber. For example, to create a larger format CNC to cut larger and deeper pieces or to create a better system to place the material that is to be cut. It would be beneficial to provide a way for the user to place the material in an exact position by locating the origin. Without an easy way to locate the origin, human error can lead to pieces that are not aligned (Figure 5). This will allow for a precise aligned cuts from both sides.

INFORMED DESIGN PROCESS THROUGH INDUSTRY COLLABORATION

While a "jack-of-all-trades" is often considered a master of none. The current "digital revolution," however, is changing our perception to this concept and raising critical questions about whether or not it even applies any longer. Current technological breakthroughs are starting to circumvent the time and dedication required to master certain skills. As technology advances, machines are becoming more integrated into the everyday lives of the public. The machine may become the master of all trades in regards to repetitive processes, specifically in computation and/or calculation and physical motion on a certain scale. Integrated practice currently advocates for architects, engineers and manufacturers all to be engaged in the same design conversation. Having diverse and comprehensive input from all stakeholders during the design process could arguably improve product innovation, quality, and efficiency. Typically, after the project designer has reached a concept, individual groups will begin to focus on their particular areas of specialization. It is not until all parties have approved the final iteration of the design concept that the product is fully realized. Professionally, it is important to establish a relationship between architects, engineers, and manufacturers. The architect needs to stay in close contact with manufacturers to learn what material options that will allow them to provide for the most innovative design solutions by utilizing today's state of the art products. Through such collaboration, the process gives engineers and manufacturers more opportunity to explore new ideas. Architects have the opportunity to inform the manufacturing process concerning efficiency and the minimal number of steps necessary to reach the final product. The architect can—and should –not only design the end product but also think about the way it will be built. This means that it is important for the architect to have knowledge about manufacturing and engineering in order to design with the process of construction in mind.

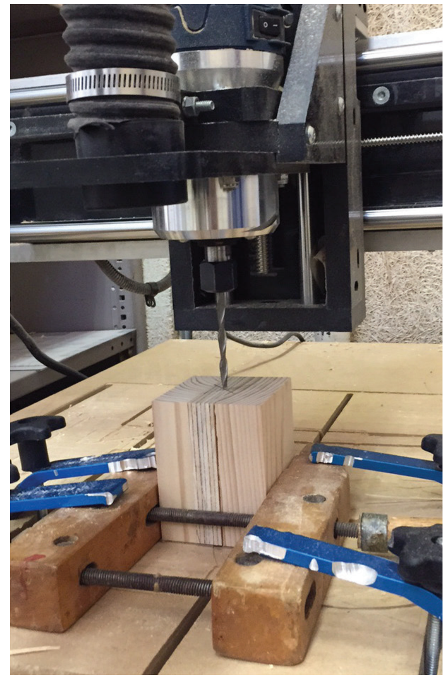
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Figure 4: Developing strategies for CNC router limitations

Figure 5: Alignment errors as a result of human interaction with the machine

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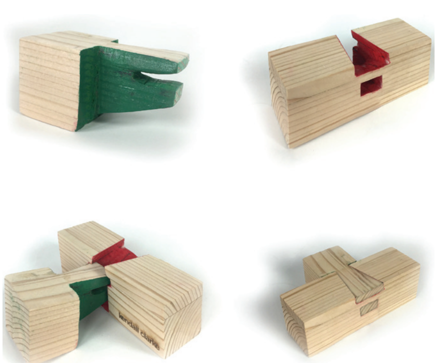

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Figure 6,7,8: Sumiyoshi double tenon transformation and manual alteration using a Ryoba traditional saw.

In our experiment, students had no option but to think deeply about how the joint would be constructed before they started building the computer model of the object then transfer it to the CNC machine to cut. For example, one student had to transform one of the angled cuts (Sumiyoshi double tenon) (Figure 6) into a blunt end because of the limits of the router diameter. In order to get the angle she needed to make up for what the CNC could not reach with its router, she needed to add a deeper incision by hand using a traditional Japanese saw (Ryoba) (Figure 7). Her solution was to construct a void in the female piece. The wood piece-had to be split in two in order for the router to cut these hard-to-reach places. If she were to design a new joint, it would be important to think about the manufacturing process of timber lamination and avoid extra steps (that is, increase efficiency) by designing specifically for the capabilities and limitations of the CNC machine (Figure 8).

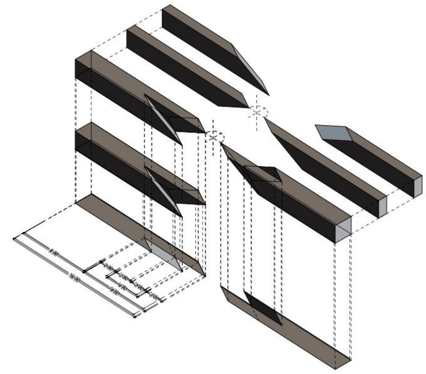
UNDISCOVERED DESIGN POTENTIALS

The advancement of rainforced concrete as we know it today goes back to Francois Hennebique, who left contracting to focus on the engineering and design of structures, ultimately creating a revolutionary technological development in construction systems. His achievement blurs the distinction between construction and engineering because, while he was not trained as an engineer, he was able to patent one of the first modern reinforced concrete construction systems that is still widely used today.[4] Such potentials may be exposed through the exploration of cross-disciplinary integration. Architects working with technology to manufacture timber joints, for example, will ultimately make new discoveries. For example Shigeru Ban's recent Tamedia office building in Zurich. These insights may include the benefits, challenges, and limitations of using technology such as computer parametric programs that inform a CNC router to cut timber joints originally designed to be made without the use of digital tools. Arguably, a benefit of using the CNC router is its potential to be precise with cuts than a human hand. However, the round bit that the CNC router uses limits the interior timber cuts and requires rounded corners, a technique not exalted in early Japanese joinery design and construction. These challenges may lead the designer to suggest ways of repairing the unwanted rounded edges. Our students found that the joint could be modified to celebrate the technological deficiencies, or it may lead the designer to discover new means of cutting through materials with digital technology. Through experimentation with the other disciplines related to architecture, one may discover new design potentials. As technology progresses in tandem with population increase, one can deduce that design potentials and breakthroughs are also on the rise. Within the industry of design and construction, technologies such as CNC routing, laser cutting, and 3D printing have been of interest. None of these technologies, however, have yet been able to make a significant impact on current mainstream construction practices; rather, they have been limited to educational institutions. However, custom manufacturing processes for architectural projects have been proven to be a prudent method of designing and building to suit a specific client's needs. Future design/build processes may implement digital fabrication and automation in a more regular and cost effective manner with construction. Currently, technological advances in computation and software have exceeded developments in building material technology; therefore we are unable to unleash the undiscovered potentials without a new reliable building material to influence future design and construction practice. We have yet to invent a primary building material as compelling and as useful as steel, timber, or concrete, apart from the myriad of available building "skins" that currently influence aesthetic and weather barriers. Just as Hennebique patented one of the first techniques in developing modern reinforced concrete, architects also should perform their own analyses to find innovative systems that they can incorporate into their projects and enhance the profession as a whole. A great deal of this innovation will stem from the advancement of technologies such as CNC processes, some of which our students were exposed to during this experiment. These new trends will not only make the architecture and construction process more meaningful, but will also allow us to reach aspects of design that were not feasible in the past due to time constraints or structural capabilities.

PROVOKING NEW MEANINGS IN MATERIALS AND FABRICATION

As discussed, technical challenges and limitations ultimately lead to new developments in materials and fabrication that would not have otherwise been discovered. Designers thrive in an environment that presents them with limitations, and it is through these limitations that innovation is born. Utlizing computer modeling and CNC machines to manufacture Japanese joinery that were designed to be cut by hand at first seemed like it required little to no “mind work”. The assumption was that computer would do all the necessary computations and adjustments as long as the joint was modeled and drawn in 3D. However, several challenges presented by the CNC process which forced the students to make certain decisions about the joint while not compromising its overall integrity. These design decisions would not have been made had these challenges not existed. For example, one student challanged the traditional Miyajimi Splice by introducing complex miter that allowed the joint to be stable in multiple axis (Figure 9). After figuring out the proportions and understanding the geometry, he diseccted the joint in bilateral symmetry (Figure 10). The student found that the 3 axis mill could not perform under cutting and therefore he had two options; first was to horizontally slice the joint in accordance to glulam construction, second cut then laminate instead of laminate then cut (Figure 11). The final joint provoked new meanings through fabrication and introduced a poetic tectonics in construction (Figure 12).

The experiment was a profound reflection of the industry as a whole, especially in terms of creating building assembly with the aid of digital practice. For operators with little knowledge of wood craftsmanship, it was helpful to be able to use the CNC router in order to make the precise cuts that were necessary to create the joints. It is also a time-efficient method to utilize when one needs to make repetitive elements for mass production. Once the resources are in place for the CNC, it is just a matter of cutting each piece with automation and the focus can be on other portions of the project to make the construction more time efficient. The use of the CNC then streamlines the construction process and ensures that there are as few mistakes as possible, which saves time and money. However, an understanding of the nature of materials can be lost. The downside of using the CNC process is that in most instances, there are parameters that are involved with the machine that limit some of what it can do. For example, unless one has a 4 or 5-axis CNC machine, one can only utilize the process to cut from one direction. This is acceptable when the user only needs one side of the piece to be precision cut; however, in most cases, both sides of the object must be cut in order to complete it. The issue becomes problematic because one would have to make the first cut, and then flip the material in order to cut the other side. This takes away from production time and also opens the window for mistakes to occur if the material is not aligned perfectly or rotated into the correct position onto the cutting table. This observation also applies to many other construction processes which seemed that not all of the processes could be completed solely using the assistance of computer numerical controled processes. Each student first had to make the cuts with the CNC machine and then adjust or modify the joints by hand in order to take off the rounded edges that were made by the router bit in the CNC machine. Also, some students had issues with the material moving on the router table because it was not anchored down sufficiently or because the CNC malfunctioned and cut a wrong [path] in the material, resulting in the need to either re-cut the piece or simply cover it up when re-cutting was unfeasible. With this experamint, students were able to utilize the CNC router to understand how a newer fabrication method might be able to expedite a process that from its beginning has always been done completely by hand. In creating a Japanese wood joint, students were able to use the CNC to make the precise cuts that were



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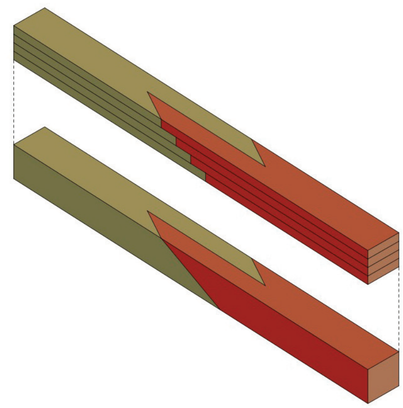

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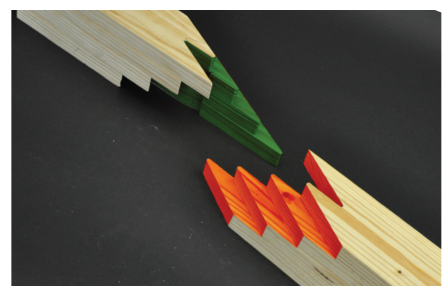

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Figure 9,10: Miyajima Splice proportions, bilateral symmetry dissection and CNC modification (Traditional vs. Contemporary)

Figure 11,12: Final modified Miyajima Splice laminated after cut instead cut after laminate needed to make a tightly fitting wood joint. In the past, it would take years for a Japanese woodworker to acquire the skill and precision to make these joints by hand. What students learned, however, is that while the CNC made the required cuts that were needed, each joint still needed to be adjusted and modified by hand tools to ensure that the joints fit the way they were intended to. The CNC would leave rounded edges on all the cuts because it utilized a rounded router bit. This was not the fault of the CNC; it was just the nature of the tool. What one comes to understand is that while the tools of modern technology might be utilized, the nature of each tool might not be equipped to do the intended work.

CONCLUSION

Our students found that progress is made through a series of trial and error attempts. The more something is explored, the more we learn how those particular processes failed. Students had the opportunity to find the greatness and faults in particular systems and devote time to experiment with ways to make them better. It was a true learning opportunity to explore ways of using the CNC to create structural joinery and see the benefits and drawbacks of different methods of construction. From their experience with this project, they observed how the CNC could make precise cuts in a way that they could not achieve without years of practice. However, they found issues in the way the CNC makes particular cuts and how the linear aspect of a router bit cannot possibly get into every detail of a complex joint. It could be argued that the 4 or 5-axis CNC routers or robotics is the solution to this issue, but that is reserved for yet another attempt at making Japanese joints with CNC technologies. Design research was informed through our students' materials investigation, which certainly will influence their design decisions. Moreover, technological and digital preconceptions were being challenged and the dialogue between materiality and manufacturing processes takes on an in-depth understanding of the relationship between structure, construction and tectonics.[5] Our current architectural education model is in desperate need for real collaboration with manufacturers and industrial designers. Modern history tells us that both the Ulm and the Bauhaus schools advocated for a parallel education between architecture and industrial design. It is through this proximity and synergy that architectural education cultivated the culture of making and began to influence industrial processes—precisely what we attempted to explore in our experiment. Today, students learn differently with new knowledge and tools from the industry available to them. Having access to Computer Numerically Controlled machines and other digital fabrication technologies is essential to the process of questioning industrial processes and testing them. Design potentials, as our students discovered, stem from real exploration with materials and machinery. Through an education that is immersed in the culture of making, students can reshape the field by producing new knowledge, which often times is related to mass production in the industry. It is important to integrate both traditional and technological knowledge within our educational curriculums and design studios and challange students with real provocative questions on their propositions of architecture. In this way we can encourage the techne (art, skill, craft in work) they will need in the bringing forth (poesis) of the future.

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