

# Traditional Wood Joint System in Digital Fabrication

Kenji Kanasaki<sup>1</sup>, Hiroya Tanaka<sup>2</sup>

<sup>1</sup>Keio University, Japan., <sup>2</sup>Keio University, Japan

<sup>1</sup><http://web.sfc.keio.ac.jp/~kenji915/wordpress/>, <sup>2</sup><http://fab.sfc.keio.ac.jp/>

<sup>1</sup>[k.kenji.0915@gmail.com](mailto:k.kenji.0915@gmail.com), <sup>2</sup>[htanaka@mva.biglobe.ne.jp](mailto:htanaka@mva.biglobe.ne.jp)

**Abstract.** *Tugite and Shiguchi are traditional architectural techniques of Japan, which connect materials without the use of nails or adhesives. Tugite is a technique to connect materials to augment the lack of length of available materials. Shiguchi is a technique to connect materials at an angle. With a firm basis in this tradition and the craftsmanship involved, we are aiming to apply these traditional joining techniques in digital fabrication. We expect that the application of Tugite and Shiguchi will refine digital fabrication methods and that the value of Tugite and Shiguchi will be rediscovered in the era of digital fabrication. This research was conducted in three steps. The first step was to research all patterns of Tugite and Shiguchi to define its foundation and typology. The second step was to modify Tugite and Shiguchi shapes to allow application in a digital fabrication environment, and also to add functionality. The third step was to create Lego-sized blocks with Tugite and Shiguchi to verify their applicability outside of the field of architecture.*

**Keywords.** *Traditional wood joint system; digital fabrication; joint without metal.*

## BACKGROUND

In recent years, 3D printers, CNC milling machines and other digitally controlled machining equipment as well as digital fabrication equipment have become increasingly less expensive and more compact, expanding the horizons of manufacturing. This change has created a new manufacturing culture in which instead of mass production, users can create their own goods through personal fabrication.

On the other hand, as machining equipment becomes more compact, the output range limit of the equipment becomes less forgiving. Therefore, when creating an object over a certain size using small machining equipment, it is necessary to output these objects as multiple components and assemble them, making joining techniques for assembly an important aspect. However, current joining methods used in digital fabrication include adhesives or

extremely simple shapes of adjoining pieces, leaving much room for refinement.

Traditional Japanese architecture has in its tradition, culturally and technically refined joining techniques known as Tugite and Shiguchi. These joint systems have a lot of types. Figure 1 shows typical shapes which often exist.

These techniques include hundreds of joining methods and the artisan carefully decides on the assembly order and usage location, creating structures with enough rigidity to withstand use as works of architecture. Such organic joining techniques are non-existent in the field of digital fabrication. We believe that the application of these techniques in digital fabrication will promote expressive horizons of assembly methods and expand the possibilities of digital fabrication.



Figure 1  
Typical traditional joining techniques.

## CONTRIBUTION

Tugite and Shiguchi are currently held as tacit knowledge among artisans. By generalizing this knowledge and making digital fabrication possible, these techniques will be opened up as common joining techniques.

## ABOUT TUGITE AND SHIGUCHI

### *Joining Techniques*

Traditional Japanese architecture uses Tugite and Shiguchi, a joining technique that is advanced from a cultural and technical viewpoint. Although joining techniques with similar shapes also existed in Germany and its surroundings where wooden architectural structures have been built traditionally, German techniques readily use nails and adhesives. Japanese techniques, due to a tendency to prioritize appearances and due to geographic conditions, developed into joining techniques that do not utilize metals or adhesives. While Tugite and Shiguchi are both techniques to join materials without the use of nails or adhesives, Tugite is a technique to augment length where materials are insufficient in

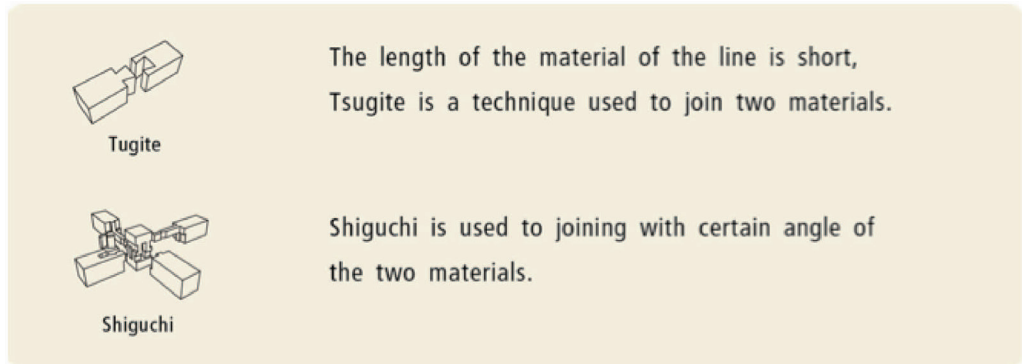
length, while Shiguchi is the technique used to connect materials at an angle (Figure 2).

### *Basic Shapes*

Only counting shapes that have been identified, there are around 200 types of Shiguchi and Tugite formats. From these many types of Tugite and Shiguchi, artisans select the single applicable type that has the appropriate function for their particular usage. At a glance, these techniques appear to be selected by the artisans using experiential knowledge, but they are actually selected using the concept of basic shapes. Tugite and Shiguchi are said to be composed of 10 to 20 types of shapes with one or two functions called basic shapes (Figure 3). Using these basic shapes, artisans consider the required functionality for the location where Tugite or Shiguchi are used, and fabricate the most appropriate shapes by combining basic shapes that fulfil these functions (Figure 4).

For example, *koshikake-aritugi* is fabricated following the process described below. First, functionality is considered based on the usage location. Here, we assume that a joint must have resistance in

Figure 2  
What are “Tugite” and  
“Shiguchi”?



the direction of gravity and the direction opposite the joining direction of the materials. In order to fabricate a Tugite and/or Shiguchi joint that fulfils these criteria, we must first select the *koshikake*, a basic shape with resistance against the direction of gravity and the *aritugi*, which resists force in the direction opposite to the joining direction. By combining these two basic shapes, *koshikake-aritugi* is generated, which is resistant to gravity and force applied in the direction opposite to the joining direction (Figure 5).

## APPLICATION IN DIGITAL FABRICATION

### *Joining Techniques Generating Function Through the Combination of Basic Shapes*

Tugite and Shiguchi are both originally joining techniques used in architecture. Therefore, these joining techniques are based on conditions specific to architecture. For example, in architecture, the materials

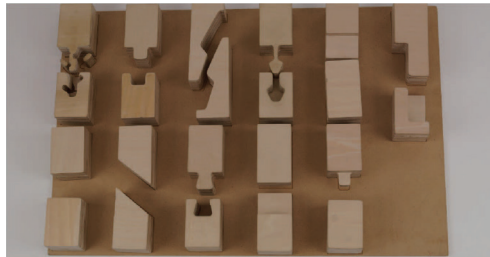
themselves have significant weight, so joining methods can utilise the weight of the materials themselves. Also, there only exist joining directions required in architecture, so there are no diagonal joints or other joints not required for architectural uses.

In other words, conditions for usage change in applications outside the field of architecture, and functions required of the joining technique changes as well. Therefore, Tugite and Shiguchi must be augmented with additional functionality to match conditions of the field of application.

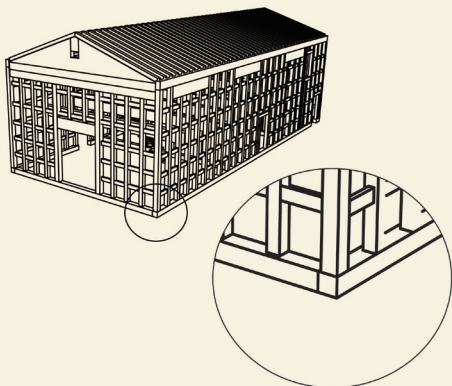
As explained above, the functionality of Tugite and Shiguchi is generated by combining basic shapes. These generation methods were carried out by only combining basic shapes with functionality requisite for architectural uses. Therefore, by using basic shapes that were not combined before, Tugite and Shiguchi with new functionality can be generated. For example, in architecture, joints with significant strength are required, but applications in other fields may require Tugite or Shiguchi that are less strong, but with a high degree of freedom. In this case, the following process is used to fabricate Tugite or Shiguchi with new functionality.

There is a basic shape for Tugite and Shiguchi called *hozo*. It is weaker than other shapes but has a higher degree of freedom. By combining this basic shape of Tugite and Shiguchi, Tugite and Shiguchi with a high degree of freedom can be generated (Figure 6).

Figure 3  
Basic shapes of “Tugite” and  
“Shiguchi”.



Building where traditional techniques are used



Joints with a similar functionality

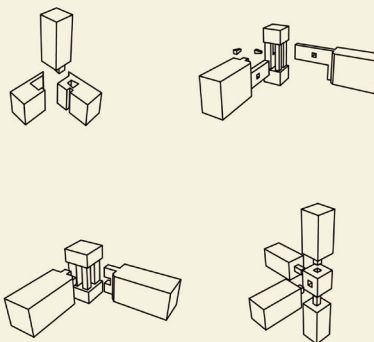


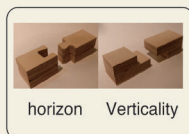
Figure 4  
Selection process.



Think



select

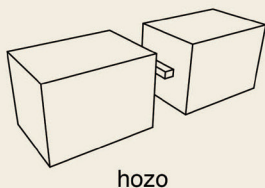
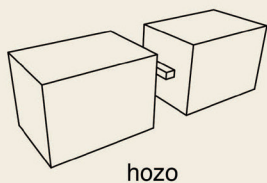


composition



Figure 5  
How to fabricate "Tugite" and  
"Shiguchi".

Basic Shapes



composition

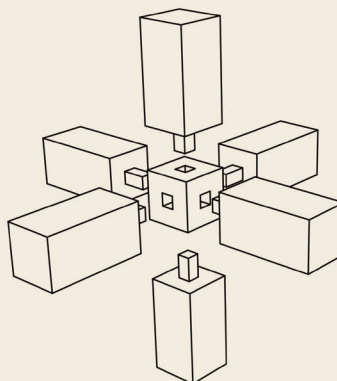
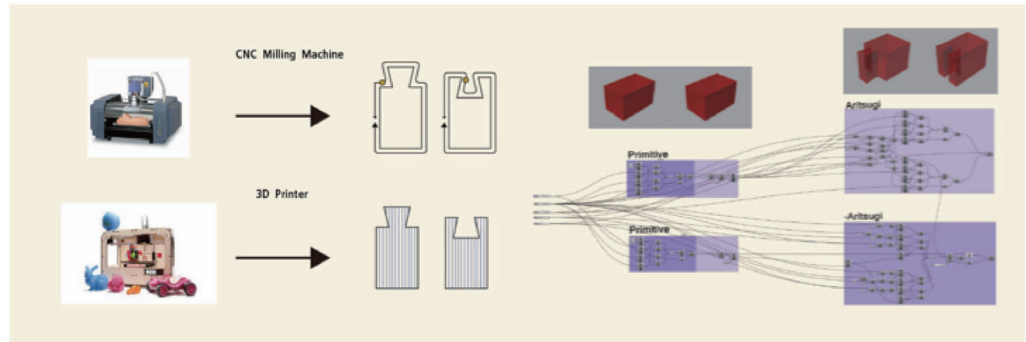


Figure 6  
Generating function.

Figure 7  
Machine feature, parametric modeling.



### **Fabrication in a Digital Fabrication Environment**

Tugite and Shiguchi were originally handmade by artisans. When fabricating via digital fabrication, there are cases where the characteristics of a machining facility may prevent reproduction of handmade shapes, requiring a change in shape. With a CNC milling machine, the milling tool diameter may generate rounded corners and the machine vibration will create slight fluctuations in the cutting surface. With 3D printers, the slight thickness of the filaments will cause the shape to be slightly larger than the data. These characteristics of machining equipment may vary based on machine performance and the external environment, which does not allow for a single optimal shape to be defined. Therefore, Tugite and Shiguchi which are specific to each machining equipment must be generated. We have fabricated a parametric model for Tugite and Shiguchi, and put in to use software that can alter

shapes freely according to the machining equipment (Figures 7 and 8).

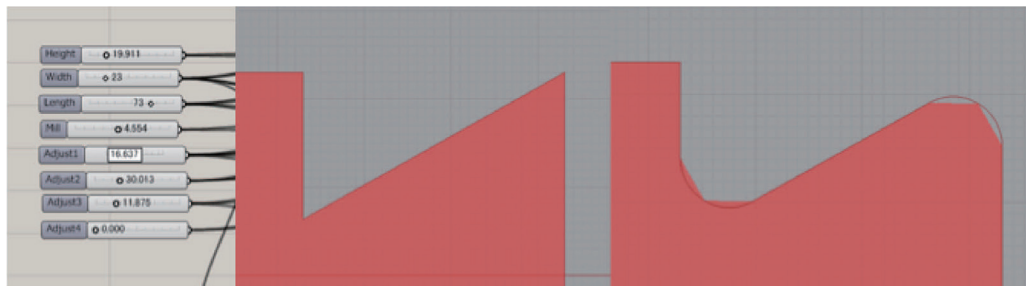
### **APPLICATION**

#### **Blocks**

Up to this point, we have described generalization methods for Tugite and Shiguchi. Here, we use this method to fabricate blocks with Lego block-sized Tugite and Shiguchi joints, and consider application of these techniques to toys.

We fabricated blocks that are able to form grids that can express three-dimensional shapes. Also, just as Tugite and Shiguchi were utilised in consideration of beauty and strength, the blocks were also given these characteristics. In core locations of the structures, joints with a high degree of strength were used, and where ease of assembly is highlighted, blocks with more freedom and less strength were used, thus making it possible to fabricate

Figure 8  
Shape change for CNC milling machine.



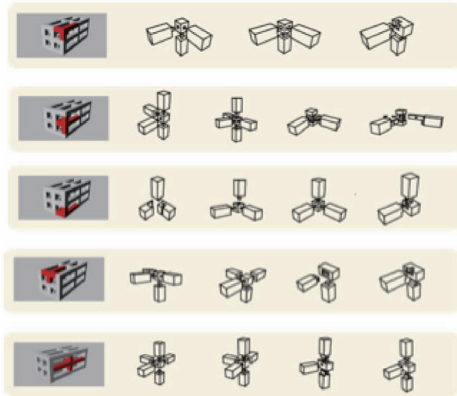


Figure 9  
Systematization of joining  
technology for block.

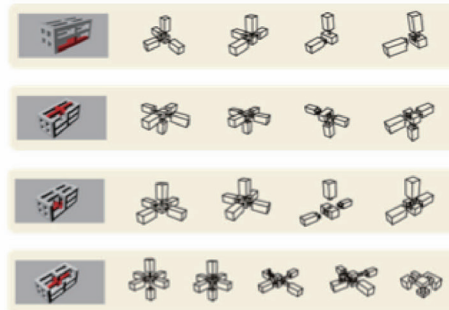


Figure 10  
Fabrication.

blocks with strength (i.e., less likely to disengage) and freedom.

### **Generation of Functionality, systematization and Fabrication**

As Tugite and Shiguchi with such a degree of freedom were non-existent in architectural uses, they must be newly created.

There is a basic shape for Tugite and Shiguchi called *hozo*, which is relatively weak compared to other shapes and which has a higher degree of freedom. By augmenting this basic shape, Tugite and Shiguchi with a high degree of freedom can be generated. By generating blocks by combining basic shapes of Tugite and Shiguchi, a new Tugite and Shiguchi joint system that combines strength and freedom was created (Figure 9).

The shapes have been categorized based on joining directions for creating a grid, and these categories have been further classified according to strength and freedom. Using parametric modeling, we have altered these shapes to allow digital

fabrication of these shapes. We used CNC milling equipment and 3-D printing equipment to fabricate Tugite and Shiguchi blocks (Figure 10).

### **FUTURE WORKS**

By fabricating toy blocks in this case, we have focused on applying the characteristics of Tugite and Shiguchi outside of the architectural field. In the future, we would like to apply this technique to fields with clear functionality requirements (such as tools and furniture). Further, we are considering software applications that automatically allocate Tugite and Shiguchi blocks from 3-dimensional data (Figure 11).

### **REFERENCES**

- Daiku Dogu kenkyukai, 2011, *Technique of traditional joint*, Japan.
- Kiyoshi Seike, 1979, *Japanese joining techniques*, Japan.
- Shinzo Togashi, 2010, *Traditional joining techniques of wooden building*, Japan.



Figure 11  
System for blocks.



