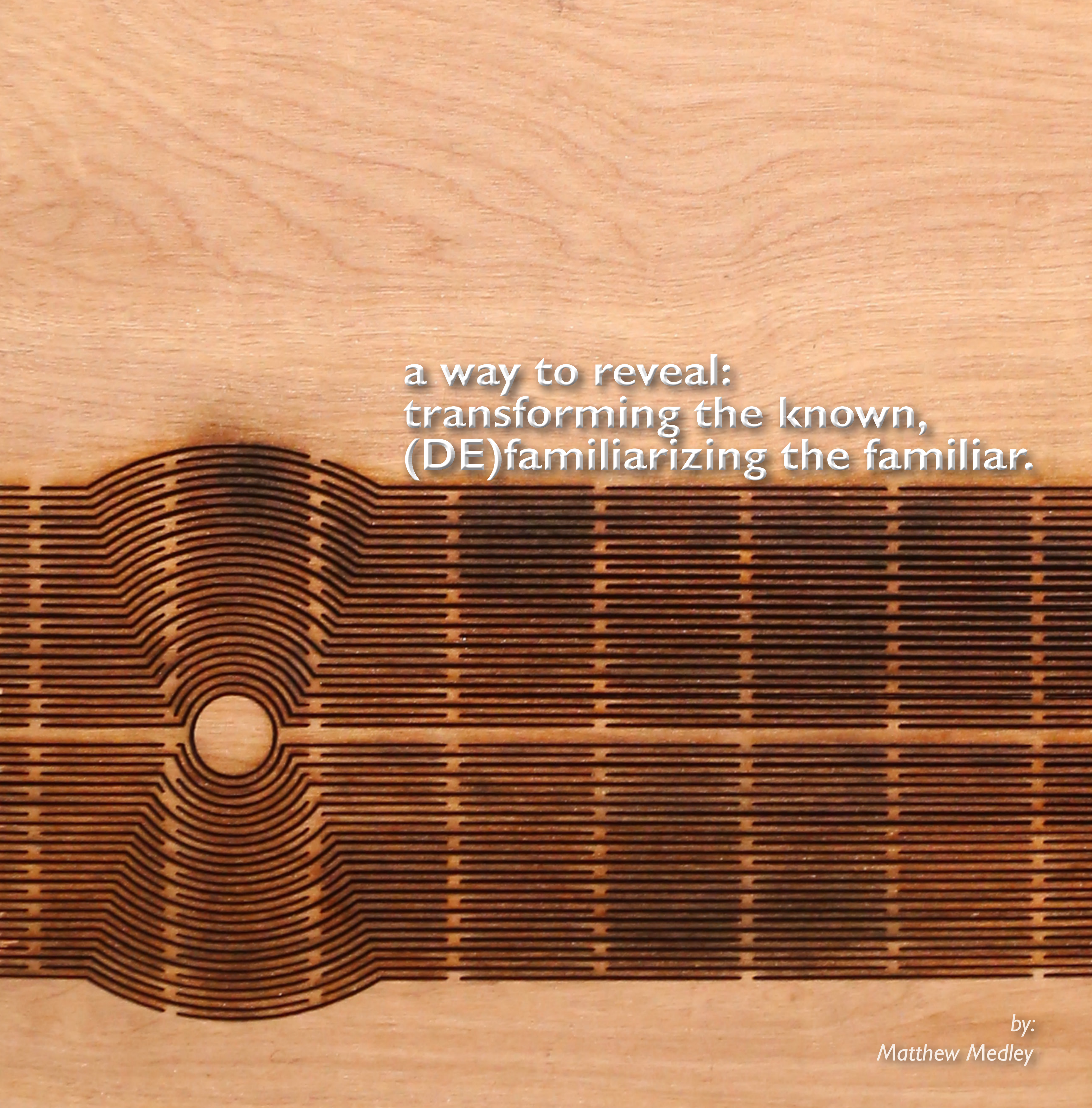

a way to reveal: transforming the known, (DE)familiarizing the familiar.

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2015 - 2016
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"Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand."

-Albert Einstein-

Design intelligence: "Making becomes knowledge or intelligence creation. In this way of thinking and doing, design and fabrication, and prototype and final design become blurred, interactive, and part of a non-linear means of innovation."[1]

-Michael Speaks-

1. Speaks, Michael. *Design Intelligence and the New Economy*," Architectural Record. January 2001. Print.

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Chapter 1
Introduction

The exploration of materiality is a key part of this research, viewed from multiple perspectives. As Peter Zumthor wrote in his essay "A Way of Looking at Things," materials play a role in creation of an architectural atmosphere. He describes the material quality of the work of another artist as "precise and sensuous" which illuminates why materials help to shape our experience of a space. Zumthor says that "materials themselves are not poetic,"[1] but that they can gather meaning and power. This work strives to create that same rich, layered experience, which is full of mystery or wonder, in the spaces and forms created, while reflecting how materials that fill them add a certain tangibility, acoustic quality or other specific meaning.

This thesis will focus on the place where concrete materials are "assembled and erected . . . [and] becomes a part of the real world," looking at the creation of forms in a context of the limitations and opportunities of new technology to intersect with craft and tradition

This study has been an exploration of how modern technology can be used in traditional and non-traditional ways to transform materials. Both traditional and non-traditional joints create a static connection, one that if done correctly has limited, if any, movement. Can we use modern technology as a way to explore something more dynamic, something that isn't fixed? How will this transformation change the way we think of the material?

Beginning with case studies on industrial forms and precedent studies on Japanese woodworking and digital fabrication, this thesis ruminates on myriad opportunities to make the fixed fluid. Incorporating research and theory into an extended exploration of materiality and making, this study illuminates the creative process and shows learning done through play, prototyping, extension and production. Although it was not possible to capture every iteration in this book, it captures the processes followed, the tools used, the ideas awakened and the lessons learned.

1 Zumthor, Peter. *Thinking Architecture* "A way of looking at things". 3rd ed. Birkhauser Architecture. 7-26. 2010. Print.

Chapter 2
Deconstruction - case studies

The path to assembled materials and erected forms begins with the ideas, feelings, and needs that will be given shape in the concrete world. This process of production is removed from the direct experience of many in the 21st century, and so this examination of materiality and its intersection with craft and technology begins with an exploration of how things are typically made. Identifying the constraints that packaging and cross global shipping place on the design of things, particularly things intended for a large consumer audience, was part of the first step of "deconstruction". An initial set of case studies focused on "the Box," a ubiquitous element of the current marketplace, and the Intermodal Shipping Container.

The Intermodal Shipping container revolutionized the way goods are transported. As Marc Levinson puts it in his book, The Box: How the shipping container made the world smaller and the world economy Bigger,

"This standardization of a container changed the way the United States would do business. Its original intent was to increase shipping reliability. However, it had a much larger impact, as it would change the global economy."

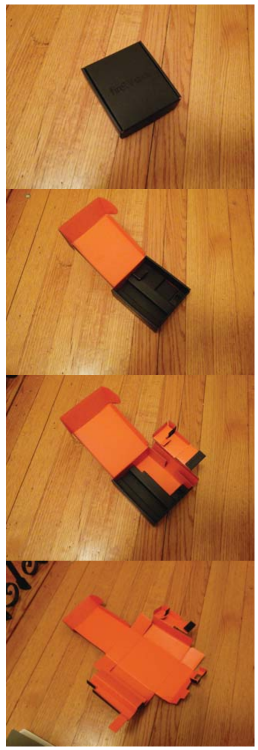
Shipping containers and the boxes in them have caused a shift in the way our goods are delivered, what we consume and how we value packaging. The packaging has become more than just an outer shell to the product. That is just one layer. When the item is shipped it often comes in multiple layers of protection, most of which are one time use only items.

The Box

Basic Cardboard Container

Things to consider:
Uses more resources
Takes up more room
Abandoned
Large
Throw away
Potential for many uses
Easy to transform
Cheap
Can hold a lot

Designed Cardboard Container



Things to consider:
Confined
Appreciation
Complex
Small designed box
Designed
Playful
Single Purpose
Throw away

Wooden Container

Things to consider:
Designed
Thought
Value in material
Made to last at least as long as contents
Value in quality
Reuse
Homeostasis

This case study examined a number of questions

* What becomes of this box? Could there be value found in this cardboard?

* What happens when a container is designed?

* What value is there when the container is made of a different material?

* What if it is well-crafted?

* Is there a inherit perception that one container is better just because of its size?

This experiment looked at the size and the materials of containers and what is involved in deconstructing these containers. This investigation included research on the economics, history, and science of this industry, as well as a hands-on material deconstruction of many different types of boxes. It was determined that varying approaches to packaging were linked to differences in valuation as well as in outcomes.

The production of the box adds value to a product, but results in waste, and commonly the cost associated with that waste is increasing, as the expense of design, materials, inks and other inputs goes up in alignment with the value of the item. This case study showed that this packaging could be viewed as raw material for new design purposes and that more thoughtful front end design could limit the negative impacts identified, including waste and other social and environmental impacts. This opened up new questions about how to better align methods of transporting goods with storage and design.

The Container

The second related case study emerged from this initial work. Here the focus was on shipping containers themselves, their purpose, structure, and economics. In this case study, attention was also paid to the many architectural responses to the excess number of shipping containers in the United States and possible uses for them. The question of re-use of these containers as housing was considered, but not in the typical way.

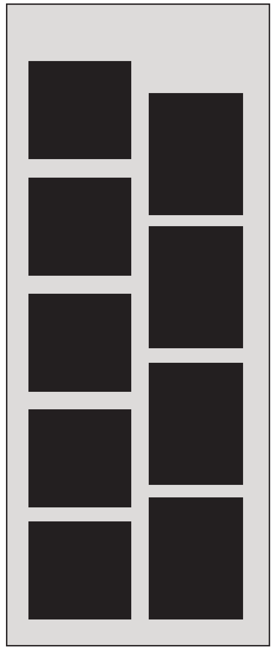
The shipping container is designed for the following purpose: easy delivery of goods between markets. Its size and shape and materials all derive from this. It is made to be easily moved from ship to rail to semi-truck.

Many of the common architectural responses to the container issue is that they are strong and quick to put up as shelter. However, many architectural responses do not consider that the strength lies in the vertical stacking. Cantilevers, overhangs and openings in the corrugated sheet steel change this, and so when these treatments are required, additional reinforcements must be added.

Investigation of the valuation of the materials used in a shipping container raised some important questions: The container is made of steel and wooden floors. Both are treated with toxic items to make them last longer. Could they be made with a shorter lifespan in mind? Another direction in this research shows that perhaps the metal could be melted down and down cycled. According to Lloyd Alter's article *What's wrong with shipping container housing? One architect says "everything."* a typical 40 foot vessel contains enough steel to make roughly one thousand eight foot metal studs.

These findings led to the idea of unfolding or deconstructing. Could containers be deconstructed for use in other architectural ways? One conclusion from this study is that a more open ended approach, which involves new design of these spaces to allow for greater secondary or tertiary use is critical. This is an important question, and the basic idea of re-imagining a common item would carry forward to become the central focus of this study.

Intermodal Container



Wasted space

The Shipping Container:

"A soulless aluminum or steel box held together with welds and rivets, with a wooden floor and two enormous doors at one end: the standard container has all the romance of a tin can. The value of this utilitarian object lies not in what it is, but in how it is used. The container is at the core of a highly automated system for moving goods from anywhere, to anywhere, with a minimum of cost and complication on the way. The container made shipping cheap, and by doing so changed the shape of the world economy."[1]

1 Levinson, Marc. *The Box: How the shipping container made the world smaller and the world economy Bigger*. Princeton University Press, 2008. Print.

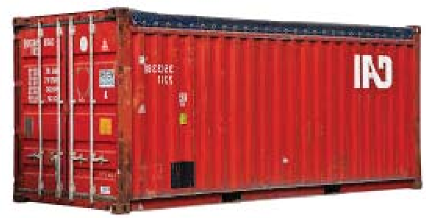


Fig. 1: common intermodal shipping container

Designed Intermodal Containers

Fig. 2: common shipping container reuse application

Storefronts

Fig. 3: reuse application for businesses

Mobile Businesses

Fig. 4: common reuse application as (vacation) home

Housing

Considerations

Fig. 5: raw materials need to be processed for the thousands of containers

Raw Materials

Fig. 6: raw materials need to be processed for the thousands of containers

Fig. 7: reuse application for emergency response

Emergency Responses

Chapter 3

With Nature - *Precedent study of Japanese Woodworking*

"You must treasure the foundations laid by tradition. Incorporating modern technology into traditional techniques helps bring out their true value" [1]

-Yuji Nagatani, Potter from Iga Japan

An exploration of the theory and history of Japanese woodworking took the subject of materiality and perspective into a different and important direction, serving as a precedent study for the central focus of this thesis. This investigation of traditional Japanese wood working highlighted the need for attention to technology, material and craft.

In sharp contrast to the highly manufactured, disposable shipping container, Japanese woodworking rests in an altogether different set of values and approaches. The Japanese woodworker, Hisao Hanfusa, speaks about working "with nature or against nature."[2] Known for craft and artistry, the materiality of wood as the entire form, without use of nails or other fasteners, Japanese woodworking was a counterpoint to the very industrial materials of the previous chapter.

Traditional Japanese wood workers create beautiful, well-crafted art, furniture and structures. End results are not tantamount, but rather the process in which the wood is crafted and the preparation of the tools are equally important. For example, sharpening of the tools starts the day and this includes the hand plane, using up to 8000 grit stone[3], the sharpness and fineness of which a mechanical plane cannot match.

In this tradition, the tool and the fixture or jig can be as important as the wood that is used. The craftsmen will spend hours first sharpening the plane before touching the

1. Spurlock, Morgan (Director). (2015). Crafted [Motion Picture]. United States: Warrior Poets.
2 Ibid
3 Ibid

wood. A fixture or jig is also an unseen part of the process but extremely important in transforming the natural form into a human scaled product. Both of these unseen things are crucial in the precision that is created. Wood finish is not done with man-made chemicals but through controlled burning of the surface.

The study also looked at the Asian wood saw, which resembles a long flat spatula and is a precision tool that "cuts on the pull, not the push" requiring less effort and greater accuracy than its Western counterpart.[4] It radically changed the way wood was joined, as it allowed for intricacy in cutting the connecting elements to interlock, like dovetails.

Fig. 8: Asian saw - cut on the pull

All manner of joints were developed for strength and length. The pieces were joined with such precision that they have stood for hundreds of years. These joints influence Oriental architecture, especially royal buildings and temples, where joints had to be ornate and beautiful or invisible.

An important area of research was on the joint. A joint is a fixed connection. A wood worker takes pride in the joint they create. The precision is part of its beauty and its strength. This contrasts with the metal fasteners used commonly to join two pieces. They are typically hidden because they are not nice looking, or in the Japanese way of thinking, because they are not moving with nature and are not in harmony with the materials. However, the two different ways of doing things represent very different needs that exist in the world and illustrate the two sets of values in tension with material construction:

Design with a focus on precision, beauty, harmony and integrity of materials
Design with a focus on speed, expense, ease of assembly and production

Time is a real constraint and influences which set of values is predominant in any construction.

Fig. 9: Western style saw - cut on the push
less precision and more force

4 Noe, N. Ran. "Joints of Wood" *Theme: Asian Culture Quarterly. Spring 2006, p.70.*

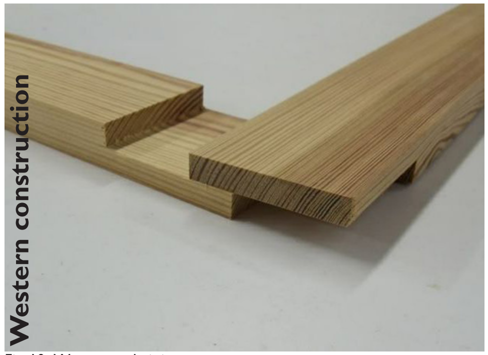


Fig. 10: Western style joint

Fig. 11: Japanese style joint

The rigor of their process evokes Heidegger's concept of "techne," to mean a bringing forth or revealing. Likewise here the act of construction allows the material to come to life and build meaning, and connects people to the thing itself. When people play a part in the transformation of materials, it builds value for them and adds to the experience others have with that object or space.

The use of wood is important here because even when transformed for industrial purposes to plywood, it can return to nature. This contrasts with the shipping container, the production of which required the mining of metals, removing them deep from the earth and when they are finally returned back, they are so dislodged from their origin, is there every opportunity for them to become what they were. A thousand years from now will they be able to be located as they are now in nature?

Exploring these processes and many examples of this craft were precedent studies for the later investigation of kerf cutting and joint vs. hinge.

Chapter 4
Transitions

In the case studies and initial deconstruction, many possibilities were examined, but main conclusion was that treating problems with multiple potential solutions is critical and requires openness to multiple "right answers". The next sections show the progression in approach, ideas and outputs that derive from the central big questions in this thesis: can the integration of 21st century craft into the use of new technologies allow a transformation of various materials and an exploration of an open set of potential solutions to modern design problems.

This exploration has truly been an iterative process, and these sections attempt to show not only the many potential solutions or new ideas, but also a mental map of the learning that happened in the making, in the prototyping, in the conversation and interaction between thing and person.

The study of Japanese and Western woodworking highlighted the fixed nature of a joint and the limited fluidity of a hinge, which typically only moves in one direction. The central thesis question was evolving at this point and further exploration required an examination of what materials could bend in more than one way. Through the next series of studies, it became apparent that many could and that through death or evolution, the familiar can be completely transformed.

In woodworking there are a variety of ways to bend a piece of wood. Some of the common techniques are steam bending, molded and laminated plywood, and kerf or relief cuts.

The first two processes allow for the wood to take the form of a mold or negative body.

Fig. 12: Paimio Chair

Fig. 13: Eames Lounge Chair & Ottoman

In steam bending one uses steam or boiling water as a way for the fibers in the wood to become pliable. This process allows the wood to be bent without the fibers splitting apart. The wood is typically bent and clamped to a form allowed to cool, once it is cool it will maintain its new form. This method can be seen in "boat building where it is used in the shaping of hull's ribs and lap boards, the production of traditional wooden lacrosse sticks, musical instruments such as violins and in the manufacture of wooden furniture like the Windsor chair and much of Michael Thonet's work."[1]

Molded and laminated plywood is a process where thin strip of wood with each layer receiving glue and they are laminated or pressed to a form. This technique can be found was used by Alvar Aalto's Paimio chair (Figure 12) as well as many of the Eames' designs (Figure 13). This process was and is a popular way of making furniture, skateboards, and even vehicle construction.

Neither of these processes allow for future movement.

This led to a study on kerf or relief cuts using Stuart Lees' article *Kerfing - Bending wood on the tablesaw* as a guide. In this process one makes a series of evenly spaced cuts running with against the grain of the wood and experimenting with the amount of wood left on the face surface. When the gaps from the reliefs in the wood are compressed the wood bends leaving a curve and uninterrupted grain pattern on the face side of the wood.

1 Keyser. Jr. , William A. *Steambending: Heat and moisture plasticize wood in Fine woodworking on Bending Wood.* Taunton Press. p. 2–119. 1985.

Chapter 5
The Joint or The Hinge

Although the joint is often a minor architectural detail, many theorists, like Frascari, lift up the details as the smallest part of meaning making in a building, and "tell the tale of a building".[1] In fact, his discussion of details in that article focuses quite heavily on the joint as both a functional and expressive element in building design.

A focus of this thesis became the question of a joint versus hinge and this has been done through an examination of a kerf, which is a small slice or notch that can transform the movement of material. Traditionally kerf cuts in woodworking are used to create a temporary hinge but ultimately end up as a fixed joint. Traditional wood joints are mimicked but often not true to their origin using metal fasteners. Both traditional and non-traditional joints create a static connection, one that if done correctly has limited, if any, movement. Can we use modern technology as a way to explore something more dynamic, something that isn't fixed? How will this transformation change the way we think of the material?

1 Frascari, Mario. "The Tell Tale Detail". Theorizing: A New Agenda for Architecture Anthology, edited by Kate Nesbilt. Princeton Architectural Press NY. 1996.498-511

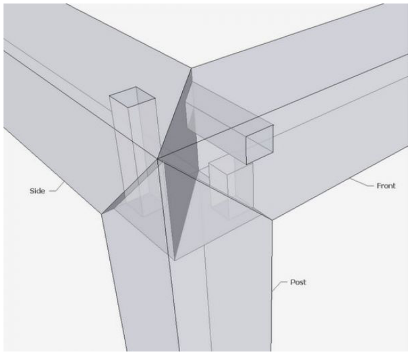


Fig. 14: wooden fixed joint


Fig. 15: wooden hinge

Joint verses Hinge; fixed vs flexible

A joint is a fixed connection. Its purpose is to join two or more pieces for either strength or to increase the size. Both traditional and non-traditional joints create a static connection, one that if done correctly has limited, if any, movement. If it does move, it is with nature, meaning the way wood naturally expands and contracts.

A hinge is a moving connection that allows for multiplicity but typically bidirectional. The purpose is to permit movement in a particular direction and in some applications is utilized in space saving.


Fig. 16: tablesaw

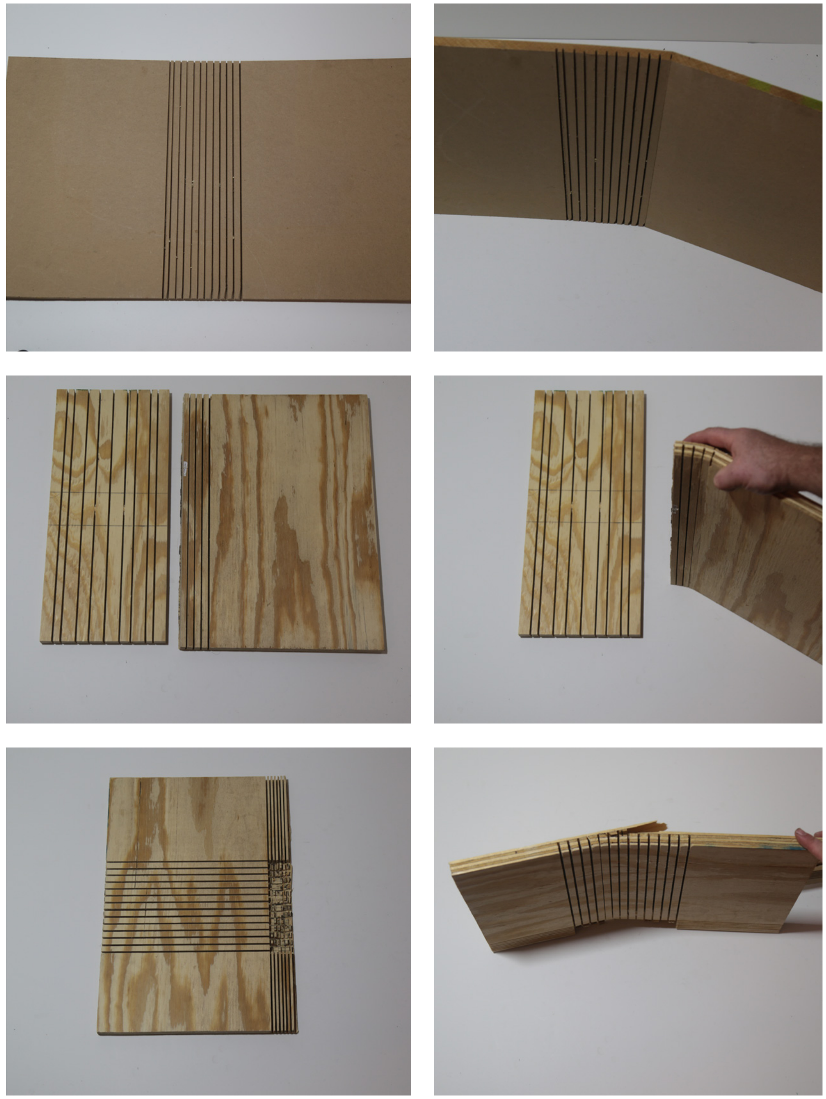

Fig. 17: traditional woodworking kerf or relief cut

Traditional Kerf Cut

The Webster dictionary defines a kerf as "a slit or notch made by a saw or cutting torch or the width of cut made by a saw or cutting torch."

This is a method of curving a solid board in traditional woodworking. These cuts (above) are glued to create a solid object.

A typical table saw blade will have a kerf of about 0.125". The thinnest kerf saw blade currently made are 0.059" (about 1/16") thick.



Hinge becomes a Joint

This was an experiment to see if using a table saw to create kerf or relief cuts made it possible to have plywood or MDF become flexible. Although it was flexible it quickly would break at these points when trying to treat it as a hinge. Pictures above show the various spacing and depths of cuts.

Chapter 6
Technology - a way to reveal

These next chapters look at an extensive exploration of how modern technology can be used in traditional and non-traditional ways to transform materials.

With the advances in computers, microprocessors, and motors, the access to and use of the tools that are being created are quickly evolving. One could think of these tools as simply advanced printers. However, instead of simple moves in the x and y-axis and printing ink on a sheet of paper, these tools can make movements in the third (z) direction and ink is no longer a limitation. 3D printing for example has a similar additive process but allows for many mediums as well as actual physical objects. This tool has become more readily available to the home user for prototyping.

Unlike the printer, the other tools that are evolving and becoming easier to access are ones that use subtractive processes of prototyping. Some of these tools include CNC routers, Laser Cutters, Waterjet machines, and CNC Plasma Cutters.

All of these tools share a common language that is referred to as g-code. Although, there are several types of code and variations, g-code is the most common. The language itself is how the software translates the drawing or 3D model to tell the tool the numerical controlled movements. This includes how fast, and the movement of the bed, the cutting tool, or both depending on the machine.

Further advances in these machines that are far from the average user include the ability to use a 5th axis that allows for much more complex forms.

CNC Router

A CNC Router is a computer controlled cutting machine related to the hand held router used for cutting various hard materials, such as wood, composites, aluminum, steel, plastics, and foams.

Since these machine spindles are based on a traditional router most bits will work in them. However, most work is done with bits that are at least 0.25" (1/4") and areas for detailing a bit that is 0.125" (1/8"). Bits that are as small as 0.0.313" (1/32") can be easily found but are not used much as they break easily. This tool can easily cut two dimensional parts as well as three. Advances have been made to be able use these to cut almost any form. The main limitation is the size of the cutting bed and the time it takes based on the cutting tool being used.

Fig. 18: CNC Router

Laser Cutter

The laser cutter works by burning away a portion of material. They can be used to make clean cuts in flesh to cutting thick metals. This is also known as the laser kerf and with a prototyping cnc laser its width ranges from 0.010" - 0.025", depending on the material type & thickness, the machine, as well as other conditional factors. Common consumer machines use a laser with a wattage rating from 40 to 60 watts that can cut thinner woods, acrylics, and other materials, where industrial machines operating at over 100 watts that can cleanly cut metals. The focal length of the lens and pressure of the compressed air both have an impact on the thickness of the kerf.[1] Thickness of the cut can also vary if the cut is straight or curved, as the machine tends to slow down at the curved portions. A laser operates mostly as a two dimensional machine, running in directions similar to a printer. The tool can not only cut material but also etch or burn into it, creating images or patterns. These tools are not currently used to create three dimensional forms; however with advancements it is easy to see where it will become a viable option.

Fig. 19: Laser Cutter

1 https://www.epiloglaser.com/how-it-works/laser-faqs.htm

Waterjet

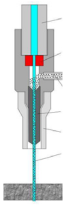


Fig. 20

A waterjet uses a high velocity stream of high pressure water (30,000-90,000 psi) which is produced by an intensifier pump.[1] Abrasive material may be introduced into the stream depending on the material and thickness.

In commercial applications waterjets are used for cutting anything from diapers to granite.

The kerf of the cut can be adjusted by swapping parts in the nozzle as well as changing the type and size of abrasive. Typical abrasive cuts have a kerf in the range of 0.04" to 0.05" but can be as narrow as 0.02".

1 http://www.flowwaterjet.com/Learn/How-Waterjet-Works.aspx#basics

Fig. 21: Waterjet cutting through steel

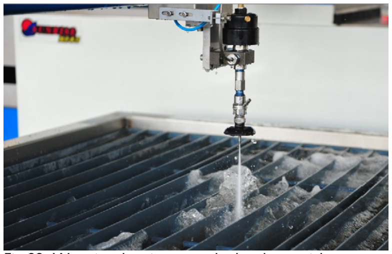


Fig. 22: Waterjet showing water bed and material support

CNC Plasma Cutter

Thus far the tools that we have examined have the ability to modify a variety of materials. This next tool's main operation is for cutting through metals. The Plasma Cutter works by the use of an electric arc through a gas that is passed through a constricted opening. This gas can be compressed air, nitrogen, argon or oxygen. Through this process the temperature elevates to a point of the 4th state of matter, which scientists refer to the state of plasma.[1]

When applied to a CNC machine the plasma cutter can provide quick and accurate cutting operations on metals of a variety of thicknesses. Like many of these tools this machine has become more available to individuals. The thickness of the kerf, like other operations varies depending on the thickness of the material but typically a plasma cutter if going to require a much thicker kerf than a waterjet, ranging from approximately 0.30" - 0.150".[2]

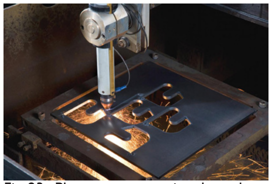


Fig. 23: Plasma cutter, cutting through steel

1 http://torchmate.com/white-papers/How-a-plasma-cutter-works
2 http://www.esabna.com/us/en/education/blog/what-is-cutting-kerf.cfm

These tools talked about so far allow for explorations of defamiliarizing as a subtractive process as the machine dictates. One needs to ask the question, how does the form change through an additive process, like 3D printing? Moving back and forth between additive and subtractive means and tools was also explored.

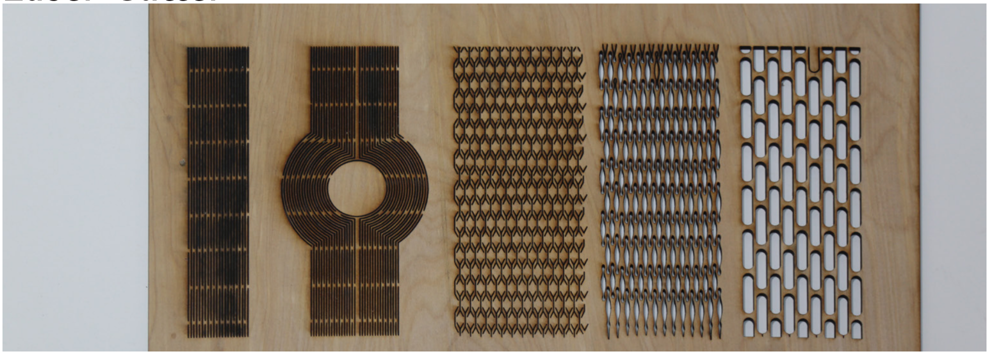
3D printing

3D printing is different from the tools examined thus far as it is an additive process instead of a subtractive one. A three dimensional model is created in a design software and the printer creates the model using a build-up of layers of material. This material ranges from several types of plastics, like ABS, to metals, and even castable waxes. There are many different types of 3D printers as well, for the most part each relies on a build of layers to create a 3D form. A downside of this layer buildup is that overhangs require support material and there are also concerns with microscopic spaces between the layers. For the purposes of prototyping these are not major issues, however, less expensive consumer machines do not yet provide the best resolution of parts to easily prototype objects. The majority of these machines are made to fit on a desk so the scale in which pieces are produced must be taken into considerations. However, scale is not necessarily a restriction, as automotive companies have used 3D printers for many years and there have already been houses printed using forms of concrete as the medium that is extruded from the printer. Many hobbyists have made their own 3D printers and used them for self-replicating.

Fig. 24: stereolithography (SLA) (resin) high resolution 3D printer

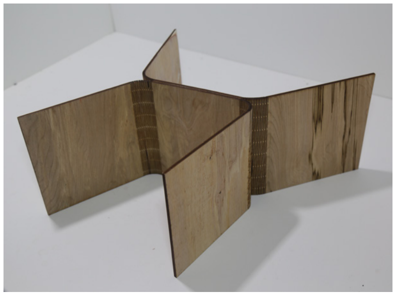
Fig. 25: common filament based home 3D printer

Laser Cutter



Patterns & the Living Hinge

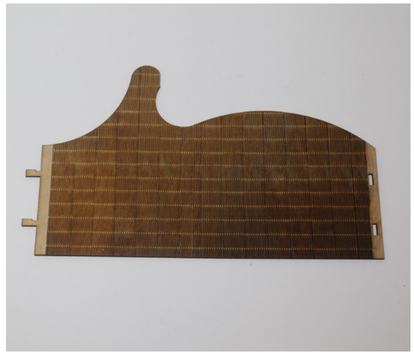
Different patterns were created in 0.210" thick underlayment. This was an exploration of what movements were possible in a normally rigid material. This not only transforms the material from how one thinks it can move, but also the value in the material.

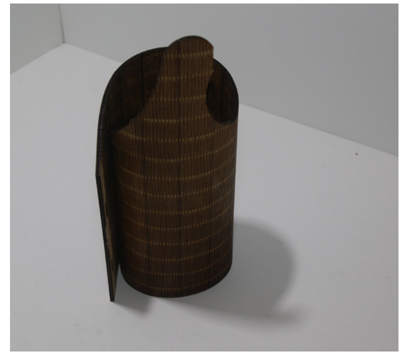


Laminating

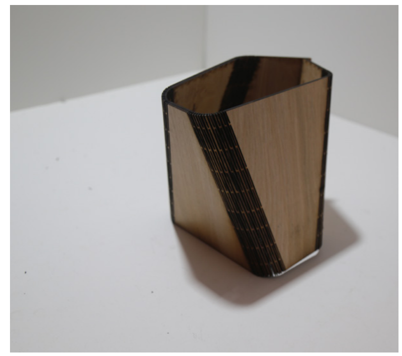
An experiment to test two pieces that were cut on the laser cutter and the center section later laminated together to test additional possibilities of creating forms

Underlayment transforms to almost fabric allowing to be tightly wound

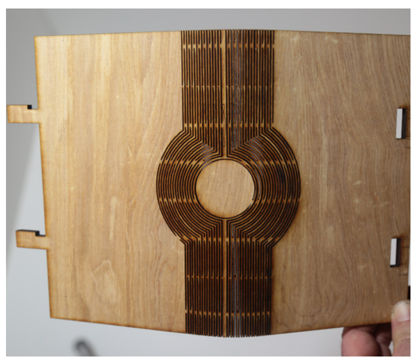


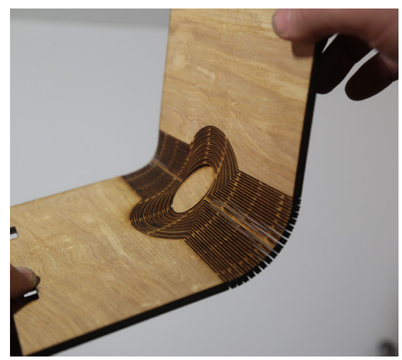


The form can be changed based on the angle of the kerf cuts



Patterns can be designed within the kerf and still allow for this flexibility



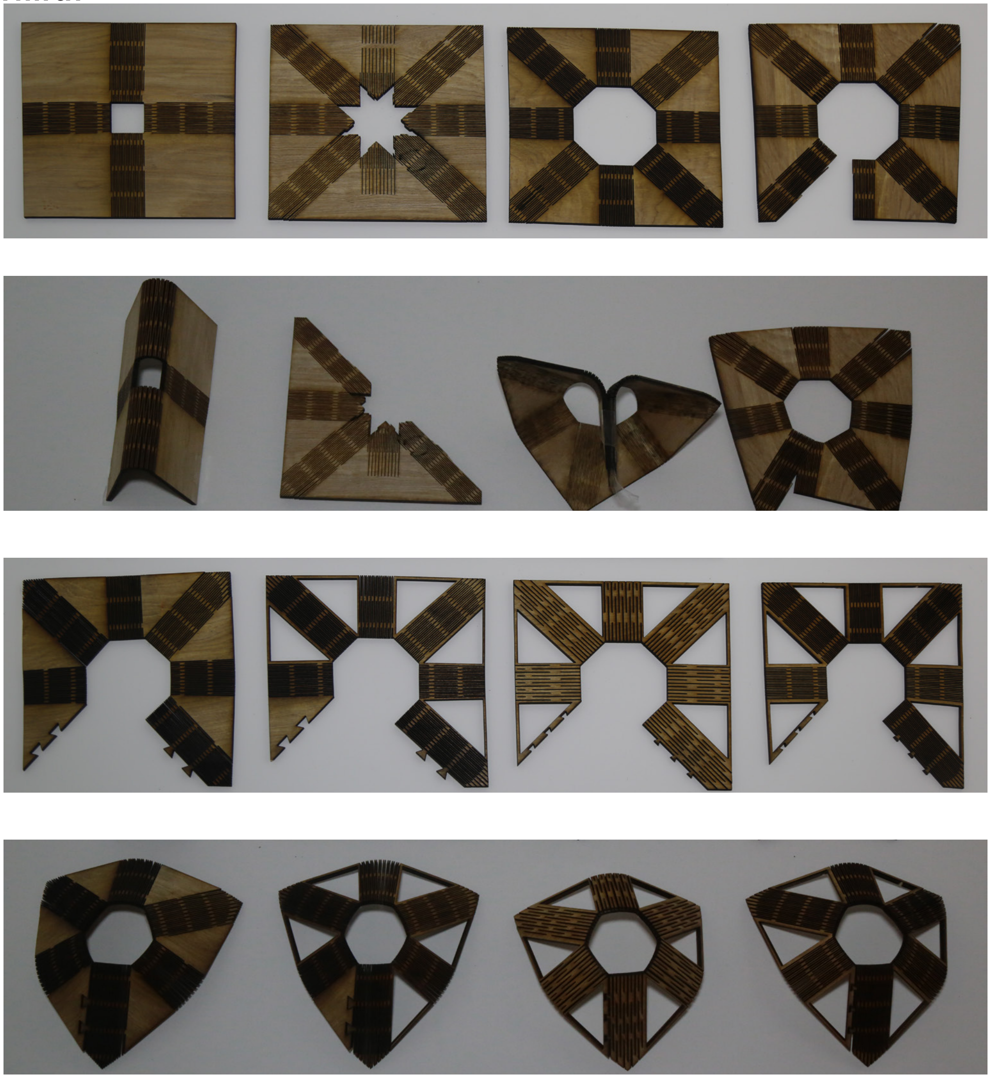


Kerf transforms

A series of tests to explore what happens when the maximum amount of kerfs are applied to a given sheet, different angles, and patterns. All tests concluded benefits from flexibility to form creation and possible aesthetics could be attained.

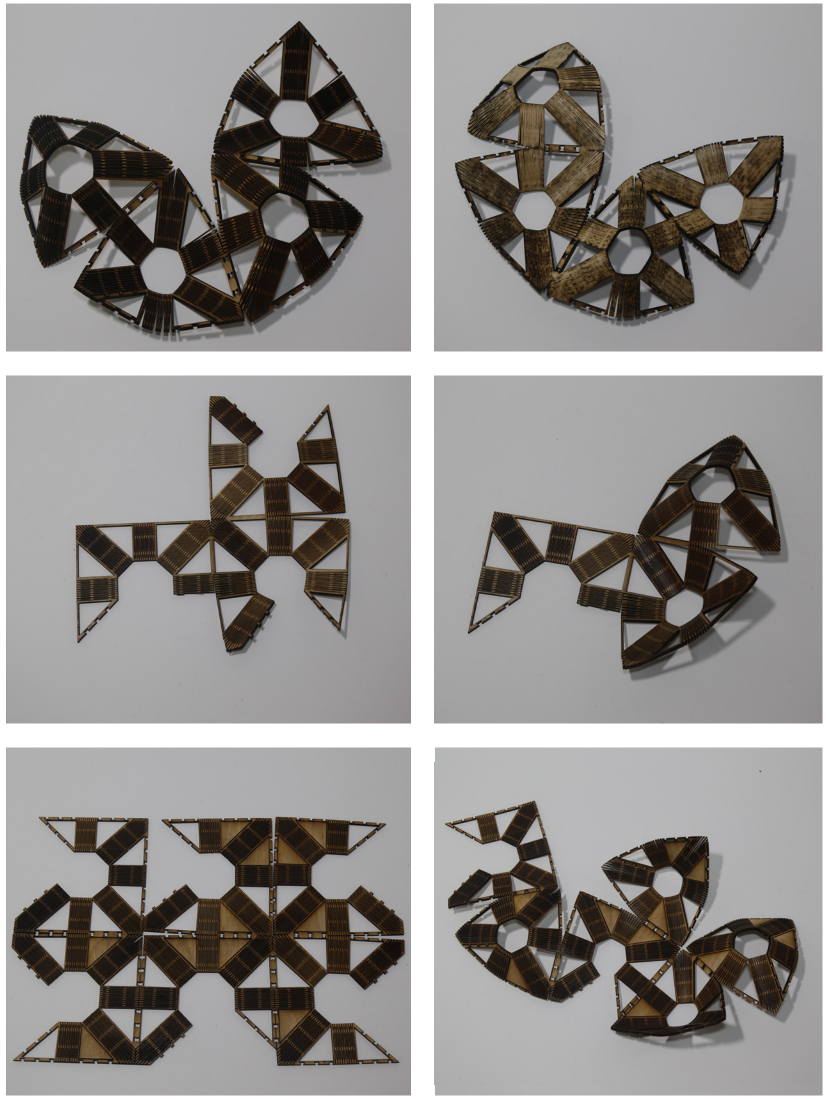
less familiar

Bending in one direction was transformable but it becomes fairly natural to ask the question can this process be used to bend in two directions and if that works how many directions can it bend?



Through this series of studies it was revealed that multiple directions of bending were possible. What made this possible was using the same technique as the bend, to remove material, as what brings strength and rigidity can be removed to allow for flexibility.

This series also reveals a linage of evolution and a transformation. Unlike a scientist who first speculates where the evolutionary change happened, the evolution occurred through playing. The last piece in the top row broke and its death exposed another possible transformation explored in the following iterations.

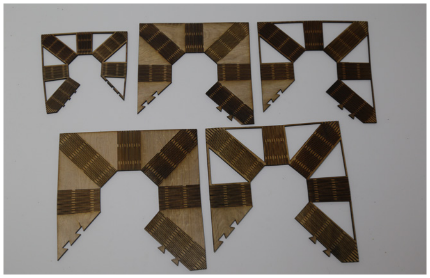


The sheet changed form and position depending on the way each piece would be formed in the z axis.

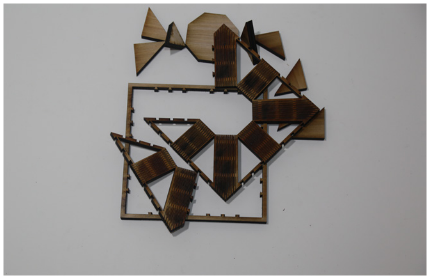
transforming one sheet

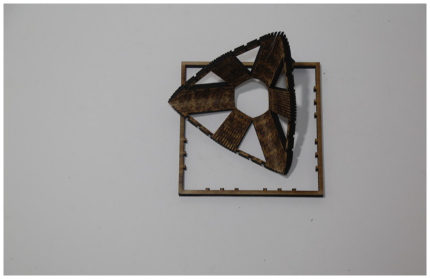
Instead of crafting one object, here a study was conducted to see how a single sheet of objects would react while leaving a point of connection built into the form.

scale - increasing object size



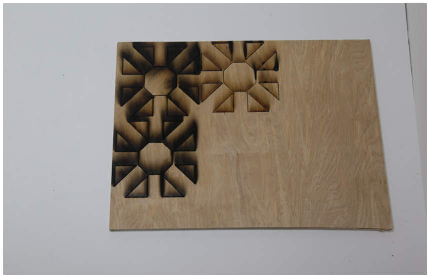
scale - material thickness (laminated 2 sheets of .210")

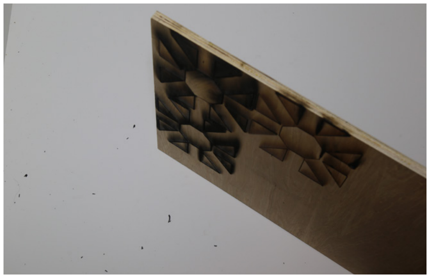




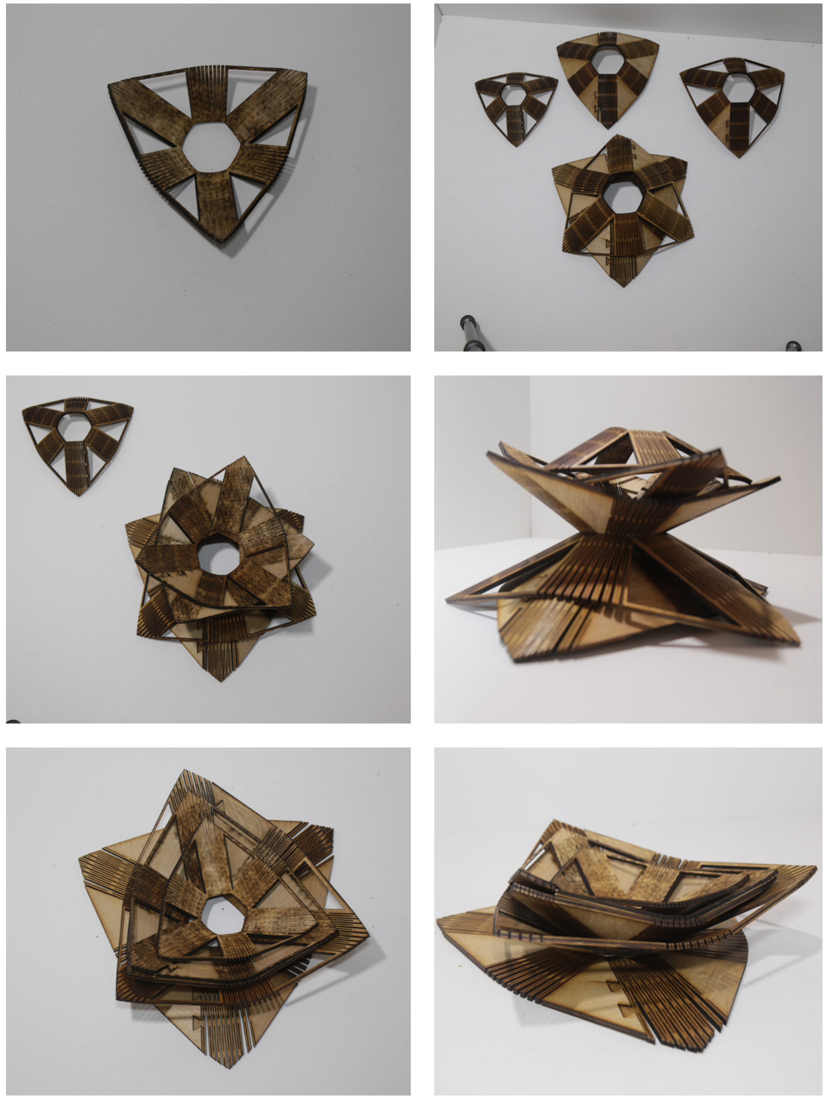
Two sheets laminated together proved to be successful, although the structure seemed to be weakened from the longer exposure to the heat.

scale - material thickness (laminated 3 sheets of .210")





The 60 watt laser cutter did not have the power to cut through three layers and setting the machine to a slow enough setting resulted in burned material.



Looking to the form in a variety of scales to discover

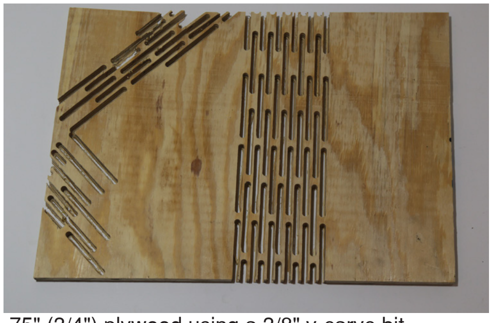
Module

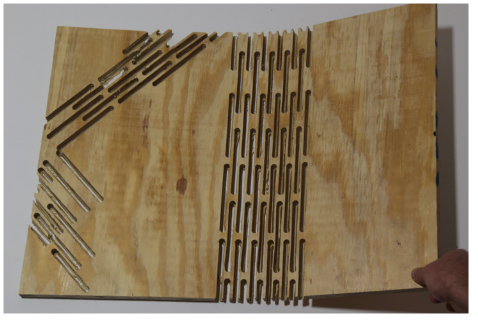
Through testing in various scales, it was determined that depending on application the larger the piece the less kerf cuts were needed for the same flexibility.

CNC Router

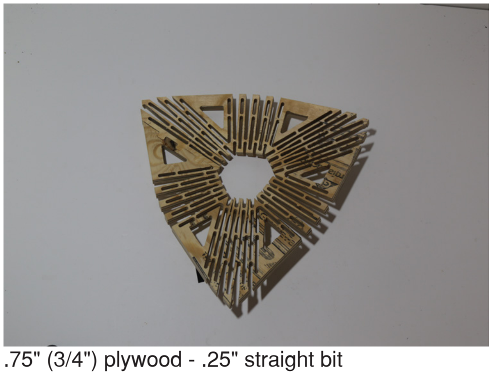
Previous sections were done strictly using a laser cutter. The laser cutter does have a thickness limitation. Therefore, the CNC Router was tested as an alternative.

How does a similar material respond to a comparable cutting process?
This is not an exact comparison as material being used is different as well as the capabilities of the machine. The laser cutter was cutting a kerf approximately 0.010" thick in material that was 0.210" thick which is not scalable with the CNC router.





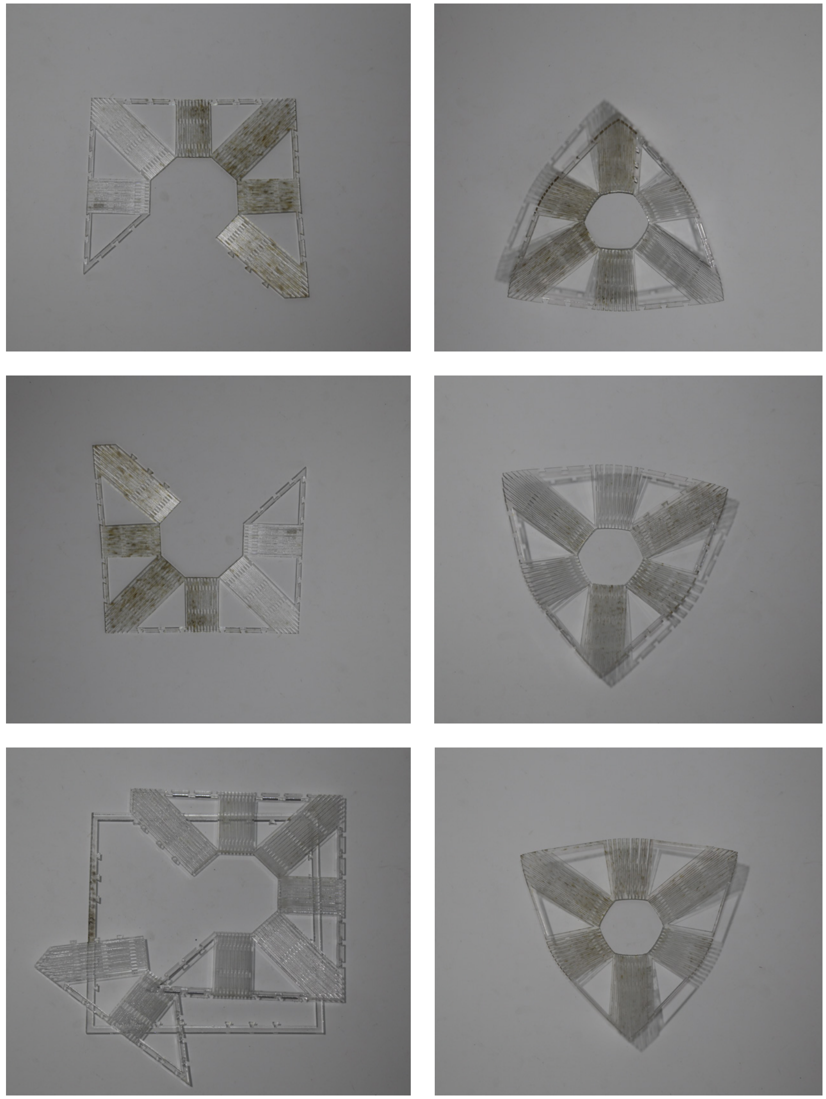
.75" (3/4") plywood using a 3/8" v-carve bit



.75" (3/4") plywood - .25" straight bit

transforming

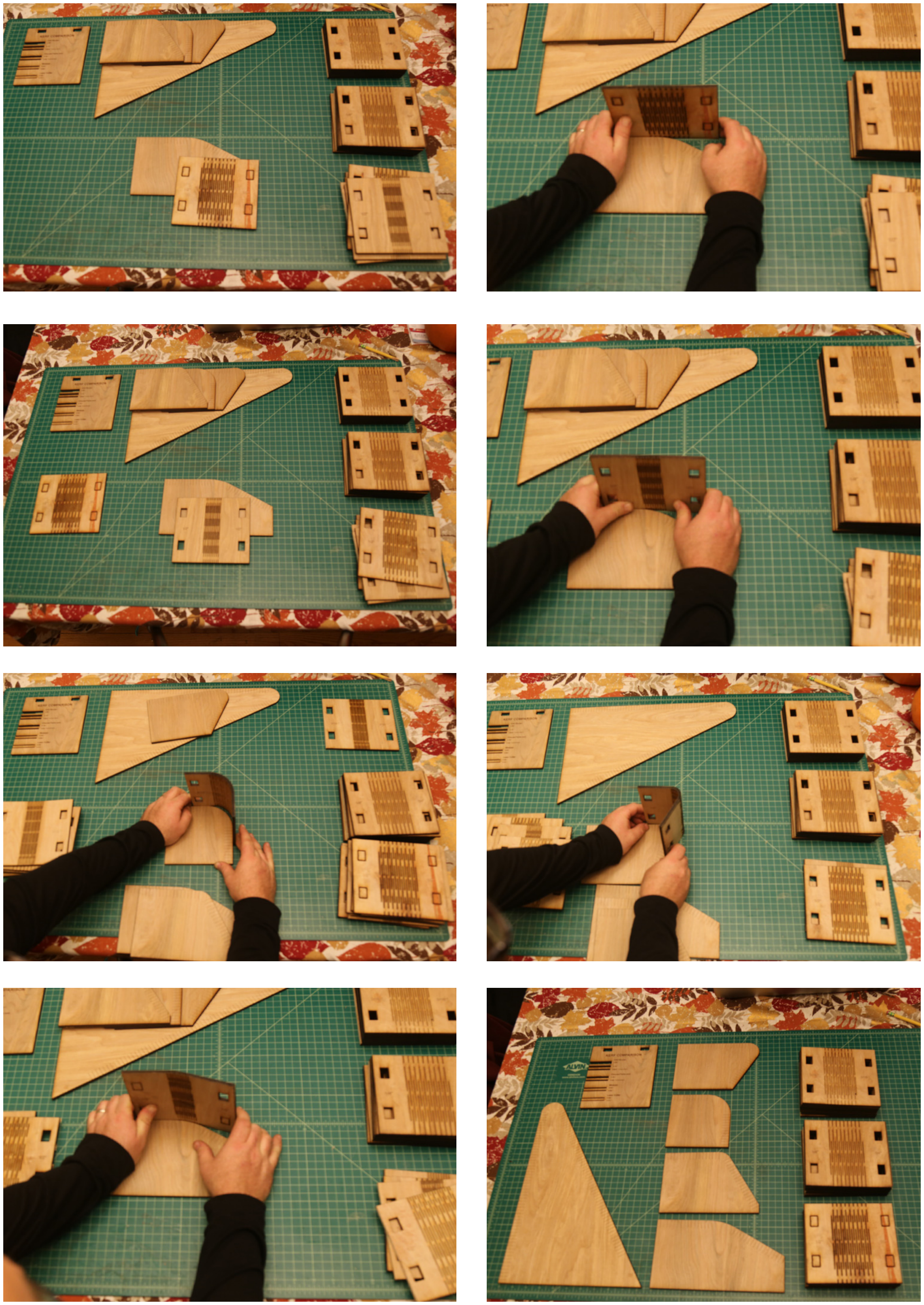
Here it was found that not only can this process work on thicker material the form can also be transformed through tension and compression like the laser cut pieces. The process of using the CNC router must be taken into account - not only does one need to be concerned with which lines are cut first to maintain rigidity in the piece while its being cut but also if the tool cuts on the line, inside, or the outside needs to be taken into account and programmed as required.



several tests were performed on acrylic with thickness ranging from 0.08" to 0.25".

Materiality

When a transformation happens in a material, one asks the question is it limited to just this material or can the same thing be applied to others. Through these series of investigations it was found that this technique can be applied to acrylic as well and in some instances it worked better than plywood. Some of the reasons it works better is the uniformity of the material, although the order of the cuts were even more important to avoid melting of the material.



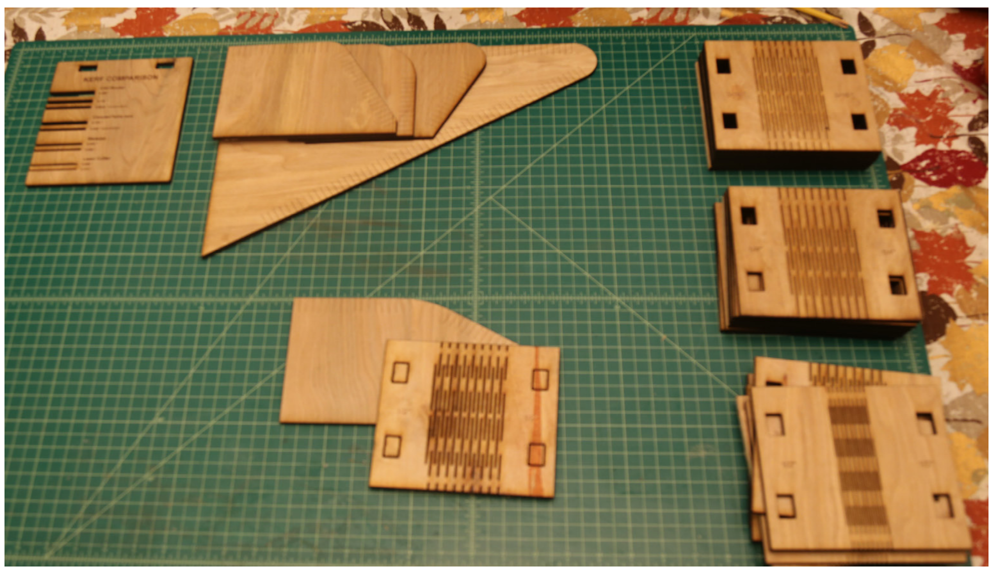
These pictures show a series of strength and flexibility tests on various kerf cuts.

Strength and Flexibility

A series of over 30 different parallel kerf cuts were done to test strength and bending capacity. Each of the versions were put through a series of bending tests that started with ten degrees ending at one-hundred and eighty degrees, in ten degree increments.

Some of the main observations included:

* For the best bending capacity all cuts need to cut through to the end
* Most flexibility happened with cuts placed closer together
* Additional strength was not obtained by just increasing distance between cuts
* For most applications closer cuts are best suited for strength and flexibility
* Difference in machines can highly impact the thickness and quality of cut
* Longer individual cut do not mean more flexibility



Chapter 7
Explorations

as Furniture

as a Surface

as Modular & Flexible

as Formwork, Structural

Furniture
flat-pack seating

Some questions and/or restrictions needed to be asked when starting to explore using this technique to create furniture. Some of these questions were:

Does it have to be made from all the same material?

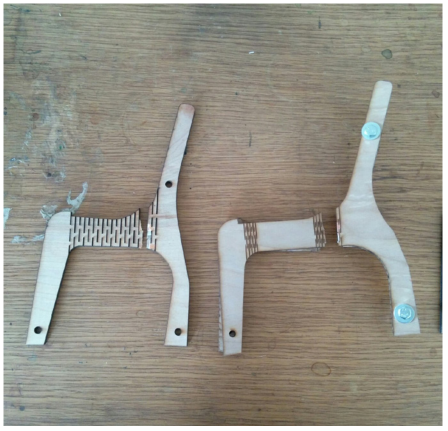
If it is a sheet material should it be made all from one sheet?

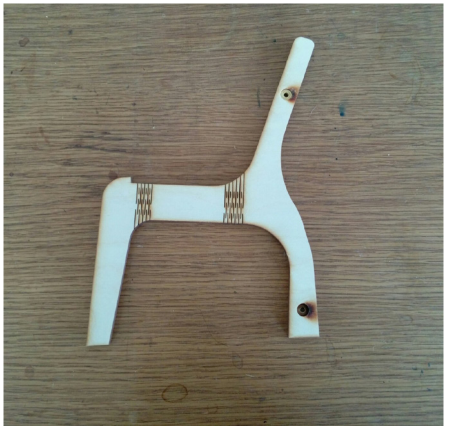
Do all the joints have to be wooden?

Can there be metal fasteners? (This certainly would be the easy way)

Does it need to just flat pack when received and created or also return to flat stage for easy storage?

The seat is simply the same form I have been creating, with the exception of some minor modifications. The way it would mount to the framing had to be dealt with. Thus far the mount has been created by using a simple slip joint that maintains its position because of the force created by the legs. The only other main experiment in the form was removing kerfs to still allow for the transformation yet provide a more solid seat as well as less flexibility.

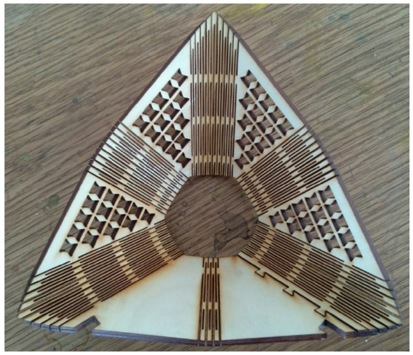


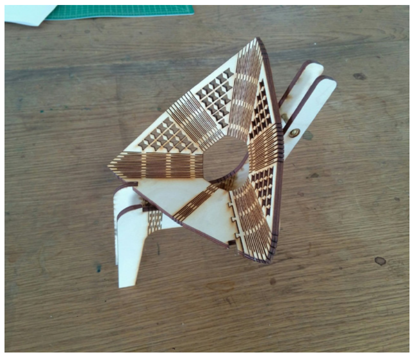


more becomes flexible & stronger

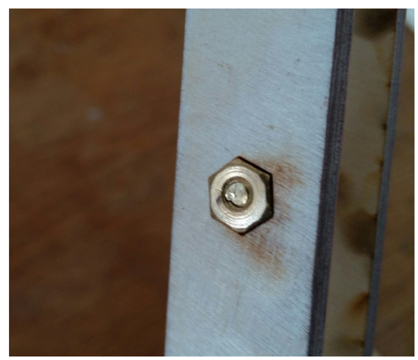
The legs went through several iterations from the amount of kerfs to the placement of the kerf. There was an important balancing act between the flexibility, strength, and providing tension on the joint for the seat. The leg that thus far has worked the best is with fewer kerfs that are placed at the locations that require most movement, on the angle of the seat base. The angle helps the strength of the leg where it is need in the vertical compression, instead of all the compression on the remaining kerf only the compression is placed on this piece and the load is carried on an angle to the next piece instead of straight down. This is similar to how an arch structure acts.

connection: materiality or aesthetics or both





Even though a bolted connection seemed to an easier solution there were a number of iterations needed to create a more aesthetically pleasing outcome. It was important to create a inlay for the nut to sit flush and tubing for the center section that would cover the otherwise exposed threads.



When making flat-pack seating, the question of the how the legs connect to each other and how the seat would connect to the legs needed to be addressed. The connection of the seat base to legs would be solved in three ways: through the design of the leg conforming to the seat, a simple connection joint, and the tension from the kerf in the legs on this joint.

Connecting the legs became a deeper design question of materials, use, and aesthetics. A bolted connection would be easy, however going in this direction it wouldn't be created all from one material or one sheet.

Full scale Flat-pack Seat

The full scale seat offered new challenges as going from the laser to the router is not scalable. Where the leg kerfs were placed on an angle so the forces wouldn't be applied directly vertically down the larger kerf from the router bit do not allow to take full advantage of this. In this version, all the parts were from one material, using no metal fasteners.

Similar to the construction of a traditional roll top desk, duck cloth was tested to see if it would add strength and longevity to the kerfs on the legs. It did add these qualities. One does need to consider the aesthetics when adding this element.

Flat-pack Display and Desk

When designing the chair it seemed to be a good opportunity to test flat-pack displays as well as a flat-pack desk. The desk could be used to store the chair inside. This exploration in using the CNC router provided insight into some issues with the tool. Since cutting speed is based on the bit size and these pieces requiring large living hinges it was revealed that each hinge would take approximately four hours. This time could be reduced depending on design choices like chamfering the first few passes. This operation could be done faster as it is a larger bit, which in turn reduces the number of passes required for the smaller bit.

Surface
fabric and formwork

Additional precedent study on tessellation informed this exploration of surface. Tesselation is another old technique made new with digital technology. Typically defined as a collection of pieces that fit together without gaps to form planes or surfaces, these tight formations are familiar across cultures and regions as mosaics, stained glass windows, and screen walls. These "surface systems" filter views, define space and convey meaning.[1]

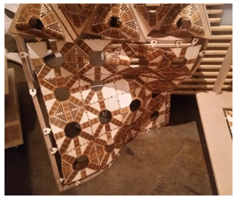
Research in this area has focused heavily on new technologies and re-imagining the skin of buildings and other surfaces. A key feature of digital built tessellations is the need for an internal construction system to create structural stability.[2] This aspect was evident in the kerf applications to surface explored in this study.

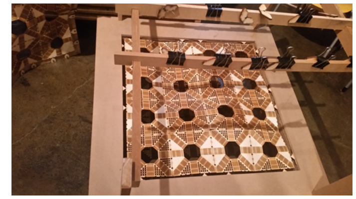
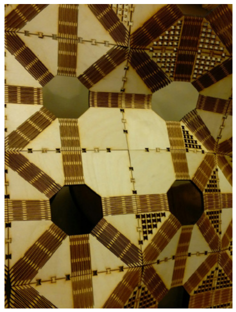
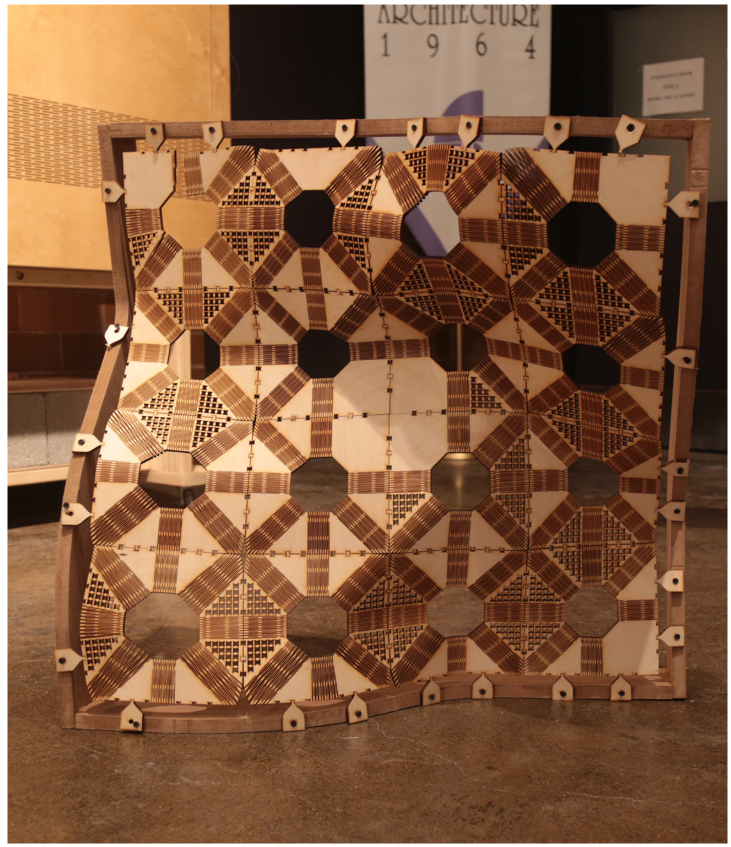
Even though this surface is wood, because of the change in the nature of the material from a very solid form to a flexible fabric type, one must treat the assembly as such.

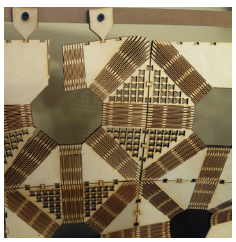
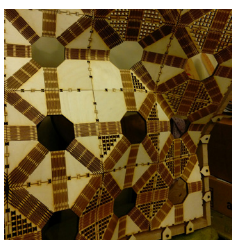
When first attaching it to the framing it was attached like one might attach a traditional wood surface, one spot completely then moving to the next. This resulted in pieces breaking and some pieces flexing and others staying rigid. When treating it more like a fabric and attaching each point and tightening them all in stages the material was more flexible and did not break.

1 Iwamoto, Lisa. *Digital Fabrications: Architectural and Material Techniques* . New York, Princeton Architectural Press. p.36. 2009. Print.

2 Ibid. p.37



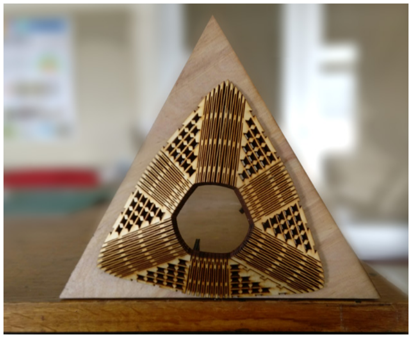




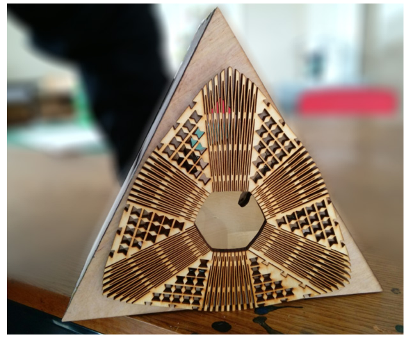



How would a series of these act as flexible tiles?

In this exercise several things were learned, including that the material had changed. It no longer was a solid object it was more like a fabric or tent structure.

When you connect a series of the tiles, they can conform in multiple directions, following the frame. Due to this flexibility, one person is not enough to attach this sheet of tiles to a solid frame.





Modular Flexible System

responsive wall

This was an exploration into the creation of a responsive modular wall system. Each module connects and can be offset to create a dynamic non-linear wall. The module, through the use of arduinos (mircocontroller), sensors, and stepper motors that would respond to the human scale, moves in and out based on the person and their proximity. This exploration became more about the longevity of the pieces to function, as well as designing the modular system and the mechanics, than a human experience.





Formwork
concrete

Kerf cut wood is strong enough to hold concrete. The joint becomes as important as the kerf. While pouring the concrete one example failed. This was not a direct result of the strength of the kerf, because the joint was loose, causing the kerf to move a lot and eventually fail. In an identical piece where the joint was in the correct orientation the form held fine. In both pieces care was still needed when pouring the concrete. At this scale it could not be poured as one would pour a sidewalk or foundation.

Does this still happen if thicker plywood was used, as these tests were performed with 0.210" underlayment? Could duck cloth be used like in the chair?

Chapter 8
Other Potential

It is important to recognize that like life this Thesis could have taken multiple directions. One area that was not explored was the urban condition of how "maker spaces" can effect a community. These studies would not have been possible without the access to a shared tool space. The school did not provide the tools used through these studies. However, one could connect how spaces that allow for people to come together to create can strengthen a community. Another question that could be addressed is does tool share allow for a change in the way a community is designed? Does housing need to be as large? If everyone does not have a need for individual tools can spaces be eliminated or decreased in size?

Another potential for furture exploration is use of these ideas for building surfaces. The way buildings are built today and for at least the last hundred years it has been about surfaces. We cover the structures with something that no longer speaks to the nature of the material. We transformed the way the building's material is thought of - brick is a veneer that is meant to beatify the wooden framing. Aluminum and vinyl siding were designed to mimic wood siding, a surface designed to conform to the traditional box. Both of these materials are manmade and through this creation many forms could be had, in fact in most cases they are further manipulated to have the strength to conform to the box. Similarly the wood was modified against its nature to slabs that fit the box.

If our buildings use such cladding as a surface that has just been transformed to cover its structure why not reimagine the structure and allow design to move away from the box? Or let us reimagine surfaces and have the structure conform to it? Historically structure has been the surface, and then surface conformed to the structure. Why not have the structure conform to the surface?

This is similar to the way furniture is designed today. A veneer of the quality of beautiful wood is used to cover the structure.

Words of Closing

One year is not enough time to study even the direction this took, it is just a start.

In closing thoughts it is important to share reflections on the question "How does one become richer as a student or architect based on this exploration?".

One could say, it is just an object and it is nothing but it is an idea and everything. As Albert Einstein said: "Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand."

Architecture should challenge the way we think, and elicit a reaction from us as we experience it. The desire to touch it, to move it, to play with it, to imagine, and to explore the pieces created capture those things.

One can see the things created here being developed to become part of the material of amazing buildings or spaces, where it might be a skin on the outside, or part of the interior or furniture inside. This investigation is limited to a year and it offers just a phase. Although it has been a deep investigation it is just a beginning to many possibilities. It not only questions the way we use a new tool but how we can re-imagine how materials work.

The ability to take the way people think they know how things work and totally change the way they see the world. That is architecture.

Acknowledgments

This has been a long journey. I would like to thank the professors and administration at University of Detroit Mercy School of Architecture. I would especially like to thank Dean Will Wittig. If it would have not been for his efforts, I am not sure I would have chosen to attend UDM. His help and mentorship throughout my studies at UDM made it a place I wanted to be.

I would like to write about each professor I had, but it would not do justice to those important relationships. I will say there have been some that have truly helped me see the world in a different way and recognize how education and the way we think about educating can be different. Some of you were assigned mentors and others took on that role unofficially. I consider many of you true friends.

I would also like to thank the University for seeing the importance of The Detroit Collaborative Design Center and those that work so hard to make it happen. I am thankful for my experiences there and the people that I worked with.

My family...when you take on a program like Architecture it is taxing on you. When you decide at an older age as a parent to return, it is extremely taxing on you and everyone around you. Words do not express the thanks one has to those around you. However, I would like to thank them for all the big or small things. You helped me through this.

I would like to specifically thank my wife, Kate, and my children, Marilyn, Abraham, and James. We weathered many sacrifices in order to make it through this chapter, but we made it through it, and I look forward to the next phase. I couldn t be a more proud father and husband, and I am humbled that you continue to trust in me as I work to become the best version of myself that I can be. Thank you for shouldering some of my share of the load in this great partnership. I promise,, I am now ready to finally patch the ceiling. I'm also very grateful to my mother, Susan for remaining a rock and source of confidence during troubled times and seasons of doubt. I extend further gratitude to my Uncle David, and my siblings, David, Sarah, Billy, and Doug. Thank you for helping me become the person I am. Without you, I am not sure where I would be. I certainly would not be the same.

Finally, I would like to thank my "in-laws." Ann and Mike, certainly, you have stood by us to care for our children during this journey, but I hope you know that you are more than merely those who watch over our family as babysitters. My own parents could never be replaced, but you have shared the love and guidance of parents, and watched over me as well. I am also grateful for the support of the siblings and spouses I married into. All of you could not feel more like family to me.

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Images:

Figure 1: Red container
http://www.containerhomesplans.com/2015/05/The-Consideration-Before-Building-a-Shipping-Container-Home.html

Figure 2: Storefront
http://retaildesignblog.net/2013/02/05/shipping-containers-restart-shopping-mall-christchurch-new-zealand-2/

Figure 3: Tesla
http://fortune.com/2015/05/22/tesla-pop-up-store/

Figure 4: Vacation home
http://inhabitat.com/how-to-spice-up-a-shipping-container-home/

Figure 5: Steel production
https://www.evrazna.com/LocationsFacilities/EVRAZReginaSteel/EVRAZReginaSteel/tabid/143/Default.asp

Figure 6: Steel forming
http://atomicdelights.com/blog/a-glimpse-at-how-the-apple-watch-is-made

Figure 7: Emergency
http://inhabitat.com/8-innovative-emergency-shelter-designs-for-when-disaster-hits/

Figure 8: Asian saw
http://www.dwell.com/photo/9824/western-handsaws-cut-push-stroke-alone-or-push-and-pull-steel-blade-has-be-thick-and-springy-enough

Figure 9: Western saw
http://www.joe.ie/news/pic-tough-guy-amputates-own-leg-with-a-saw-and-a-fruit-knife-to-avoid-hospital-fees/379552
http://www.maxicours.com/se/fiche/2/1/441812.html

Figure 10: Japanese Joint
https://hillbillydaiku.com/2015/04/23/article-series-on-japanese-joinery/

Figure 11: Western Joint
http://allbiscuitjoinerreviews.com/wood-joint-techniques-take-a-sneak-peak/

Figure 12: Paimio Chair
http://craftcouncil.org/magazine/article/bent-design

Figure 13: Eames Lounge Chair & Ottoman
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Figure 14: Wood joint
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