I, Zachary T Grajewski, hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture.

It is entitled: Hybrid Craft: Designing a workflow for traditional and digital craftsmen

Student's name: Zachary T Grajewski

This work and its defense approved by:

Committee chair: Michael McInturf, M.Arch.

Committee member: Aarati Kanekar, Ph.D.
Hybrid Craft
Designing A Workflow For Traditional And Digital Craftsmen

by
Zachary Grajewski
June 2015
B.S. Architecture Ball State University

A thesis submitted to the graduate school of the University of Cincinnati in partial fulfillment of the requirements for the degree of
Master of Architecture
in the College of Design Architecture, Art and Planning

Thesis Chair: Michael McInturf
ABSTRACT

In an industry that is increasingly opting for off the shelf assemblies and components, skilled craftsmen are an endangered commodity in the modern design and construction trades. The result of this is architecture that is visually homogenous and plain, with very rare attempts at complexity of form or custom solutions. Simultaneously, the architecture and construction industries have yet to embrace technologies at their disposal, namely digital fabrication techniques. The use of digital tools in tandem with the hands and knowledge of skilled craftsmen allows architects to design more formally and materially complex structures, which are tailored to users’ desires.

Utilizing some combination of traditional and digital methods, more visually interesting results can be achieved with levels of accuracy and speed currently unmatched by current means and methods. Embracing the use of digital tools can introduce traditional craftsmen to a new market. This will be achieved through research in the areas of methods and theories of customizing, traditional craft, as well as those of digital design and fabrication, establishing the strengths of both, and then proposing the optimal workflow to utilize both in a variety of architectural applications.
Acknowledgements

A special thank you to Nick Germann and Scott Lincoln of the Rapid Prototyping Center at DAAP, whom I have worked under for the past 3 years. Your knowledge, guidance, and friendship have proven invaluable.
CONTENTS

I: Craft.............................10
II: The Hand.......................16
III: Digital Means..............24
IV: Hybrid Craft.................32
V: Applications.................36
Bibliography....................76
LIST OF ILLUSTRATIONS

I: CRAFT

1.1- Author
1.3- http://www.delood.com/specials/shellstar-pavilion-matsys
1.4- http://matsysdesign.com/2010/02/28/zerofold-screen/

II: THE HAND

2.3- http://tedanddebbie.com/sam-maloof
2.4- http://designbezgalstuka.com/viewtopic.php?t=996
2.5- https://lamodern.com/tag/sam-maloof/
2.6- Author
2.7- Author
2.8- Author

III: DIGITAL MEANS

3.1- http://tarus.com/project/cm5p-design-studio-clay-mill-5-axis-portable/
3.3- https://www.youtube.com/watch?v=IK5CLcEjUOc
3.4- http://internal.tcaup.umich.edu/news_and_events/news/?news=856
3.7- http://www.frac-centre.fr/projets-64.html?authID=304&ensembleID=1082
3.8- Author
3.9- Author
3.10 - Author

IV: HYBRID CRAFT

4.1- Author
V: APPLICATIONS

5.1- Author
5.2- Author
5.3- Author
5.4- Author
5.5- Author
5.6- Author
5.7- http://www.designboom.com/design/matthias-pliessnig-pinch/
5.16- Author
5.17- Author
5.18- Author
5.19- Author
5.20- Author
5.21- Author
5.22- Author
5.23- Author
5.24- Author
5.25- Author
5.26- Author
5.27- Author
5.28- Author
5.29- Author
5.30- Author
5.31- Author
5.32- Author
5.33- Author
“In this domain of quality our environment is deteriorating. What threatens it most is not bad workmanship. Much workmanship outside of mass-production is appallingly bad and getting worse, to be sure, and things are seen in new buildings which make one’s hair rise”\textsuperscript{1}

-David Pye, The Nature and Art of Workmanship
I: CRAFT
Master craftsmen are an endangered breed, while at the same time, contemporary architecture is becoming increasingly materially bland and poorly constructed. Architects have lost touch with craft and materials. The architect as the “master builder” is rarely applicable anymore. Architects are often times stuck at desks and rarely step into the field. They lack the understanding of the work that they prescribe and therefore lose the ability to learn from these processes to inform their designs. Designing and building are becoming increasingly disparate disciplines, when they should be tightly integrated.

Architects have been pressured by industry and budgets to abandon the care for craft in design. Highly skilled masons, woodworkers, steelworkers, and artisans have been abandoned on all but the highest budget of projects. They have been traded in for ready to install, off the shelf, mass produced components. There are no longer any custom solutions, any further than picking out the set of prescribed parts you want from a manufacturer’s catalog. Nothing is tailored to the end user, and therefore will rarely, if ever, meet all of the user’s needs or desires. Customizing should be a major focus for architects. Meeting a client’s desires with design is a noble pursuit.

Craft is more than care in physical making, it is a mindset that can be applied to any field in which one seeks excellence. As Richard Sennett says, “Craftsmanship may suggest a way of life that waned with the advent of industrial society- but this is misleading. Craftsmanship names and enduring, basic human impulse, the desire to do a job well for its own sake. Craftsmanship cuts a far wider swath than skilled manual labor; it serves the computer programmer, the doctor, and the artist; parenting improves when it is practiced as a skilled craft, as does citizenship.”

1 Pye, David. The Nature and Art of Workmanship, 1971, 18
2 Sennett, Richard. The Craftsman, 2008, 9
1.1 CNC cut dovetail joints

1.2: detail of Hans Wegner’s chair
Typically, when one hears the word craftsman, one pictures an image that would not be out of place before the industrial revolution. The image may include hand planes and chisels, wooden mallets, mortises, tenons, and dovetails. While this is still applicable to a few craftspeople, people are largely unaware of the group of digital craftsmen that are emerging around the world.

While they may utilize different tools, these are individuals that take pride in their craft in exactly the same way that the “traditional craftsmen” do. The tools make no difference in the nobility of intent. Richard Sennett says “(tools) too can expand our skills, only if imagination rises to the occasion”.3 This is statement is of particular resonance to my argument.

Traditional craftsmen may be resistant to adopt digital tools in many cases. This does not apply exclusively to makers. Often times, architects educated in the pre-digital era are highly resistant to the computer as a tool, both as a design tool and as one for production. They either are intimidated by learning a new tool, which frankly is hardly an excuse, or they fail to see its value and potential to their trade. Their imaginations have yet to rise to the occasion.

Simultaneously, students and craftspeople raised since the advent of the personal computer may be resistant or see little value in old, traditional tools. Conversely to the educator, the architecture student should see the value in being able to draw and convey ideas by hand. It is important to any trade to have an understanding of and retain the knowledge of previous generations.

3 Sennett, Richard. The Craftsman, 2008, 195
1.3: Shellstar, a digitally fabricated canopy by Andrew Kudless of Matsys Design

1.4: Zero/Fold Screen by Andrew Kudless of Matsys Design
“Once the master dies, all the clues, moves, and insights he or she has gathered into the totality of the work cannot be reconstructed; there’s no way to ask him or her to make the tacit explicit”

-Richard Sennett, The Craftsman
II: THE HAND
In Sennett’s text, he observes the master hand craftsman, through the lens of Antonio Stradivari’s workshop. A legendary luthier, Stradivari built violins, cellos, and other stringed instruments unsurpassed in their quality in the 3 plus centuries since. The workshop was occupied by Stradivari and his apprentices, a few of whom were his sons. The apprentices literally lived in the workshop, hoping to gain any drop of the knowledge that the master could bestow. They would learn the art of carving and inlays in the style that Stradivari prescribed, while the master himself was the only one to do the final shaping and varnishing of the instruments, a crucial step in the final tone and voice of each piece.

After Stradivari’s death, his sons carried on the business with the Stradivarius name, but the instruments lacked the same impeccable quality that they were known for. The instruments built following Antonio’s death have been described as “excellent, but no more than that”. The business failed not long after the master’s death.

The example of Stradivari’s workshop is effective as a cautionary tale to today’s generation of craftsmen. If we fail to capture and record the knowledge of yesterday’s craftsmen, we lose a piece of our own history of making. We may lose the most valuable of beautiful techniques they have to show.

The hardwoods and dovetails of traditional crafts are already incredibly rare when compared to the particle board and staples used today. The result is a “throw-away” mentality from consumers, because these pieces are not built to last. Many Stradivarius’ still exist today, because they were built with quality and were built to last. Aside from the innate beauty of finely hand crafted objects, their longevity is a quality to be admired. In this sense, hand craft is far more sustainable and efficient.
2.1: Depiction of Stradivari in his workshop

2.2: A Stradivarius Violin
What are the strengths of the hand? Certainly there are some, else these methods would have been entirely abandoned at the time of the industrial revolution. Working by eye and by hand allows the craftsman tactile feedback from the material, something that cannot be said for digital tools. The craftsman can react to grain, imperfections in castings, unexpected buckles in steel, any surprise their various media may have to offer. The practiced hand can, as a result, also sculpt material in an ergonomic way that is pleasing to the human body. The hand feels, trims, then feels, refines, then feels, then sands until the hand is happy. This tactile feedback ultimately results in tactile bliss by the end user.

Sam Maloof was an influential American woodworker in the mid to late 20th century. He was renowned for his beautiful sculpted rocking chairs that woodworking enthusiasts attempt to copy to this day. Sam had a workshop akin to that of Stradivari’s, except in that Sam trained anyone that was willing to learn the craft, and tried to bestow every bit of knowledge he had to his apprentices. As a result, the Maloof workshop is still delivering beautiful pieces of furniture with the same quality that Sam built with, even since his death in 2009. The passing of knowledge from generation to generation is incredibly important in the crafts.

Sam’s chairs are incredibly beautiful, sculpture pieces of art. The seat pans are molded to the human body with elaborate carving, the slats in the backs are designed to flex and receive the human body rather than remain perfectly rigid. Even the finish of these chairs is designed to improve with the rubbing of curious hands following the beautiful contours. Sam has created an ideal cradle for the human body, because it was influenced, built, and refined with the human body.
ADVANTAGES OF TRADITIONAL METHODS

- TACTILE FEEDBACK FROM MATERIAL
- PASSING OF HISTORIC KNOWLEDGE
- COMMUNICATION WITH HAND CRAFTSMEN IS MORE ACCESSIBLE
- MADE BY THE HUMAN BODY, FOR THE HUMAN BODY
“One can make a series of unique pieces with nearly the same effort as it requires to mass-produce identical ones”

-Lisa Iwamoto, Digital Fabrications
III: DIGITAL MEANS
Digital tools have expanded the possibilities of physical modeling and production. The automotive industry is typically one of the first of the design fields to adopt new tools. Today’s automobiles are largely designed in the computer, at which point they are fully documented and modeled in the computer, down to the last small wire, nut, and bolt. This is starting to be used more widely in the field of architecture through the use of building information modeling, or BIM.

The architecture and construction industries now have at their disposal many of the digital tools automotive manufacturers use not only for design, but also for the physical production of vehicles. Prototypes of car bodies are sculpted on huge CNC machines, mockups of stamped parts are laser cut, and production vehicles have integrated the use of multi-axis robotic arms in many assembly processes. These tools have the ability to replicate and understand complex form, with unmatched repeatable accuracy. While many craftsmen may work with a tolerance of 1/16” or possibly 1/32”, these tools allow accuracy down to the 1/10,000” in many instances.

Now that it is apparent that digital design tools are here to stay in architecture, why is the field resistant to adopt the production tools that have also proven themselves useful in other fields. While these tools are highly efficient for production runs in industry, the exciting prospect within architecture is the custom, one-off application. Lisa Iwamoto states “One can make a series of unique pieces with nearly the same effort as it requires to mass-produce identical ones”5 There are a few practitioners willing to explore the possibilities these tools bring to the field, but those are, at this point, little more than niche firms. Surely there are plenty of projects that could utilize these digital tools.

5 Iwamoto, Lisa. Digital Fabrications: Architectural and Material Techniques, 2009
3.1: 5 axis CNC machine sculpting a clay car body

3.2: Model S unibody being assembled by robots in the Tesla Factory
There are a few designers/fabricators exploring the possibilities that these digital tools present. Among what I would consider to be the leaders in this field is Wes McGee. Wes is a professor in architecture at the University of Michigan. Working at the school, he has a huge amount of fabrication resources available to him. They have a plethora of laser cutters, 3D printers, 3 and 5 axis CNC mills, as well as a multiple industrial robot arms, which he has outfitted with a number of different tools. These tools, typically found in production facilities, he uses to create beautiful one-off architectural installations. He uses these tools to cut stone, shape wood, and carve foam into organic forms that would make Gaudi salivate.

Fabio Gramazio and Matthias Kohler are a pair of these digital craftsmen that are exploring the potentials of robotic arms specifically. They have programmed these arms to precisely lift and place bricks in prescribed digital forms. This manifests itself as undulating walls and screens, and even images across facades. One of their more extreme examples is their use of semiautonomous quadcopters to lift and place bricks with suction cups into a prescribed digital form.

These digital tools provide designers the ability to expand their repertoire of form. The tools can replicate complex, digitally prescribed form, with speed and accuracy not possible with human hands. at the same time, the use of these tools can free up human hands for the finishing tasks at which they excel.
3.3: Wes McGee in his shop

3.4: Canopy designed by Wes McGee

3.5: Gantenbein Winery, Gramazio & Kohler

3.6: Structural Oscillations, Gramazio & Kohler

3.7: Flight assembled architecture, Gramazio & Kohler
ADVANTAGES OF DIGITAL TOOLS

-ABILITY TO REPLICATE COMPLEX FORM, QUICKLY

-HIGH REPETITIVE ACCURACY

-THOSE TOOLS FREE UP HAND-CRAFTSMEN FOR FINISHING TASKS

-ADOPTING NEW TOOLS UNLOCKS POTENTIAL FOR NEW TECHNIQUES, FORMS
“The crafts are a border-ground of manufacturing industry, and nearly every object they make has its counterpart and competitor in something manufactured for the same purpose. In all but a very few trades exceedingly high quality is the last remaining ground on which the crafts can now compete.”

-David Pye, The Nature and Art of Workmanship
IV: HYBRID CRAFT
This thesis seeks to establish a hybrid craft, a prototype of a workflow to be used by architects and designers for fabricators and craftsmen. This workflow should do a few things. It should achieve results that would have been far more difficult to achieve by traditional means. Form and material should be tightly integrated. And the workflow should utilize each skill-set in a manner that makes best use of their potentials.

So what are the best-suited tasks for these two groups of craftsmen? Digital tools certainly don’t get bored by repetitive tasks, and can complete such tasks accurately. Digitally driven machines can handle huge amounts of data, such as defining a complex or unorthodox surface or curve. Precise shapes can be cut, carved, or formed accurately.

Hand craftsmen shine in finishing tasks: Tasks that directly affect the end user’s tactile experience. Sanding, finishing, and refining form, especially in natural materials like wood, are all best suited to human hands. Even automotive designers scrape their clay car prototypes by hand after a machine has roughed it out.

These strengths lead me to establish the workflow as such: Digital tools are used to replicate complex formwork or rough shape of digitally prescribed surfaces. Skilled hands are then used to assemble, fit, and finish components. The result should be complex, organic, “digital” form, skinned in traditional materials.
V: APPLICATIONS
In establishing a project, the scale and program are very important. The scale needed to be small enough to be able to dig into the details, and gain some level of development to the workflow. At the same time, it needed to be large enough to test the premise in multiple scenarios, details, and to gain a sense for the overall affect that this hybrid craft has.

A logical project presented itself in the home: a single-family dwelling. And a local site presented itself: a narrow lot in Mount Adams. The home seemed fitting, as it is currently a place where there is still an interest in craft and materials, and clients will often spend money on the quality of craft in their homes. The home is also a building type in which custom solutions are desired. A larger commercial project may not have presented the opportunity to either get involved in the details of construction, or use materials and form in such a free manner.
MATTHIAS PLIESSNIG

Matthias Pliessnig has created beautiful furniture using what I consider to be a strong workflow for hybrid craft. using CNC cut sections as a formwork, he then skins his projects using steam bent strips of wood. This is very similar to the manner in which many small watercrafts are built today.
Mark Foster Gage has used digital tools extensively in his architecture practice. Here he has utilized CNC technology to carve hardwood installations in a manner that looks like rippling water, lending the name “Liqwood”. These beautiful pieces utilize traditional materials that people recognize as appropriate in a domestic space, however, the form is something new, something not typically seen in the home.
Greg Lynn has been a huge proponent of the computer in the practice of architecture. In this project, he used CNC cut ribs in an “egg crate” fashion to build the form that was digitally prescribed. Upon struggling to find a typical contractor that could guarantee the quality of work in sheet rock, Lynn turned to an Italian plaster craftsman in order to complete the project with the quality that was necessary.
In this project, Gramazio & Kohler have used robotic arms, typically found in the automotive industry, to autonomously pick up and stack bricks. The highly accurate machine allows precise, fluid forms to be achieved in something as rigid as brick.
DESIGN PROCESS
5.16 FILL EXTENTS OF SITE

5.17 EXTRUDE TO CONTEXTUAL HEIGHT
LIFT REAR OF HOUSE FOR VIEWS/LIGHT

SPLIT ROOF FOR INCREASED DAYLIGHT.
OUTCOMES
3RD FLOOR PLAN- MASTER SUITE

2ND FLOOR- OFFICE AND BATHROOM

1ST FLOOR- GARAGE KITCHEN AND LIVING ROOM
The exploded view at left illustrates both the basic parti of the home as well as the various componentry. Those components highlighted in orange follow with their respective processes.
Surface is designed digitally and incorporates programmatic needs, such as seating, shelving, and other surfaces.

CNC formwork is cut in a fashion similar to that for the cavity wall.

Formwork is skinned with steam bent wood strips, in a manner similar to how many traditional boats are built.

The result is a smooth organic form, congruent with what is typically thought of as digital form, wrapped in very traditional materials.
Surfaces for bearing wall are designed digitally, incorporating building systems and space needs.

Digital information is sent to a fabricator, who CNC cuts the "egg crate" armature for the wall system.

Once the armature is assembled on site, a mason builds against this formwork, interpolating where needed, creating the fluid form of the wall in brick.
The truss is cut from steel plates using large format Cnc technology (ie laser cutter, plasma cutter).

Pieces requiring precise bending /rolling can be accomplished digitally. Once all parts are cut and rolled, welders assemble these parts by hand.

Modules can be of varying sizes, depending on site or construction restraints. Finish welding and grinding are done on site to achieve the seamless and fluid form of the trusses.
TRUSS


Gramazio, Fabio, and Matthias Kohler, Digital materiality in architecture, Baden: Lars Müller 2008
BIBLIOGRAPHY