PROCESS

AN ANTHOLOGY OF STUDENT EXPERIMENTS
IN MEDIA AND TECHNOLOGY

2017

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INTRODUCTION

In its twenty-first year, the Duderstadt Center is vibrant as ever. Each year, the facilities support hordes of inquisitive people working at the intersection of arts and technology. The building is a collaborative sandbox enabling students, faculty, and staff to explore applications of emerging trends in digital media. Scholars flock to this creative hub, and there is always something happening in their peripheral vision. Serendipitous collaborations happen daily—a natural result of people sharing work environments and inspiring each other. Constant buzzing activity indicates that users are feeling productive and supported. In some spaces, room configurations change as often as every week, every day, or even every hour.

Strong campus partnerships have led to intentional service models and assessment practices that improve our consultations in the Duderstadt Center each year. Visitors can quickly and easily seek help from our professional staff, all of whom are experts in their fields. Many past and present users, including Design Science alumnus Robert Alexander, appreciate the availability of rare or expensive tools: "In most places, you would have to be focused on 3D graphic design to be able to access something like the tablets in the Design Lab, or you'd have to be explicitly focused on film and video production to be able to film in the Video Studio," says Alexander. "[At the Duderstadt Center], you can walk in and say, 'I have this basket weaving course, and I'm interested in filming in a multi-million dollar recording studio so I can do this basket weaving tutorial.' The response is, 'Okay.' That's amazing."

"It was suggested that I go talk to the people in the 3D Lab [to assist with my thesis performance involving projection mapping]," says Carlos Garcia, GroundWorks supervising consultant and Performing Arts Technology alumnus. "The ability to be able to just bounce across the hall, get advice from them, work with [subject experts] really closely in writing software and figuring out these different techniques, and then come to Design Lab 1 for fabrication help and suggestions, and then bounce back to GroundWorks, and then go to the Audio Studio and record the music for the show, and be able to continually, very quickly iterate between what might be considered disparate fields, and then combine them all into one fluid process in this space, was immensely valuable."

The facilities in the Duderstadt Center have the ability to support a variety of coursework. Staff regularly partner with faculty to introduce new technologies into lesson plans. "In movement science, we use motion capture in our research laboratories, and a full motion capture system isn't typically available for undergraduates to use for their classes," says Melissa Gross, an associate professor in Movement Science and Art & Design. "We can't bring in a class of 20 people into a research lab and teach the students how to use the software and hardware in a research lab. [At the Duderstadt Center], there's a motion capture system that is available for undergraduates to use, and it's a full, state-of-the-art, eight-camera motion capture system, so the students have the experience of actually getting to use research-quality tools as part of their undergraduate education. I actually couldn't offer this class [MOVESCI 437, Motion Capture and Animation for Biomechanics] without the support of [the Duderstadt Center]."

The facilities have enabled some students to become more competitive when they move into the professional world. "I came into [the Duderstadt Center] not even knowing that virtual reality was something that we had—something that the *world* had, not just that Michigan had," says Computer Science alumna and former 3D Lab consultant Rachael Miller. "Coming in here and getting to use virtual reality systems and work on software that I can dig into more deeply than the sort of stuff you would see in a classroom, that's really important [. . .] I've had two Microsoft internships now, and

I'm going into a third one, and I definitely would never have made it to Microsoft if I didn't have something like the 3D Lab on my resume to talk about."

"The [motion capture] industry itself is so hybrid," says Art & Design alumnus Marc Morisseau. "If you can get an understanding of all these different things and how they merge together, then you're one step ahead of your competition, if you are in competition for getting jobs. If you can understand what the programmer has to do to get stuff to you, then you can better communicate with your coworkers, better communicate with clients, and get things done faster and better than a group that can't communicate very well. It's invaluable to get exposed to all of the different facets that [the Duderstadt Center] has to offer."

Many Duderstadt Center facilities have knowledgeable teams of student employees, who are given opportunities to practice creativity, responsibility, and leadership in collaboration with peers, faculty, and staff representing various disciplines. These students support basic services, provide expertise in relevant fields, pursue research projects that advance their academic goals, and maintain the cultural climate. Students often present their work through workshops, consultations, or demonstrations, and they are constantly speaking to new audiences.

"I'm hoping that, based on the projects that I work on and what [visitors] see me do, it will incentivize them to also create their own pieces and create their own technology to further their own interest in specific fields," says Computer Science alumnus and former Design Lab intern Shuvajit Das. "It might not necessarily be computer science, but just seeing other people have fun with whatever they are doing on their own time, working on these various projects, hopefully that will incentivize them to do the same."

"During one of my workshops, I had several students attend who were all interested in projection mapping," says Carlos Garcia.

> They showed up, they met each other, and then a couple months later I heard that they were working on this big project: they were going to do the first-ever projection mapping in [Nichols Arboretum]. They asked for my help, and I worked with them to guide them through the software creation process, through the building and fabricating, and they took it and ran with it [. . .] We work closely with some of the other parts of [the Duderstadt Center] in bringing all of these resources together and giving students, faculty, and staff from what might be specific departments an opportunity to collaborate in a way that breaks down any of the walls they feel like they have in front of them.

Rachael Miller

Robert Alexander

"I knew that in coming [to the University of Michigan], not only would I be able to interact with world-class faculty, but also there's the technological infrastructure to be able to bring these projects to light," says Robert Alexander.

> I was Design Science PhD student, and this means that I had an advisor in the School of Music and in Space Research. In most schools, you would think, "This is crazy, where's the intersection?" But this building, the Duderstadt Center, it *is* the intersection. It's the nexus. It's right between engineering and music and computer science and art and design, and it's so well-situated and focused for that. It's built for that. It's cool to be able to walk into the Duderstadt Center and to be able to throw out this idea and say, "Hey, can we try this?" and to know that the response is going to be, "Yes."

We have had many successes in the Duderstadt Center over the years. This anthology includes just a few examples of the countless projects that have emerged from this building since 1996. The selection of student work featured here is a fine depiction of the various activities we host, but the possibilities in the Duderstadt Center are truly endless. We invite you to visit us—to experience a special place with tools and collaborative space for creating the future.

PROCESS

PROJECT BRIEFS

PROCESS

THE PONTIAC GUARDIAN

BY GRACE MARTINEZ

The Pontiac Guardian is a work commissioned by K and R Studios for their building in downtown Pontiac, Michigan. The project calls for the creation of two matching guardian statues, which will be mounted atop 35 North Saginaw Street. The statues aim to complement the art deco façade of the building, which lacks a decorative frieze. The figures themselves reference both an art-deco style and the Native American motifs of the city of Pontiac.

Process:

1. Sketch statue and clay mock-up
2. Create 3-D scan and digital model finishing
3. 3-D print small version
4. CNC rout and create full-scale version in foam
5. Plaster mold and ceramic cast of 3-D print version
6. Fire and glaze small-scale ceramic casts for distribution
7. Sculpt clay and finishing of full-scale statue
8. Mold full-scale statue and cast in fiberglass
9. Mount both statues on 35 North Saginaw

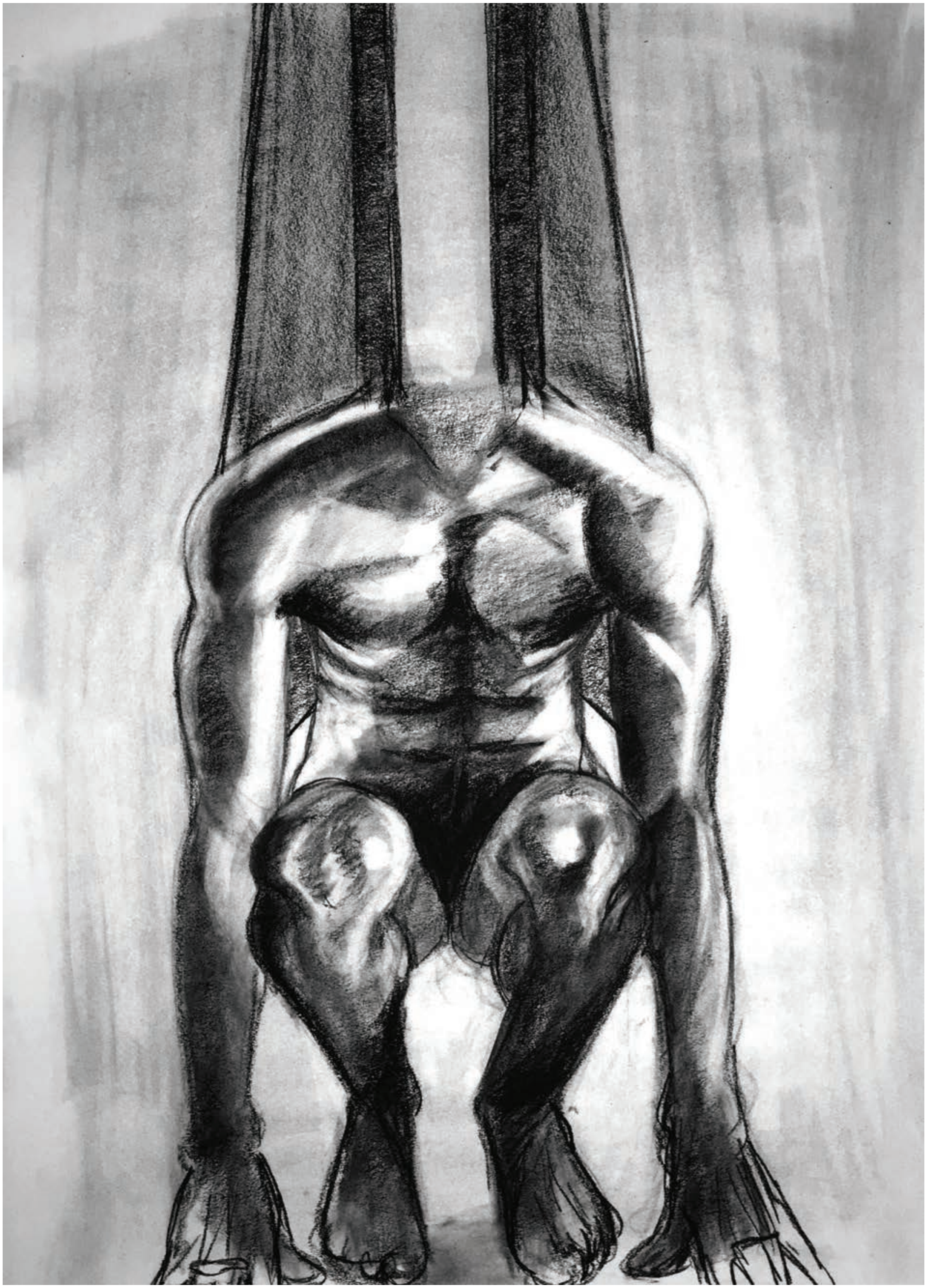


Figure 1. Initial Guardian Statue Sketches.

Figure 2. Initial Guardian Statue Sketches. Concept for statue pose.

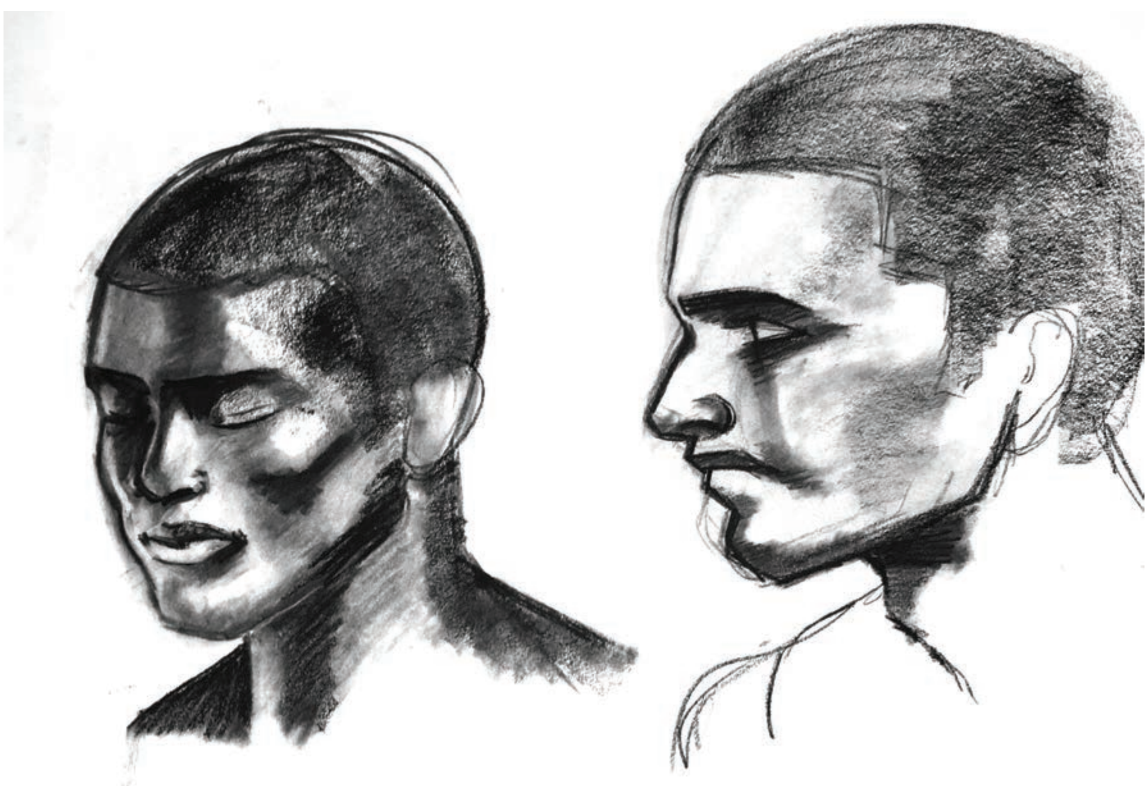


Figure 3. Initial Guardian Statue Sketches. Concepts for geometry of face, highlighting rigid Art Deco motifs.

Figure 4. Oil Based Clay Mock Up of Guardian Concept.

Figure 5. Oil Based Clay Mock Up of Guardian Concept.

Figure 6. Oil Based Clay Mock Up of Guardian Concept.

Figure 7. Geometry of Face and Head Mock Up. Emphasis on rigidity.

Figure 8. Geometry of Face and Head Mock Up.

Figure 9. 3D Scanning the simplified clay mock up. Scan took place in the Duderstadt Center.

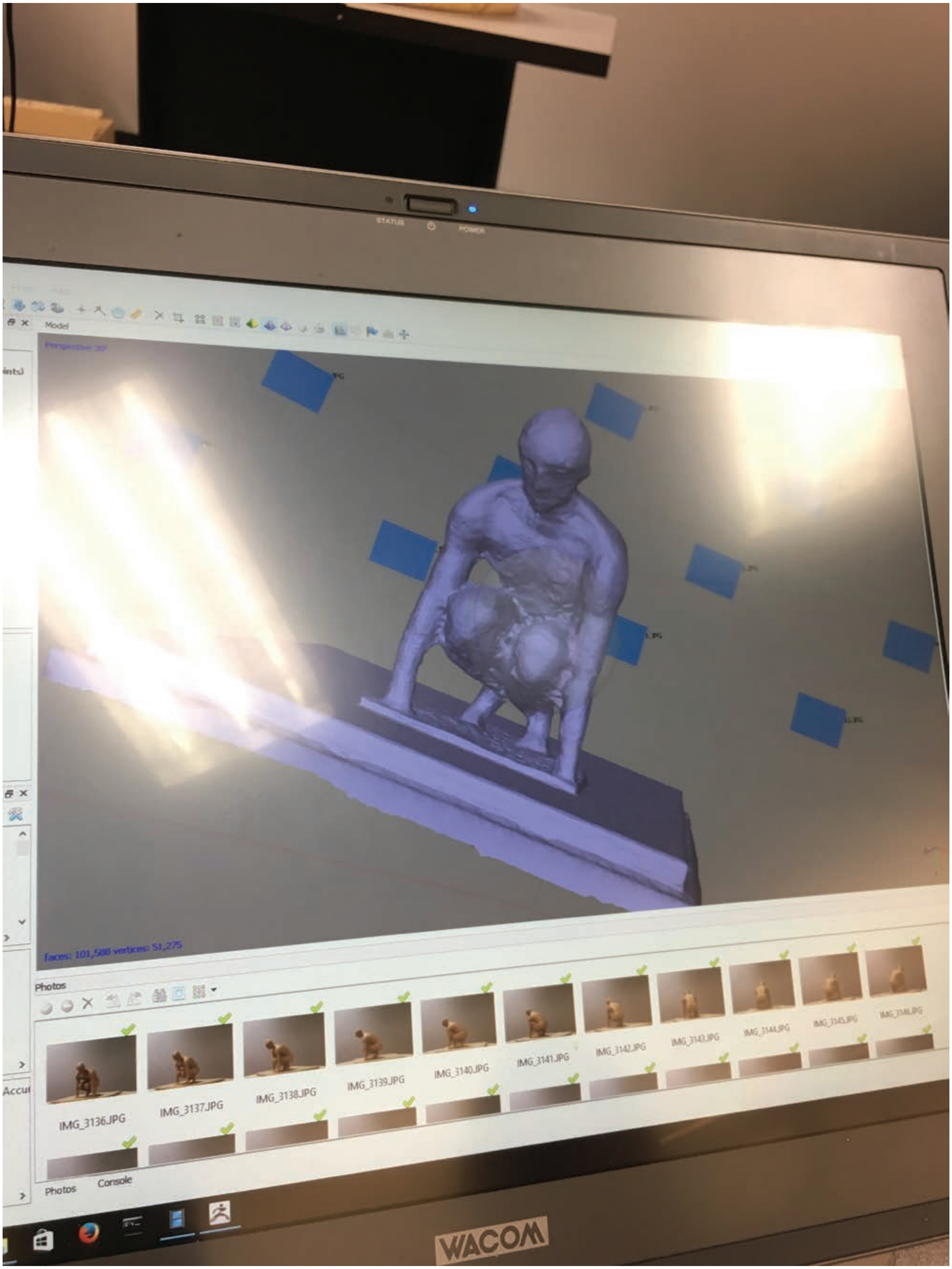


Figure 10. Scan Result.

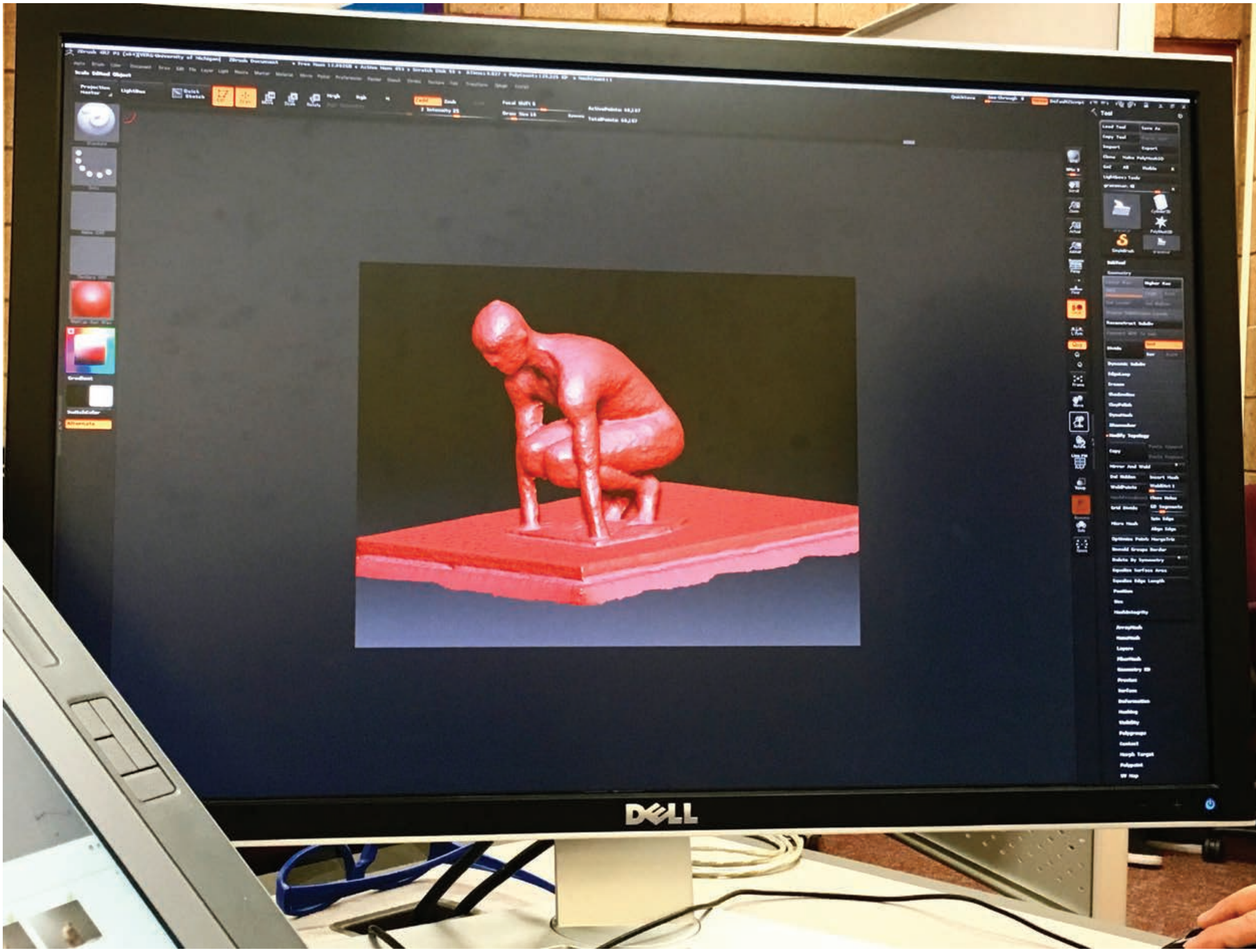


Figure 11. 3D Scan file imported into ZBrush.

Figure 12. Early Remodel in ZBrush.

Figure 13. Early Remodel in Zbrush, Face and Head.

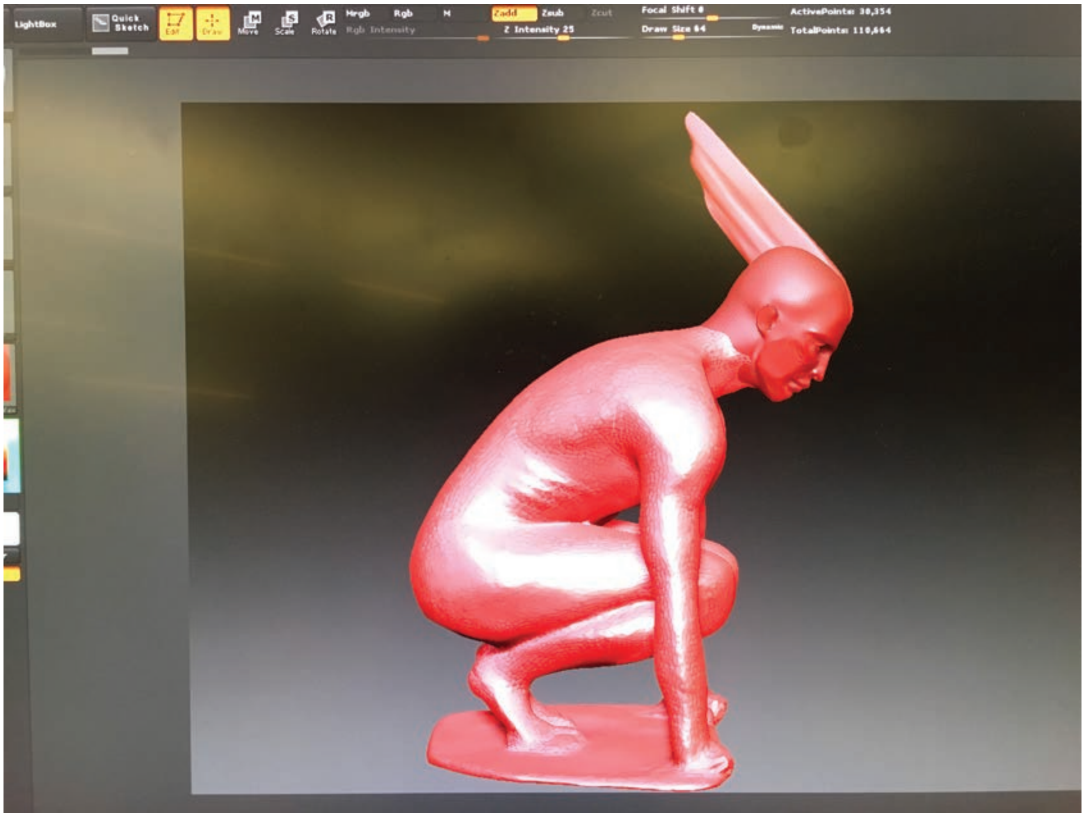


Figure 14. Early Remodel in Zbrush.

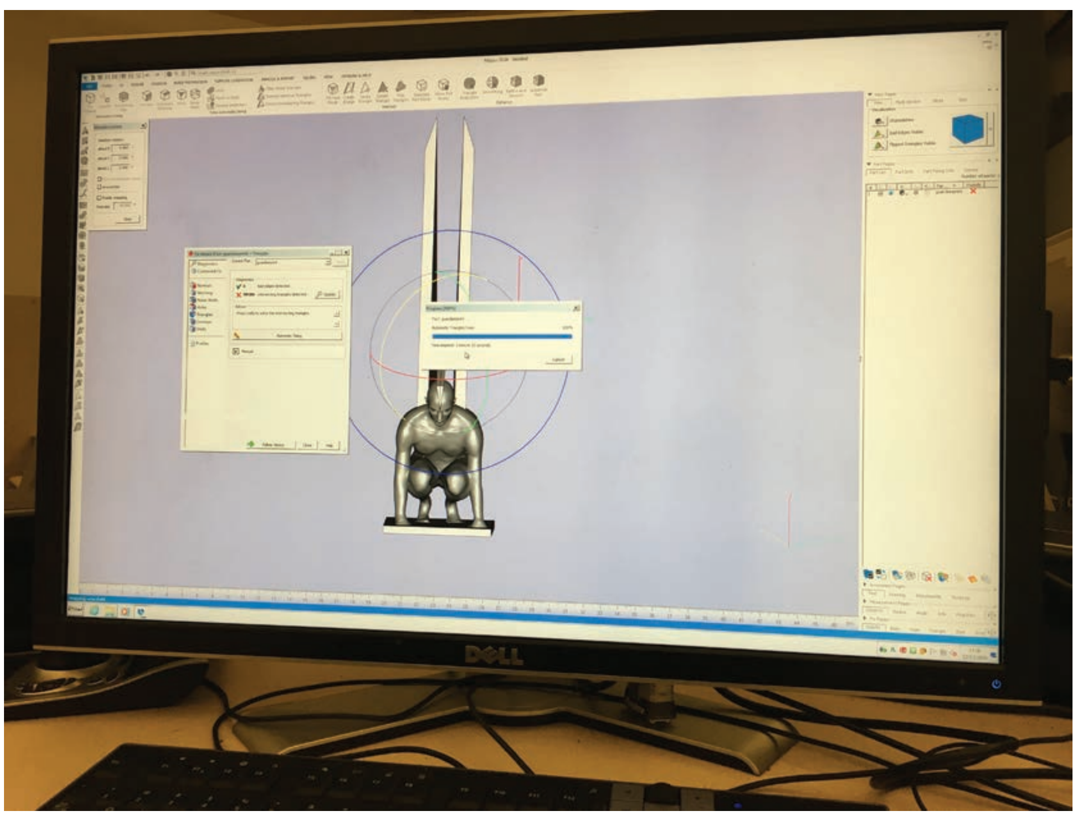


Figure 15. Stl File Fixing in Materialise Magics, Duderstadt.

I began the project outside of U of M, and brought it to Ann Arbor as part of my final project for my intro to digital fabrication class. After the initial sketches and clay mock ups, I scanned my model in the Duderstadt Center. The 3D scanner utilizes three DSLR cameras, which take photos of an object as it rotates. The images then map out points of the object in space which then come together to form the digital rendering. I was assisted in this process by Stephanie O'Malley in the 3D Lab. The 3D scan provided me with a digital model of my sculpture, which I then altered and finished in Zbrush. Zbrush is a modeling software available in the Duderstadt which combines 3D modeling, texturing, and painting. Zbrush lends to this project as a modeling package that offers an experience that is more akin to sculpting. The finished model was then imported into another software called Materialise Magics. This software converted my model into a file format suitable for 3D printing, and ensured that the model would print without any problems. This file format is called an STL (stereolithography), and is generally generated by a computer aided design (CAD) program as a file that describes the layout of a three-dimensional object.

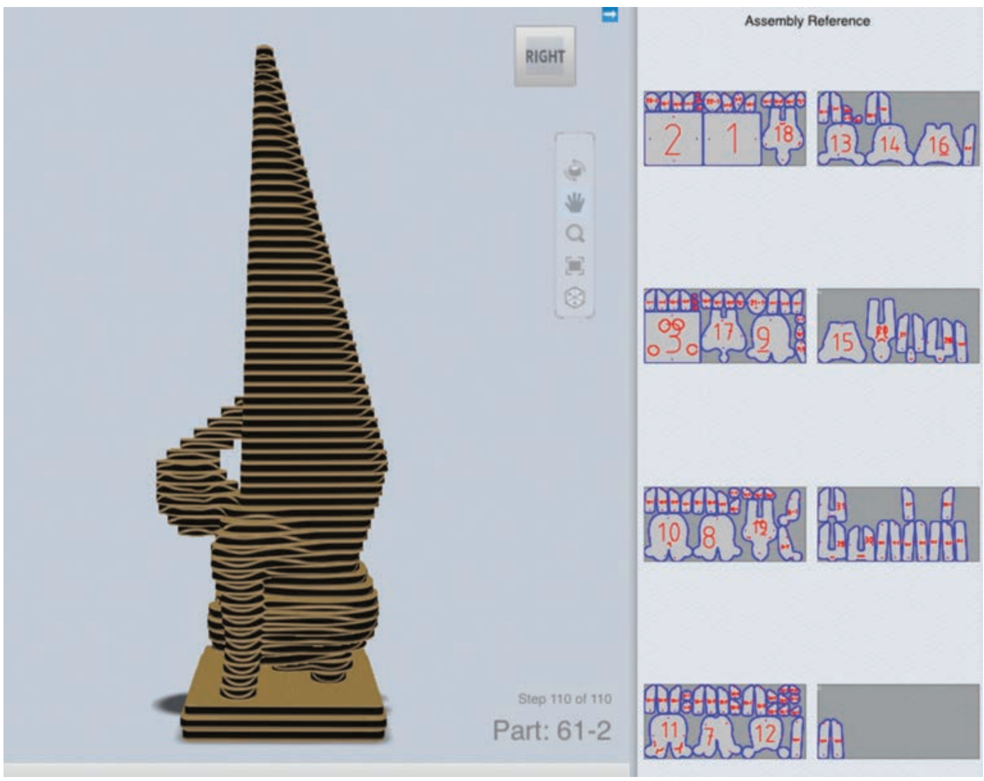


Figure 16. 123DMake File Generation for CNC Routing. Slice depiction on left.

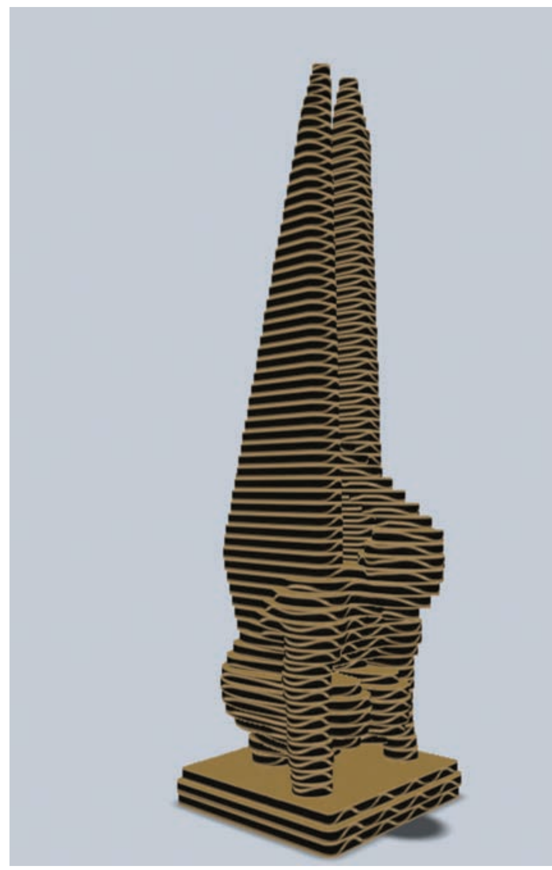


Figure 17. 123DMake Slice depiction.

Figure 18. CNC Cutting Foam with Mike Vitale. Taubman Fabrication Lab.

Figure 19. Foam Cut. Image shows how individual pieces are still connected to the larger sheet. This allowed for me to transport all of the small pieces more easily.

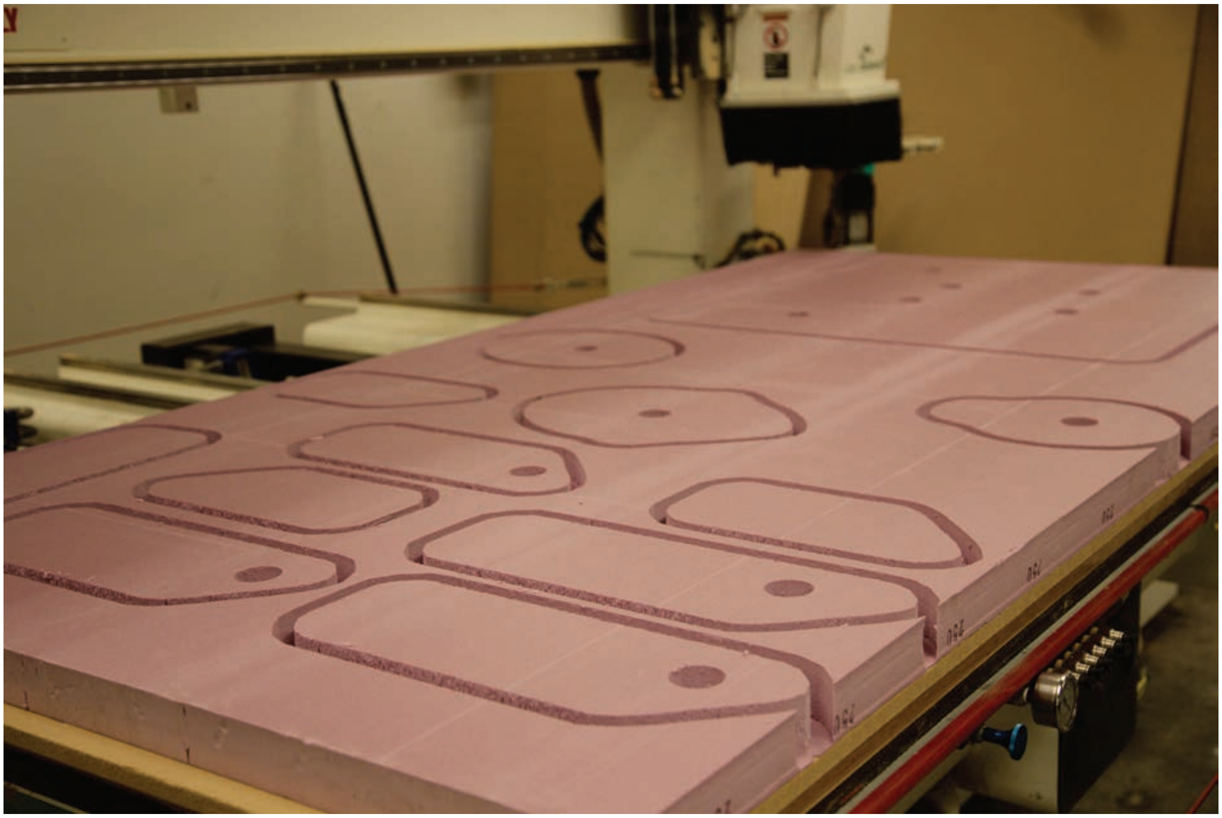


Figure 20. Cut Sheet.

Figure 21. Another fully cut sheet. The numbers written on each piece exhibit the stacking order.

Figure 22. Stacked Sliced ready to be moved to the Slusser Work Commons.

Figure 23. The foam pieces stacked and prepared for full assembly. They broke out of the larger sheet easily.

Figure 24. Full foam assembly.

I then used 123DMake to generate my CNC routing file. 123DMake is a software that turns 3-D models into 2-D build plans with assembly instructions. My model was then converted into a file that would allow me to cut pieces of foam that could be stacked and assembled into my full-scale model. The total height of the statue is about ten feet, and the material I used was a 2″ × 4′ × 8′ pink insulation foam. I chose to use insulation foam because it is easily cut, takes up a larger amount of space, and is sturdy enough to withstand the weight of clay. I cut my foam pieces on the ONSRUD CNC Mill in the Taubman Fabrication Lab with the help of the Stamps DigiFab Studio coordinator, Mike Vitale. I then assembled the foam model in the Slusser Work Commons at the Art and Design School.

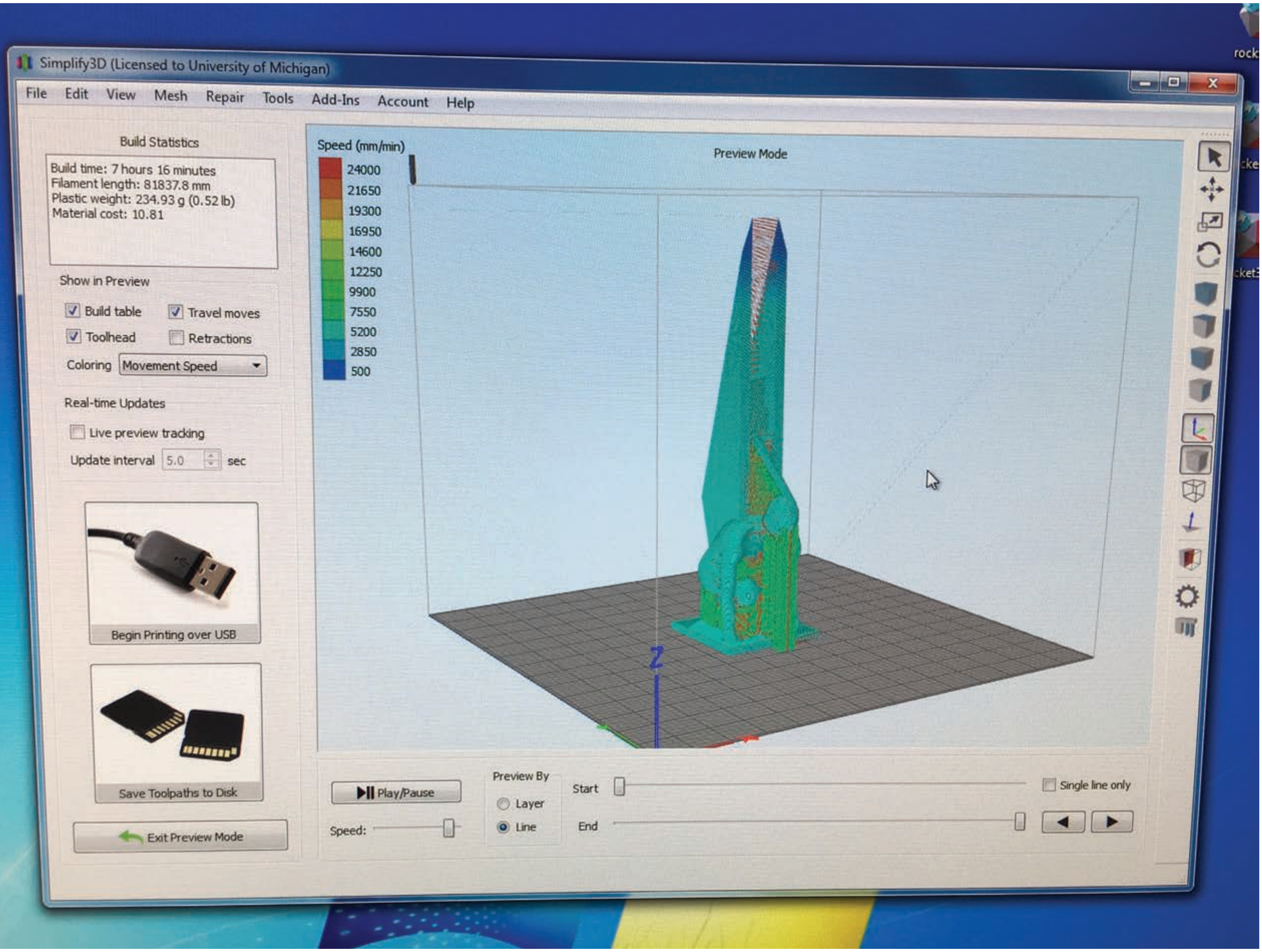


Figure 25. File Generation for 3D Print on the Fusion Printer in the Stamps Digital Fabrication Lab.

Figure 26. 3D Print disaster. File was then fixed in Magics, and reprinted.

Figure 27. Final 3D Print.

Figure 28. Final 3D Print, and Assembled foam model. Next step is foam smoothing and clay application.

At the same time that I was CNC routing and assembling my full-scale model, I was also 3-D printing a smaller version on the Fusion printer in the Stamps Digital Fabrication Lab. Image 27 demonstrates how there were problems with my first model that I 3-D printed. Those problems were fixed in Magics.

At this point in time, I am preparing the small 3-D print for casting. I will be making a mold of the print in plaster, which will then be cast, fired, glazed, and distributed by K and R Studios. The foam of the large-scale model will be smoothed out and then covered in a water-based clay. I will then sculpt and finish the statue in clay, mold the entire form, and cast the figure in fiberglass for the final statue. The date for mounting the final statues on top of 35 N Saginaw is set for mid- to late spring.

I have high-resolution copies of each of the images that follow. Additionally, I have a high-resolution video of my foam statue assembly. You can find this assembly video here: https://www.instagram.com/p/BOOGCCbDOhF/?taken-by=gracemartinez_art

VIRTUALLY DESIGNED

BY DUNCAN ABBOT

It's often happenstance that draws one to a place. During my freshman year, in a knee-jerk reaction to taking EECS 215, I enrolled in a multidisciplinary design course, Creative Process, for the winter semester. Over the stretch of four months, I made abstract architectural prototypes, created wire-and-paper armor, did a dance on the word "bye," and built a 2 × 2-m meditation fountain. Most of these took place in Design Lab 1, a space I would end up considering my home on campus.

Those projects are exactly what is indicative of the Design Lab spaces: creative, abstract, thought-provoking, and most of all, deeply rooted in a passion for experiencing the "new." Working in Design Lab 1, I was able to prototype ideas not just for classes but for any project I was interested in exploring. The community there encouraged me to create without judgment, and visitors from nearby buildings, companies, and departments all popped in regularly to see what was going on and support the creative efforts taking place. As I entered my sophomore year, though I had no courses in the space, you could still find me on one of the couches or surrounded by whiteboards next to the electronic workbench more often than not. And as I entered my junior year, it was time to officially be absorbed into the Design Lab community and support it as a student consultant.

In the first month of my year as a junior here at Michigan, I participated in MHacks, quite by happenstance, and won the best game prize for a mobile virtual reality (VR) app with two of my friends. Dell bought us some nice monitors as prizes, and we felt pretty official, so over the following months, we dove deeper into VR development.

We worked primarily in the Design Labs (as by then I had discovered the quieter but more focused Design Lab 3), and as we met throughout the following weeks, we grew not just our skills but also our network. In mid-October, a defining event happened for our group: we had a chance encounter with the director for Child Life at C. S. Mott Children's Hospital in Design Lab 1. He had come in to chat with my supervisor, Eleanor Schmitt, about VR for children at Mott! I rushed over and joined the conversation. By the end of the day, we were set up to start working with them to try our new mobile VR game, Triangulum. It was then that my friends and I realized the potential for VR and that we needed to start a company. Thus Gwydion (Trapped Note at the time) was born. But that's another story.

I continued working in the Design Labs in the fall of 2016. Part of a student consultant's duties is working on an independent project in addition to aiding students who come in to ask questions about the design process. Because I was now an "expert" on VR, I started playing around with ideas to improve the Design Lab spaces. By October, I had decided to create a virtual tour and orientation for Design Lab 1. Not only would this help alleviate busy times when the consultant on staff was helping a student and couldn't give a tour or orientation, but it also could showcase the emerging role VR and augmented reality will be playing in our lives, particularly in education.

This virtual tour works with mobile smartphones using Google Cardboard. Users install the app onto their phones and put their phones in the Cardboard devices. The phones' camera feeds then show the users the room around them as-is. However, if the users look at certain QR tags throughout the room, descriptions appear and a narrative about that part of the space begins. Arrows overlaid into the users' vision of reality point at specific aspects of each area to draw attention to them as each is described. After the users find all the tags, the app takes them into a purely virtual environment (no camera feed) and quizzes them on what they just learned. If they pass this quiz, their information is passed along to Design Lab management to provide after-hours card access.

As I finish development on the project this semester, I turn to address the details that make or break the app as an engaging and fun experience. One of the great benefits of working at the Design Labs is the diverse host of consultants who work with you; I will be collaborating with them to create compelling visuals and narratives to give the tour a needed edge. By the end of the semester, I intend to have a few Google Cardboards sitting out on a rack under an informational poster about the virtual tour. People could walk in, read about how to download the app, then use it with a Cardboard. I hope this virtual experience can help adapt the space to be in tune with the next wave of technological developments but also keep people connected and excited to be there. As I graduate, I want to leave behind something meaningful, a little piece of me, to always live in Design Lab 1.

PROCESS

TABLETOP CARVING PROJECTS

BY JOHN SCIORTINO AND ISAAC LEVINE

In order to test the capabilities of the Design Labs' new machine, Carvey, we have completed a series of projects that have allowed us to explore the different ways in which this machine interacts with various materials.

Introduction to Carvey

Carvey is a tabletop carving machine manufactured by Inventables that gives users an opportunity to turn their ideas into physical objects. The Carvey machine uses a housed CNC router that features an 8″ × 12″ carving surface. The machine is paired with the online application Easel, which offers a three-axis modeling interface. Users can design their own objects or import Scalable Vector Graphics to be carved out of a given material. The Easel interface requires users to manipulate the depth and 2-D pattern of the carving process (within the limits of the 8″ × 12″ area), and they must also choose the size of the carving bit that will best interact with the material they have chosen. The size of the bits range from ⅛ inch to more miniscule sizes that can be used for highly detailed designs or drilling holes. These bits can be used with various materials including aluminum, copper, MDF, plastics, acrylics, and different types of wood.

Unlike many other visual design or 3-D modeling programs, Easel has a limited number of tools for designing paths or objects for carving. Though at first this may seem limiting to advanced users, the few tools available make modeling easy for *all* users—regardless

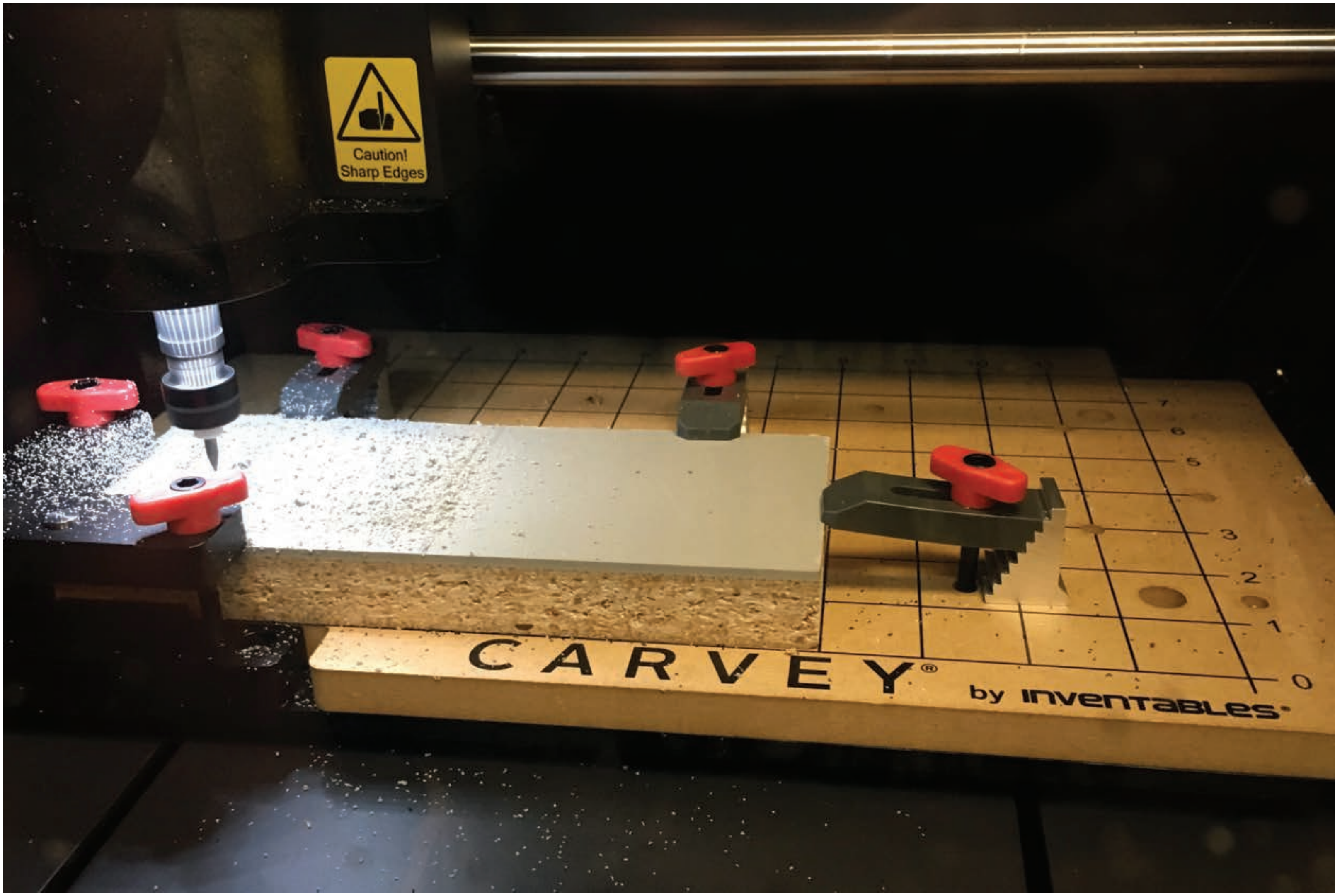


Figure 1. Picture of the Machine

of previous modeling or design experience—and present a faster, more approachable method for designing patterns or objects than programs like SolidWorks or Adobe Illustrator. Easel offers a library of shapes, and the user can incorporate lines, rectangles, ellipses, triangles, stars, text, or a variety of icons into their model. The application also lets the user customize depth values, object positions, and angles to whatever decimal values they need.

The scale of the machine's design capabilities ranges from patterned surface etching to full-scale 3-D object fabrication. Simple projects like surface etching can be completed in thirty minutes or less, and more complex projects that aim toward 3-D object fabrication can take upwards of three to four hours (or more, depending on how fancy you're getting). Because of its compact size, and the fact that it requires no ventilation (though a vacuum is useful to keep the carving space clean inside the machine), Carvey is a valuable machine that finds its place comfortably in any classroom, maker space, or shop, with area dimensions of 20.5″ × 21.7″ and a height of 16.6″. It only needs power and a connection to a computer with Internet access, which can access Easel and pair it with the machine.

From our tests of the machine in WorkBench, we have found Carvey to be very successful when carving stamps out of linoleum, which can be useful for branding, various merchandise ventures, and

Figure 2. Stamp with Brayer

personal projects. These stamps usually take about thirty minutes to an hour to carve, but they last a lifetime and can be used on fabrics, stickers, or any type of paper. Isaac and I have taken on a more ambitious and time-consuming venture: an attempt to design and carve a cassette tape case. It involves carving the housing for the cassette out of wood and carving out a piece of acrylic for the cover.

Our goal of carving these stamps, and the cassette tape case, has been to gain valuable information about what kind of carves the different bits can handle and how fast the machine can be run. We plan to continue testing the capabilities of this machine by carving different materials with more nuanced designs and reaching out to other members of the university community who may find access to this machine valuable and useful to their creative, academic, or professional ventures.

Carving a Cassette Tape Case

This project is an anomaly, so before describing our prototyping process, we will describe the final product. It is a wooden cassette box, with an acrylic cover, that uses star-shaped spokes to hold the cassette in place and a fancy hair tie to hold it all together. Inside is a cassette tape—labeled "The Cassette with the Sound of Its Own Making"—which contains a recording of each of the previously mentioned pieces being cut out inside of Carvey, from start to finish. It is a cassette with the sound of its case being assembled *inside* of its assembled case.

The creation of this arguably too-conceptual product led us to learning situations with digital fabrication, as well as scenarios for philosophical conversation about the role a CNC machine can play in a community.[1] The below article aims to document the progress of both our understanding of the CNC machine's cutting abilities and our understanding of the role it could play. We are also both in bands, and that's why we made cassettes. (Don't bully us about our nostalgia . . . we are quite aware.)

Fabrication Process

Our goals when designing and building a cassette tape case with Carvey were to make a product that is more durable than plastic cassette tape cases and to explore the ability of Carvey to carve wood and acrylic. During this process of both designing and carving the cassette tape case, we attempted to decrease the time of the entire carving process down to the shortest time possible and discover which bits and cut rates interacted best with our given material. Over the course of cutting four slightly different cases, whose dimensions were modified from one to the next in order to improve our design, we discovered that there is a point at which the increased speed of the carve sacrifices the quality of the carved product and also threatens the durability of the bit itself. Additionally, due to our attempts at designing friction-fitting points on the case, we also discovered that there were dimensional modifications that needed to be made when designing on Easel to accommodate the size of the bit that was being used during the carve. Overall, Carvey interacted very successfully with the wood and was effective, but it made for a gnarly carved edge on the acrylic.

Our first design began by collecting measurements to provide the appropriate amount of space for a cassette tape to fit snuggly into, by measuring the dimensions of the tape itself. We also drew inspiration from plastic cassette tape cases to use pegs that would hold the cassette tape secure in its case, but chose to try to pair it with an acrylic cover that would be designed and combined with the wooden case separately. We were lucky enough to find a large piece of wood deep enough to accommodate the thickness of the cassette tape and the thickness of an acrylic sheet that we would attach to cover and secure the tape in its case. We made sure to leave extra space in the case around the tape itself, and not to make the pegs too thick, so that we could improve our design in future trials by making it a tighter fit, rather than having a first trial that could potentially yield a case that was too small for a tape to fit into.

This first trial yielded a case that was effectively cut, and fit the tape with a comfortable amount of space around it, with the carve taking more than three hours to be completed. But in comparison with later trials, it seemed that the Carvey machine completed a more precise carve of the design that we envisioned on Easel when given more time to perform the necessary cuts throughout the case. However, we intended for this project to serve as an opportunity to test the maximum capabilities of the machine, so we looked into ways to speed up the case's fabrication.

1 We aren't the only people doing this sort of work, of course. For more digi-fab community queries, check out the Sudo Room's website, http://sudoroom.github.io/sudoRoom-Projects-Landing-page/, or the "additivist cookbook" (more heady than us, we swear): http://additivism.org/cookbook.

The Easel application allows the user to modify the bit size used in the machine and three cut rate settings, which include a feed rate (in/min), plunge rate (in/min), and depth per pass (in). Additionally, the application provides you with a time estimate for how long it will take the Carvey machine to finish carving out your design, and we found that the time could be decreased by slightly increasing any of these three cut rate settings. So for our second carve, we continued to use our ⅛-inch bit but increased our depth per pass by only a one-hundredth of an inch, which decreased the total carving time by more than an hour. This provided us with a much more reasonable time period for a carve but yielded a case with minor flaws at points on the case and a noticeably less smooth finish. However, none of these affected the structural integrity of the case.

For our next design, we changed the design from having cylindrical pegs to having pegs with a starred face, to see if the machine could handle a more detailed design and if our ⅛-inch bit could handle more intricate cuts. Unfortunately, we experienced a failure with this second trial, which was not due to the performance of the machine but instead due to the circumstance that we did not leave enough space around the case to remove it from the 8 × 12-inch wood block that we were using. This made its removal very difficult, and eventually resulted in the case being cracked into two pieces during the attempted removal process. We made another cut of this same case design, increased the depth per pass by another hundredth of an inch, and left the appropriate amount of room around the case for an easier removal. This yielded a case whose structural integrity was mostly intact but resulted in two small fractures along the borders of the case, which we believed was a result of the speed of the carve being pushed too fast. But even with the small fractures on this case, it had enough structural integrity to allow us to test out different cuts of acrylic to use as a slide-on case.

Initially, we attempted to carve out case covers with 1/16-inch acrylic that would use a friction fit with the case to slide over the cassette and keep it inside the case. Unfortunately, we experienced difficulties with this particular sheet of acrylic, because its thinness made it tough to secure inside the Carvey machine and, consequently, led to it moving slightly through the carving process, which negatively affected the precision of the cut. After various carving trials of these acrylic case covers, we were not able to get the exact dimensions that were necessary for a friction fit, which we believed was due both to the instability of the acrylic during the carve and also to the dimensional changes that resulted from the bit size when making the cuts. Later, we attempted to use a 1/16-inch bit instead of a ⅛-inch bit to improve our dimensional results, but this instead resulted in the bit being broken while carving the acrylic.

So for our next and final trial of carving this cassette tape case, we ordered an ⅛-inch sheet of acrylic and used a laser-cutter instead of the Carvey machine to assure that we would obtain a case cover with the proper dimensions for a friction fit with our case. This also required that we modify the depth of some of the cuts on our case design to accommodate this thicker piece of acrylic. We used the cut rate settings that had yielded the best results for us up to this point, an ⅛-inch bit, and completed our final case cut in just over an hour and a half. After some minor sanding of the borders within which the acrylic cover would slide between, the acrylic case cover fit snugly and secured the tape inside. We chose to wrap a hair tie around the case and its cover to assure that the two would stay together and to keep the tape safe.

The difficulties and successes that we experienced over the course of this tape cutting have been extremely valuable to our growing relationship with this machine. Because the size of this machine is so compact and its design interface so easy to use, one can be led to push this machine to perform beyond its physical capabilities. However, we now understand that even with its fascinating faculties

Figure 3. Finished Cassette Tape Case

for fabrication, users must pay great attention to balancing the speed, detail, and quality of the performance of the Carvey machine if they wish to yield a final product that bears the most fidelity to their original design.

Our time spent with the Carvey machine moved us to accomplish a project that even at the beginning felt much too metaphysical. But we felt that it was important to provide a singular product that could provide some documentation about the experience that this machine has had in our space. So before our final cassette tape case was carved, we came up with the idea of inserting a tape into our final case that could inform listeners about the experience of its fabrication. Both audio enthusiasts, we had grown fond of the various noise patterns outputted by the carving process of the Carvey machine and decided that an audio track of a carve deserved to be housed in the thing that was being carved at the time. Thus we set up two microphones next to the Carvey machine and recorded the hour-and-a-half-long carving process of the machine cutting out our final cassette tape case, which was spotted with instances of our movements about the room and hushed conversations beneath the humming of the machine. After some very minor mixing of this audio track, we burned it onto a CD and headed over to Groundworks to use their tape dubbing machine to transfer the track onto a cassette tape that we had picked up. The tape is titled “The Tape with the Sound of Its Own Case Being Made” and now resides in our final, finished cassette tape case as a hallmark to the joint efforts of ourselves and the Carvey machine.

Building a Community

Why would you use a modern CNC machine to cut out stamps, patches, stickers, CD covers, poetry book linocuts, and cassette cases? Why would you use a modern technology to make your own versions of older consumer items?

Our goal in this investigation of Carvey was to think of and develop a practical human-machine cooperative paradigm that encompasses the tenets of DIY-musical culture and community. We would like to think of a CNC machine as a community tool and think about what it can offer to citizens of a tactile space and their ability to spread their artwork and activism within a community. We are also trying to think about how to physicalize community in a climate in which online and virtual services offer opportunities for distribution and then transition to pay-to-play models.

PROCESS

NOUGHTS AND CROSSES

An Easy Animation Apparatus

BY LIAM MEISNER-DRISCOLL

I am a third-year student majoring in screen arts and cultures as well as an officer of the Michigan Animation Club. Essentially, my project is about making an animation apparatus that is more friendly than intimidating—that is, something anyone with an interest in how drawings come to life can pick up and put down without first having to understand the various eccentricities of an expensive animation software or to acquire the intense patience of the traditional animation process. Cinema evolved out of fun and simple animation devices like the phenakistoscope, and I would like to rekindle such elementary illusions using the convenience and authorial capacity of modern tech.

My progress on this project has been very rewarding, and I am happy to share its story from the beginning.

As a newly hired intern in September, I had no idea for such a project until I met a newly hired intern, Kevin, a student in Stamps. He recommended we get to know each other by drawing a figure back and forth on paper: I'd make one drawing, and he'd make the next. The special bit was that the figures were to be drawn in sequence, side by side, as if each drawing were a new frame in an animation. When I asked him where he learned to do this, he said he came up with this activity himself.

Kevin's activity was a success, and we had a lot of fun. What an interesting thing to do, drawing things in proximity as if they progressed through time. Days later, it

An Early Phenakistoscope
Image from Wikipedia

prompted me to ask myself, What if there was a way to treat these adjacent drawings as if they were frames in an animation and then project them in sequence, producing an animation, by means of some program? I told Kevin, and just like that, I had my project idea, epiphanized through friendship and collaboration.

I got to drawing out what the rig would look like and what it would do. There would be a tic-tac-toe-esque grid of paper in which someone would draw; a fixed camera, aiming at the grid, which would photograph the whole grid at once; and a computer that would make the magic happen by divvying up the separate quadrants into frames and stacking them into a .gif animation file, the type you can place in an e-mail or a message to a friend. Aside from failing Engineering 101 freshman year, I had no experience with coding, so I knew it would be a while until I would get what I was aiming for.

Explaining to my manager that I thought I was a little in over my head regarding computers, she led me to some resources that would prove helpful in getting hip to coding again (or for the first time). My first weeks in the Design Lab were spent completing amusing projects out of the lab's interactive Arduino Starter Kit with another intern, John, interested in learning to code. The projects were simple, but they provided a superb gateway to the interface. Now, before I would start my own project, I would need to choose and understand the most appropriate coding software, an open source program called Processing, for what I wanted to do, a venture I could not have made were it not for the tech-savvy fellow interns in the lab; they could help point me in the right direction or be confused with me. Thank you, Duncan, Isaac, and Daniel!

Flashing forward a few months, my grid of paper had been replaced with a dry-erase board. This is because the markers use such broad strokes, and it is so much easier to edit drawings with a finger or cloth than a pencil's fine eraser; I wanted to make it more simplistic. My coding is by no means exemplary nowadays, but I managed to cobble together a program in Processing that has achieved all those things I wanted previously plus a few more.

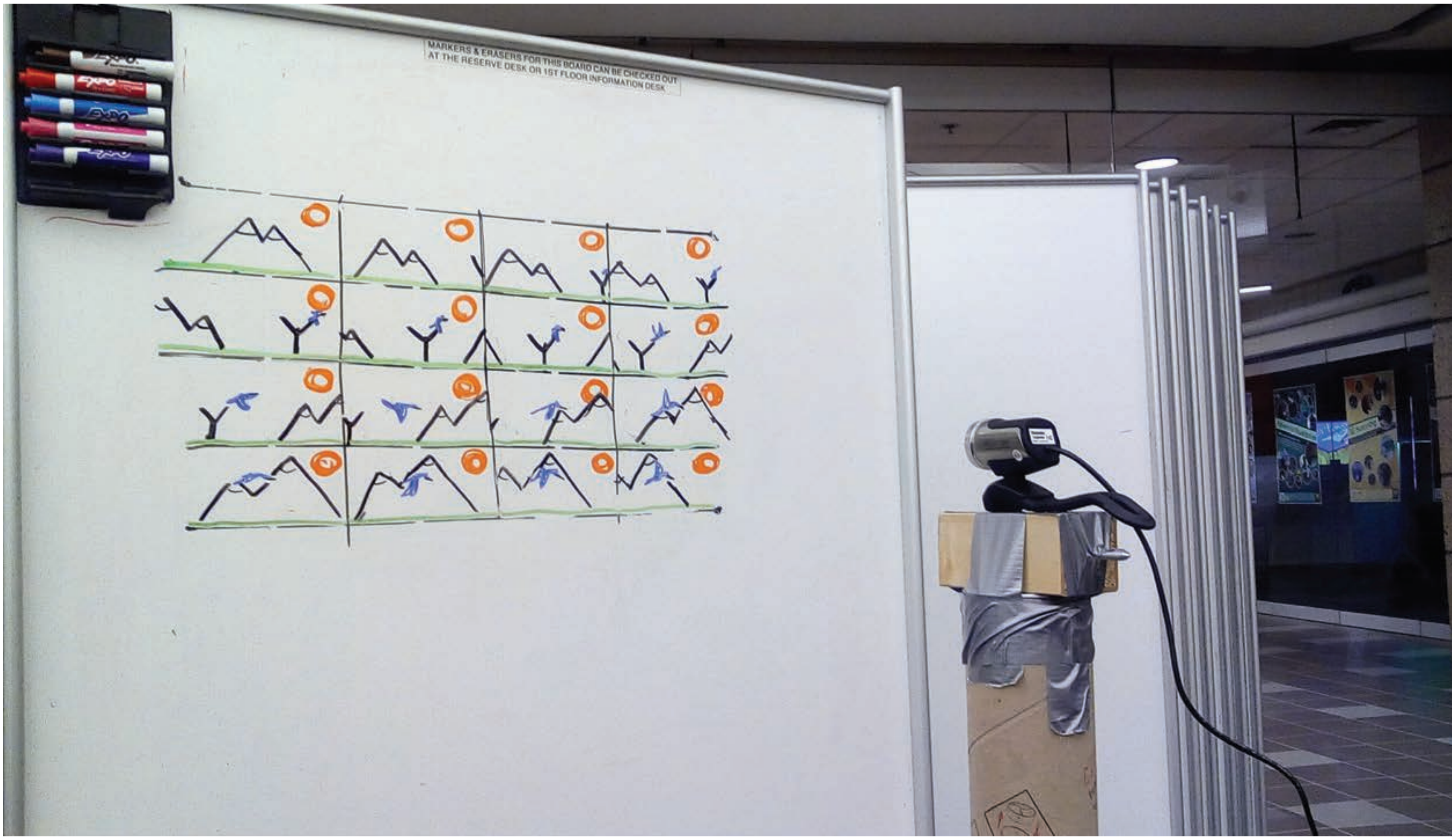


Figure 1

Figure 2

My technical goal was to make it to a 3 × 3 grid, but I had made it all the way to a 4 × 4 and now onto a 5 × 5. The only problem with this advancement is the unavoidable loss of image quality as each quadrant gets smaller. To remedy this fuzziness, my program now takes the shrunken image, blows it up to high definition, and then contrasts the image into black pixels and white pixels, sharpening the output animation, which is automated into a .gif file all with a press of the button! I will be trying to fit some colors into this limited spectrum quite soon.

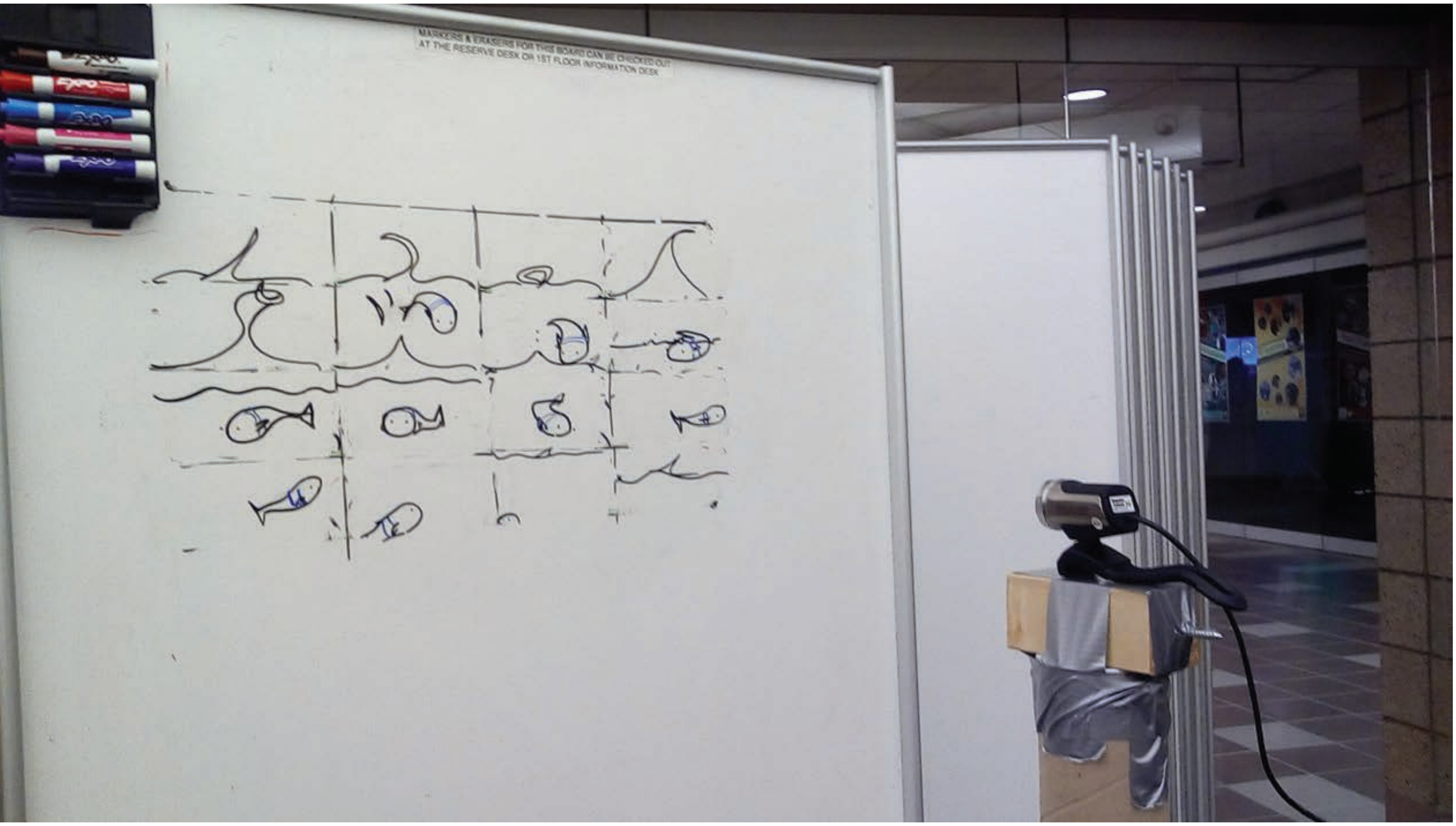


Figure 3

Figure 4

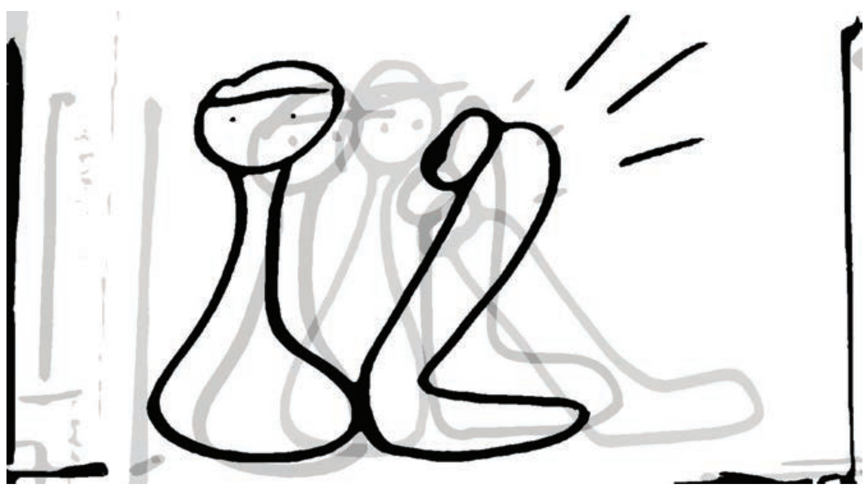


Figure 5

The biggest steps left in my project, dubbed “Noughts and Crosses,” as my project somewhat resembles a tic-tac-toe board, relate to finding a decent way to set it up. Before, I would have to point the camera at a board, trying my best not to budge it as I drew the grid out with a marker and ruler. Next, I would try to tape a permanent grid onto a whiteboard, matching it over a digital pink grid superimposed on the camera feed in Processing.

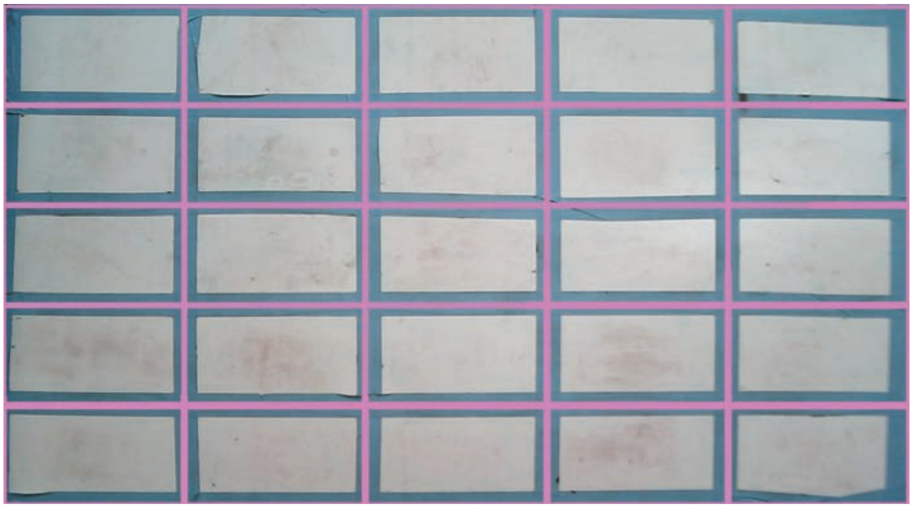


Figure 6

Still, not ideal, and the smallest jostle is enough to unsync the frames. One thing I could do would be to find a permanent spot to fasten the camera. That would create a definite station for the rig. The other idea, given to me by a student working in the design lab (I believe her name was Fay), was to use lasers! This would make for a more mobile device. For my 5 × 5 grid, if thirty-six dots were projected wherever the camera was pointed, the grid would match wherever the camera is, automatically moving with it. Just take the dots as the vertices of the boxes.

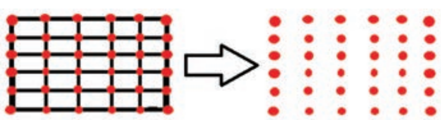


Figure 7

The next steps involve testing out diodes and laser pointers in a smaller array. Wading through the screen one frame at a time, I am very proud of my progress on this project and very grateful to all the wonderful people around me in the Duderstadt Center.

PROCESS

PROCESS REFLECTIONS

PROCESS

STRING ACCORDION

BY KEVIN ALLSWEDE

Introduction

I make digital musical instruments. I find electronics sensors, hook them up to credit-card-sized computers, and write software to create sounds that react to the sensors. I like to put all these components in enclosures made of cheap ¼-inch plywood. I'm lucky to have access to a laser cutter machine, which allows me to use computer-aided design (CAD) software to cut precise designs into wood with lasers.

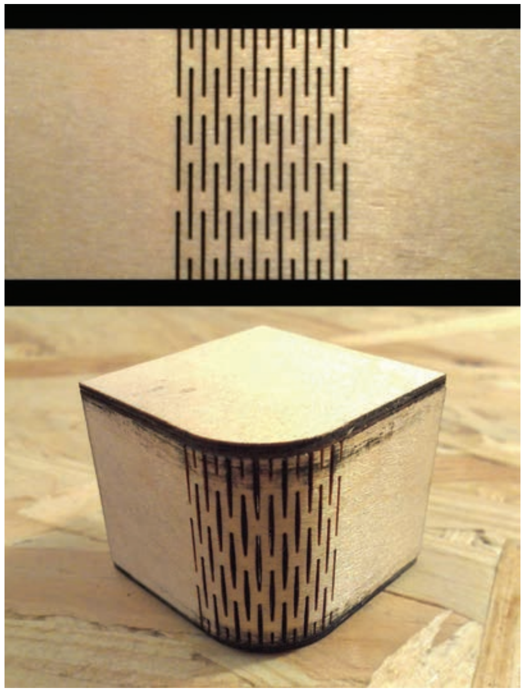
It's difficult to make a digital musical instrument (DMI) *feel* like a real instrument. Because the form of a DMI does not determine the sound that comes out of the computer, creating an "instrumental feeling" (whatever that means) is an important aspect of the instrument. Most instruments are ergonomically designed, and I wish to capture that feeling in the instruments I build and perform with. I want an instrument to feel good in my hands. Plywood doesn't usually feel good in my hands.

Why plywood? Because it is a cheap and relatively strong material that can be easily cut by a laser cutter. A laser cutter is exactly what it sounds like: a machine that cuts things with a laser. I can insert flat materials (like plywood) into the machine, upload a CAD file, and with the push of a button, the laser cutter guides a laser to accurately and precisely cut whatever I designed. The laser cutter I have the pleasure of using is an Epilog Laser Helix, which allows me to cut pieces up to 24″ × 18″ × ¼″.

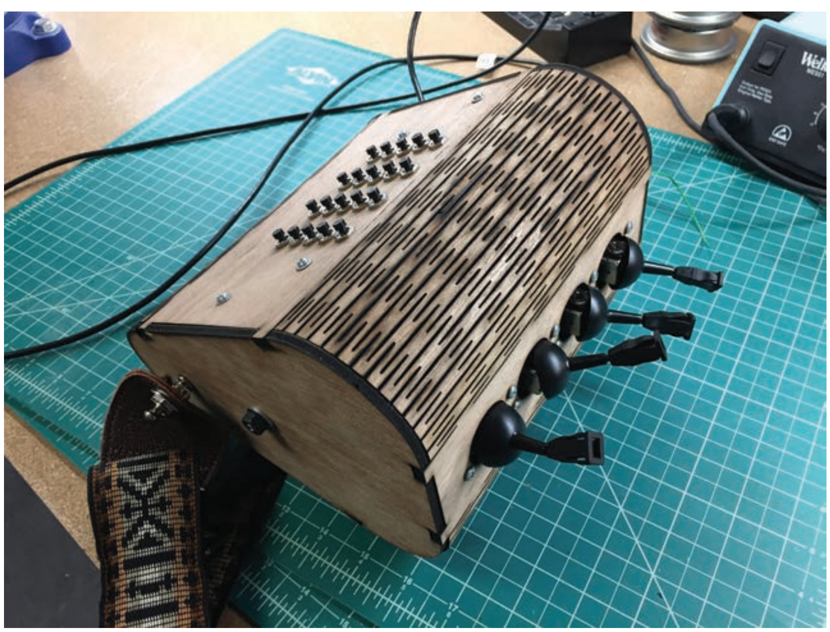
The first instrument I built had an enclosure that was literally a box with holes in it. I put a guitar strap on it and called it good enough. By the time I was looking to improve the instrument, I had done some research into using plywood to make non-box-shaped objects. I stumbled upon a technique called "kerf bending."

A kerf is a slit made by cutting. If you can cut a certain pattern into plywood (perhaps with a laser), it is possible to bend thin plywood without breaking it. I use this technique to build enclosures that fit the curve of a palm, because a handheld box doesn't feel much like an instrument to me.

The most basic laser kerf pattern looks like this (from Instructables):



As shown above, cutting this pattern of staggered lines into the plywood relaxes it enough to bend a corner without breaking. I used this exact pattern in the second iteration of the instrument I mentioned earlier. That instrument is called the String Accordion, and it looks like this:



The String Accordion uses retractable string mechanisms (recycled from GameTrak video game controllers) as sensors for an instrumental interaction. The first iteration was housed in a box, the second iteration in a rounded triangular cylinder, and I'm currently working on a third iteration as part of my master's thesis (Media Arts MA) at the University of Michigan.

While this article details my process for making a DMI enclosure using lasers and plywood, the larger picture is my dream to make a DMI that I actually like and want to play. I'm trying to build something that sounds and feels right to me (whatever that means). My previous attempts have left me unsatisfied on all fronts: the sound, the interaction, the feeling, the look. I feel like sometimes get a hint of one element that seems right, but the combination has been far from right so far.

This instrument building (and performing) process is a major component of my master's thesis. The research community dedicated to DMIs is very good at using the latest technology to make new instruments, but few people actually engage with the instruments as part of their artistic practice. I believe that when the instrument is first built, the research has only just begun: I am interested in how DMIs are used and how their use may inform how DMIs are made. Perhaps more important, I'm interested in how they can be iterated on and what that means for musical practice with DMIs.

This article will now shift into a journal entry format, sharing my perspective on the process of creating the enclosure for my next iteration of the String Accordion. I start with the idea of wanting a scaled-down version—one that fits in the hand rather than slung via guitar strap. I have an idea for a "two tacos" design, reducing the number of enclosure pieces to two (from three in the previous iteration).

January 22, 2017

At this point, I've made two physical prototypes for instrument enclosures.

Physical Prototype #1: Cut on January 17, 2017

The first prototype tested my "two tacos" design idea, employing laser kerf-bending techniques in plywood to make an enclosure with two bendable pieces. It nearly worked, confirming my design theory, but failed due to my error in forgetting to account for the material's thickness; the pieces bent around each other, but the holding tabs were not lined up. I broke both pieces in half coaxing them to fit together.

I also tested engraving an intricate design into the surface of the instrument. I was hoping to line up an engraved design to appear continuous around the instrument. The laser cutter I used was able to make the designs clear. The engraved design did not line up how I had hoped in the CAD file, and if I decide to employ a similar design in a more finalized instrument, I'll need to replace the design. My reason for including engraved designs is to help the DMI look more beautiful in a traditional instrumental sense.

Physical Prototype #2: Cut on January 18, 2017

I fixed my measurement errors in the previous CAD file. I started working on another engraving scheme but decided to save that for later, when I would have a more solidified prototype. I cut the updated CAD file, and it at least fit together. There was some awkward spacing in its three-dimensional form that is at least partially attributed to the use of a warped piece of plywood, but at least I had something to feel.

I knew I didn't like the feeling almost immediately. The bend where the hand wraps around feels too large to comfortably employ finger dexterity in any useful way. The body feels too long and would probably be heavy with electronics in it. When holding it and gesturing in a way that feels natural (like playing an accordion), I knew that the current design would not facilitate that movement in a satisfying way.

While ultimately unhappy with this implementation, I still think the "two tacos" approach may still have merit. I'm now considering cutting bends with obtuse angles for better ergonomics. I'm also sketching out other possible enclosure shapes that may yield better results.

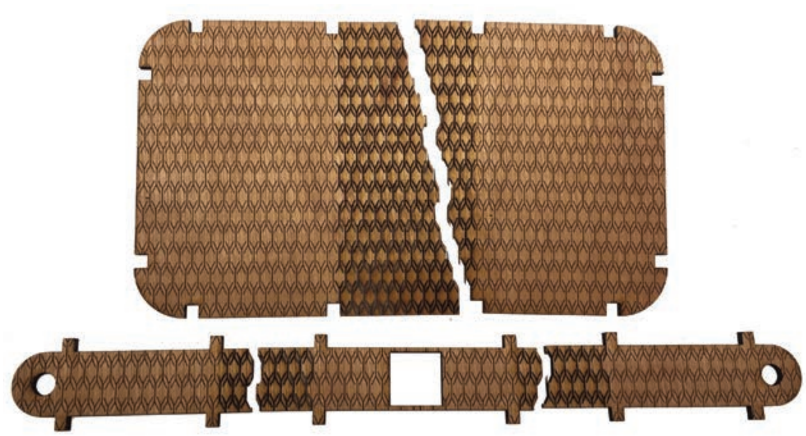
I've almost run out of good plywood at this point, so I need to get some more soon. I also need to come up with a couple more CAD files iterating on the "two tacos" method.

January 26, 2017

I have acquired a large sheet of ¼-inch luan plywood and cut it down into 24″ × 18″ pieces for use on the laser cutter.

Physical Prototype #3: Cut on January 25, 2017

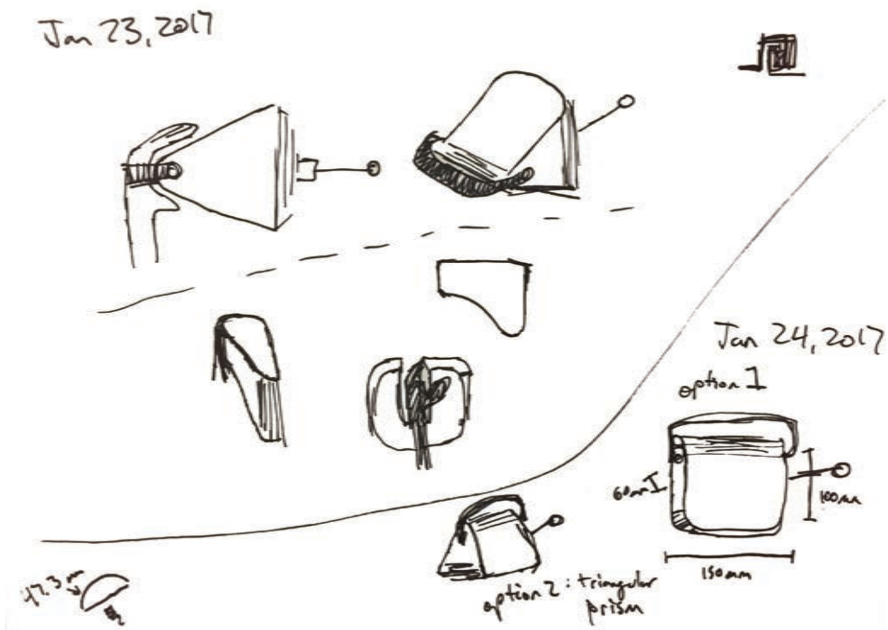
I started by sketching out an inverse "two tacos" design. Instead of cutting a curve into the end, I decided to try cutting a curve on top so that the hand faces down when using the instrument. If this works, the resulting musical gestures would (theoretically) facilitate better control of the string in the x-y plane.

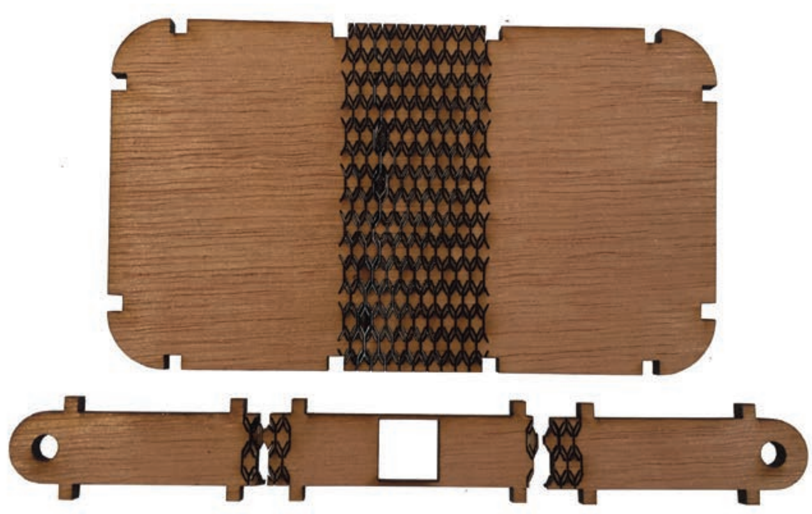


I also decided to try a new kerf-bending pattern. I saw this pattern online and thought it might make a smoother feeling curve. It also looks really cool, so I decided to make this prototype an aesthetic test as well as a structural test. I engraved the rest of the enclosure body such that the engraving lines seamlessly blend with the actual kerf lines. While the kerf cuts failed the structural stress test, I thought the aesthetic was nice. I am interested in exploring this aesthetic limitation (engraving design same as kerf cuts) in future iterations.

As stated above, this prototype did not hold up to structural stress tests. There seem to be pieces too large in the bending area to produce the dramatic curve I'm looking for.

I quickly cut a half-size version of the prototype to see if the pattern would work in small scale. While I did not completely break the main piece, I could tell there was no chance it would bend easily. The smaller piece broke when I poked it out of the wood sheet. This series of cuts did not produce what I was hoping for, but I learned some important things for the next prototypes.





January 29, 2017

Prototype shapes have shifted from rectangular to triangular to trapezoidal. I was inspired by the shape of the end-stop on a previous iteration of the string accordion, which featured a rounded triangle shape holding a kerf-bent tube together.

Physical Prototypes #4 and #5: Cut on January 27, 2017

I cut a triangle with kerfs through the middle of it to find out how it would look and feel in my hand. I cut straight kerf lines, and the shape reliably bent 180 degrees. I noticed how natural the form felt bending outward from my palm, and I figured I should attempt to facilitate that outward curve with the arrangement of the kerf cuts themselves.

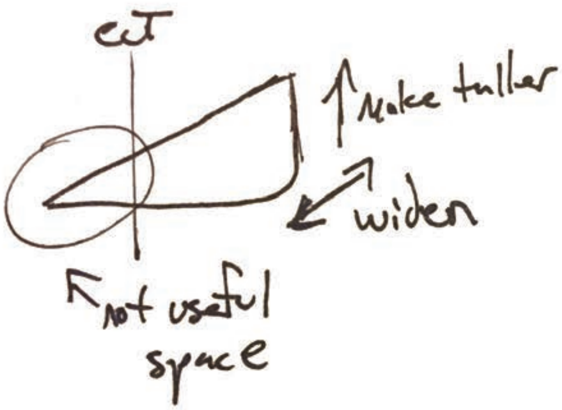
I designed the same rounded triangle with a kerf pattern arranged such that one end had lines cut 1 mm apart and the other end had lines cut 4 mm apart. The gradual change facilitated a gentle outward curve I found pleasing to hold.

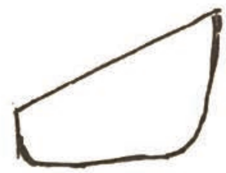
Physical Prototype #6: Cut on January 28, 2017

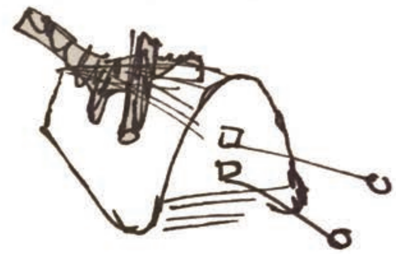
In order to fit the electronics in this instrument enclosure, I need more interior space than these current prototypes have. I designed a new enclosure in the shape of a parallelogram so the bent shape would look more like a right triangle, allowing more space on the wide end of the enclosure.

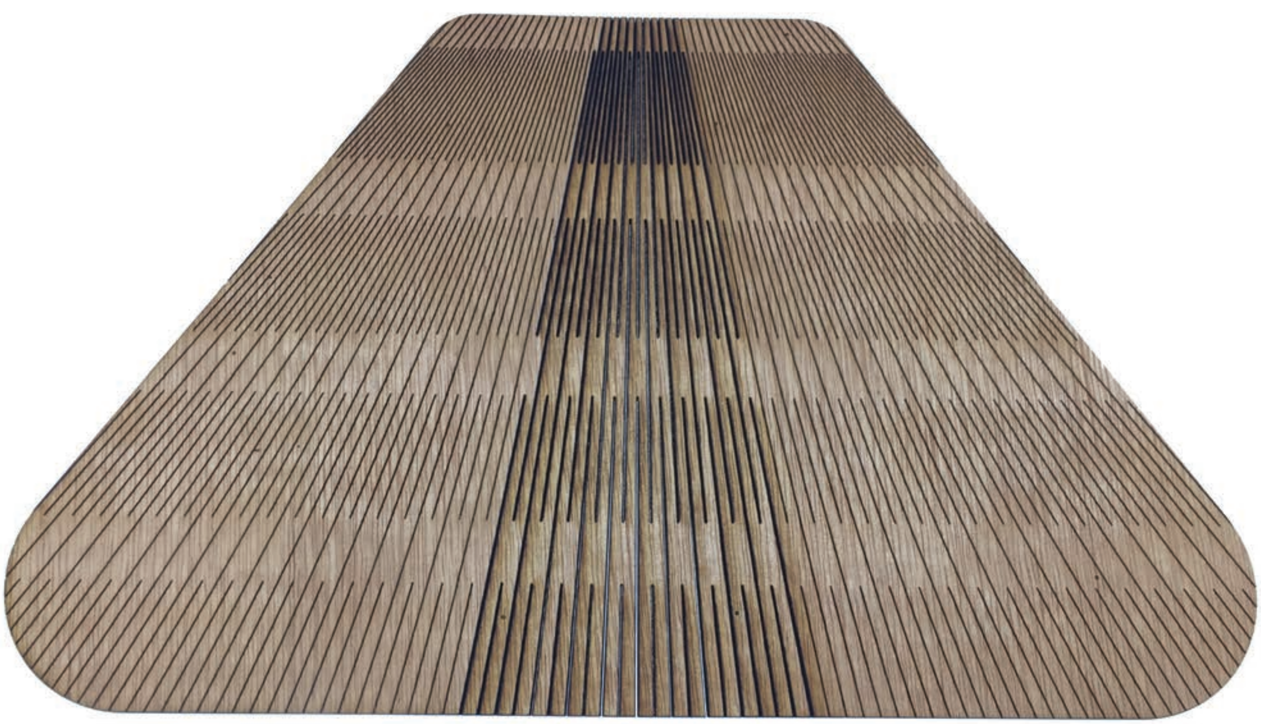
Not only was it very large, but it was also not structurally sound. Perhaps it is because I cut this piece against the grain of the plywood sheet. Perhaps it is because of the additional kerf lines I added in an attempt to make the bend more flexible. I was unfortunately unable to break this prototype in my own hands; it fell to the floor and broke before I had the chance to feel its flexibility.

I showed these prototypes to a friend, and they noticed how the design has some “useless space” at the point of the triangle would not fit much of anything inside. In order to increase space, they suggested making it taller and wider after cutting off the back end. I gave it a go, and the trapezoidal shape seemed promising.


cut
make taller
widen
not useful space







January 30, 2017

Physical Prototype #7: Cut on January 29, 2017

This one works really nicely! The rounded trapezoid feels great in the hand, the outward curve yields a fair amount of space inside, and there is room for buttons where the fingers naturally rest. Upon handling this prototype for the first time, my original idea of holding the instrument away from the body (palms down) no longer makes sense; it feels much better to hold the enclosure like an open book (elbows in, palms up).

It would also do well to bend outward even more, though this poses a potential problem. If the kerf lines move outward at a sharper angle than they currently do, the bend will extend to where the fingers naturally grasp the enclosure. This is not good because I plan to have buttons where the fingers go, and while I'm sure I could figure out a way to do that, I would more comfortable putting buttons on flat surfaces rather than curved ones.

I decided to experiment by cutting nonlinear kerf patterns. While these examples were too small to curve 180 degrees like the larger prototypes, these experiments gave me hope that curved kerfs could be a viable method for maximizing outward bend and flat surface area.

February 2, 2017

Emboldened by the results of the curved kerf experiments, I decided to go all out and use the curved patterns in the trapezoidal prototype.

Physical Prototype #8: Cut February 1, 2017

At first I thought it worked. I was ambitious in the design, widening the curvature from 1–4 mm to 1–6 mm. The piece was able to fold completely, although it clearly felt strained in doing so. Before long, the prototype cracked down sides of the kerfing area.

I could tell something was wrong soon after handling the prototype. When bent, the wide ends were clearly straining to support the position I put it in. They jutted out like crooked teeth, which is something I had not seen before in my kerf-bending experience. My guess is that I'll need to add an extra layer of kerf cuts to support the bend as it widens. I attempted that in physical prototype #6, so I'll give that method another chance.

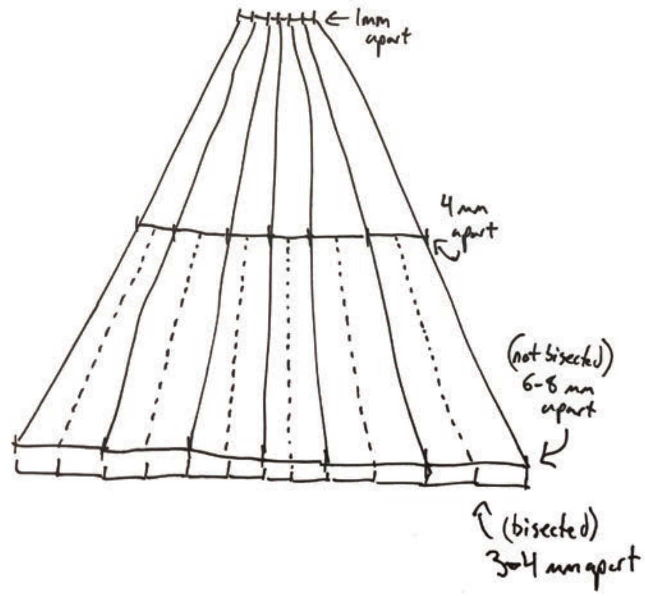
Physical Prototype #9: Cut February 1, 2017

In all my previous iterations, I've designed the kerf cuts using horizontal bands as guides. I thought about using curved bands to accompany the curved cuts just to see if it might work.

It failed immediately.

I used concentric circles at the same bandwidth as the horizontal bands in previous prototypes. I should have known how it would fail spectacularly, especially in basing the smallest circle where the larger-spaced kerfs are.

Perhaps this would work if the circular bands originated from the opposite side of the design. That would at least make more sense. I wonder if circular bands would help strengthen the curved kerf design; I've noticed that for the increased outward curve and flat space, these new prototypes are weaker than prototype #7 (which is still intact as of today).



February 9, 2017

It's been a week of what has felt like constant failure with these prototypes. I've certainly been spinning my wheels, but a new design is showing some potential.

Physical Prototype #10: Cut February 2, 2017

This is the first iteration of the design with a kerf pattern that gets denser as the lines get farther apart. I measured previously successful kerf-bent pieces and found that approximately 3–4 mm is the distance between kerf lines that have been successful in previous projects. My ideal curve requires kerf lines that surpass the 4 mm mark, so I figured I would need to bisect the major kerf lines in order to achieve the bend I'm looking for.

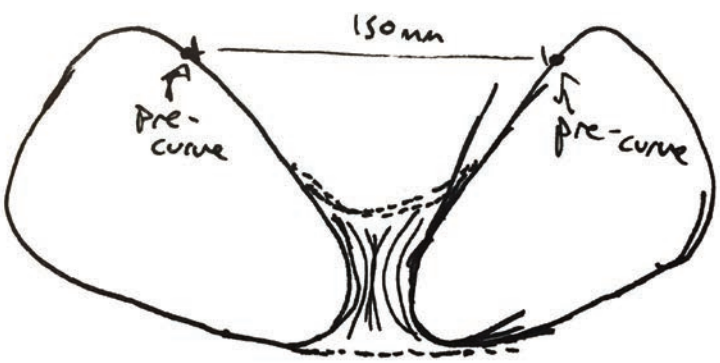
I tried it and found out that having supporting kerf lines that bisect the major lines won't solve the problem by itself. This design failed mostly in part to the high-density pattern weakening the wood so much that it fell apart with effort. I was unable to measure the angle of the bend because it broke so quickly.

Physical Prototype #11: Cut February 4, 2017

I decided to keep the same idea from prototype #10 but reintroduce the kerf pattern to the support lines as well as the major ones. I experimented with proportionally shortening the kerf pattern as a way to keep strength in the denser regions.

This, too, did not work. While the inside was much stronger, it became too strong and did not want to bend at all. The first stress test saw a crack up the side of the bending section of the piece.

With the kerf section broken away from the "wings," it could be tested on its own. While it bent fairly well, I still got the "crooked teeth" effect at the end. This effect is problematic because when I make a piece to hold this bending piece together, I need a (at least) relatively smooth curve for the supporting piece to rest against. Without that, the enclosure won't fit together at all.



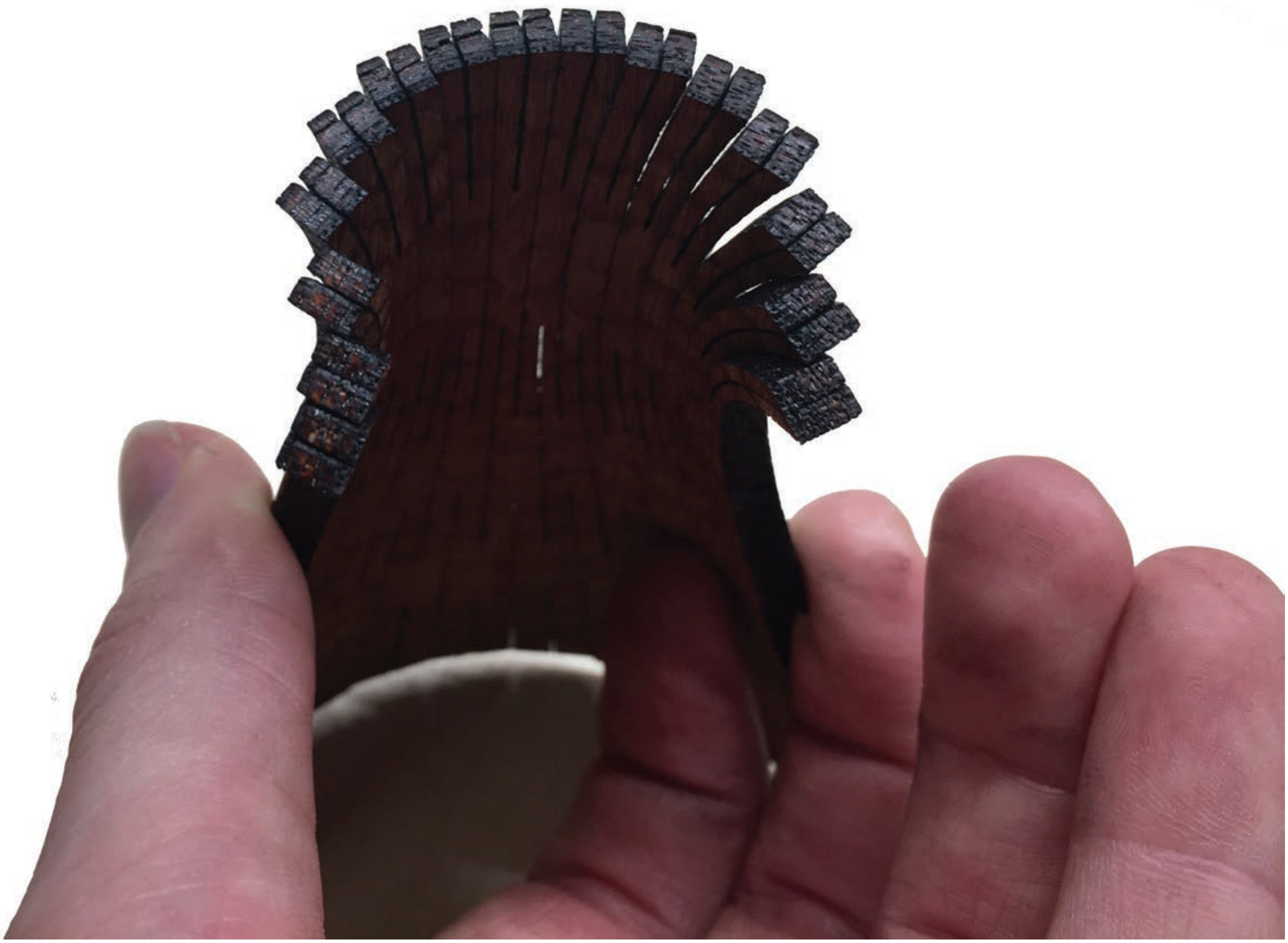
Physical Prototype #12: Cut February 6, 2017

I took the weekend to go back to the drawing board. Something clearly isn't working: Is it the curved kerfs? The spacing between the kerfs? Me trying to make wood bend in a way it simply cannot (in this small scale at least)? I talked with a few people who urged me to look at reshaping the design rather than attempt to make the shape solely through kerf-bending patterns.

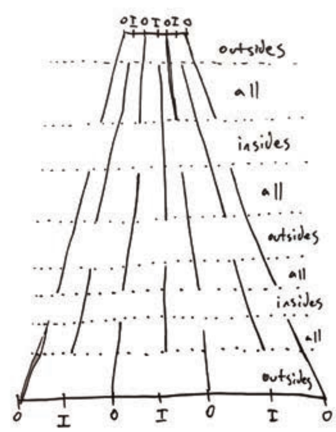
I decided to try a design that had the curve built into it. This idea would potentially allow me to use a one-dimensional bend to get a deep curve. In my previous experiments (around the time of prototype #7), I worked on a double-parabolic pattern that would theoretically work just like a traditional parallel pattern. However, my implementation failed.

The bent section, while separated from the wings, curves in a satisfying way. This design is able to sustain a pretty large curve with minimal crookedness at the ends. With some time, I would be able to make this design work.

However, instead of figuring out how to make that specific shape work, I decided to meld this design with that of the previous trapezoidal prototypes.



Physical Prototype #13: Cut February 6, 2017

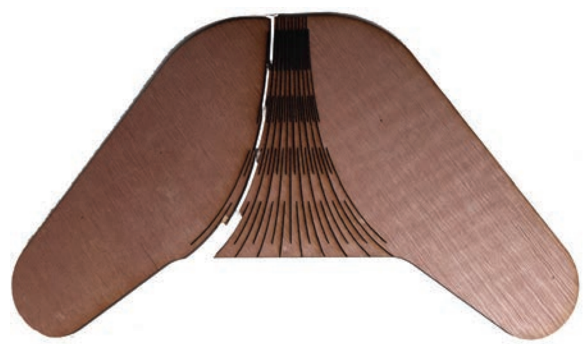


During the redesign process, I realized that I was altering the basic kerf pattern by bisecting the wider ends. I realized this might be the reason for the crookedness of the ends, and I decided to retry some previous designs with the original kerf pattern.

It didn't work. It wasn't flexible enough and broke near the wide end of the pattern. The pattern was not dense enough near the bottom.

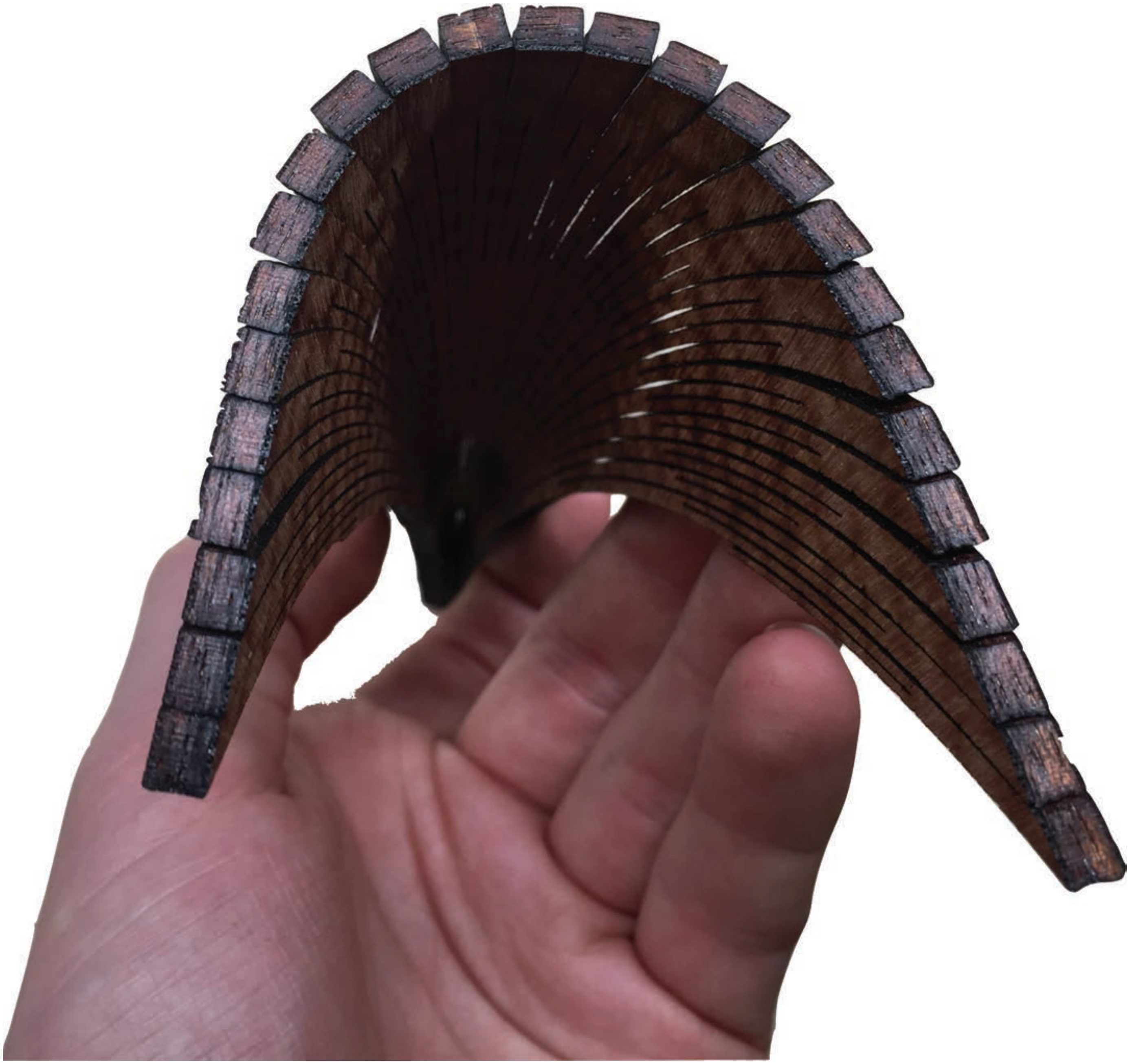
Physical Prototype #14: Cut February 6, 2017

This prototype was the melding of the trapezoidal and butterfly designs and would theoretically work if it had a denser pattern near the bottom. This one simply wasn't flexible enough.



Physical Prototype #15: Cut February 6, 2017

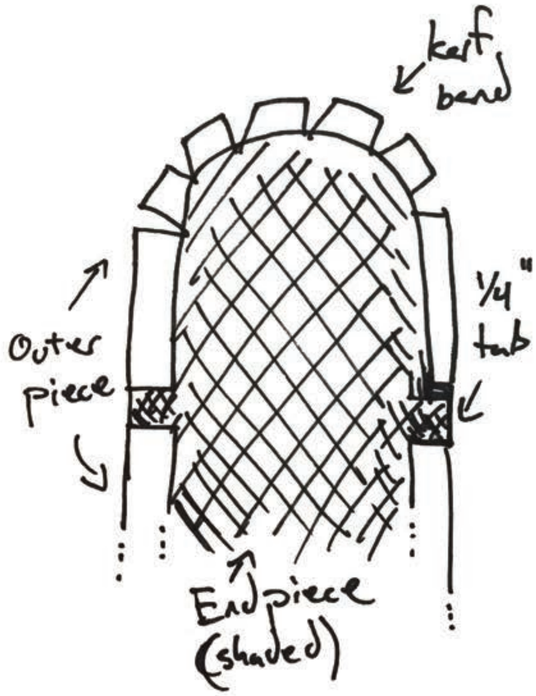
Tried the same thing as prototype #13 but with a denser pattern and wider angle. It was unable to hold together, but the ends curved in a much smoother way. The bent area was also plenty flexible but became separated where they connected to the sides of the trapezoid. My guess is that the cuts were too long or that the curves somehow reduce the integrity of the piece.

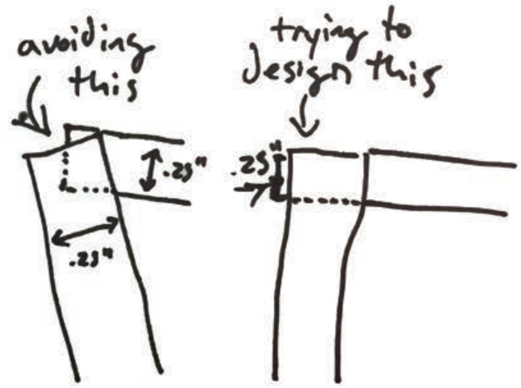


Physical Prototypes #16, #17, and #18: Cut February 8, 2017

At this point, I am concerned with making a piece that will fit into these kinds of designs. Instead of forging ahead with brute force as I have been for most of this process, maybe it's time to think smarter and go for quality over quantity.

The reason for making these designs is to make wood curve out at a specific angle. I'm not sure what angle feels right yet, but at some point, I need to make an end piece that can turn these initial physical prototype shapes into enclosures. That means I'll need to know the natural curve of a kerf-bent region. This is important because if the angles of the pieces aren't lined up, I won't have a square edge to keep everything together. This concept is illustrated in my journal sketches below.





I decided to redesign prototype #7, which has proven a reliable benchmark, such that the desired natural curving angle is built into the design itself. I have previously been "winging it," measuring the curving angle only after the piece is cut. This time, I was able to achieve a twenty-degree bend (prototype #16) and almost a forty-five-degree bend (prototype #17).

I was unable to get a picture of prototype #18 at the time of writing this entry. I was able to get an unbroken forty-five-degree bend with some slight alterations to prototype #17. This precision will be extremely helpful in designing an end piece to complete the enclosure.

Reflections and Future Work

While this article chronicles a nearly monthlong process in developing an enclosure for my instrument, it is worth pointing out that this is a creative process on only one aspect of the instrument and that the physical form will likely change as I work on electronics and sound. This process was guided by touch, in how the instrument will feel. However, an arguably more important aspect of an instrument's design is its sound at this point of the process.

Sound is abstracted and is not limited by the form of a DMI. Since the sound is programmed and generated by a computer, DMI makers do not need to think so much about how form will affect the sonic identity of the instrument. This means it is rather difficult to create an instrument that looks like it would make the sound that will eventually emanate from it.

Engaging in a process like I have does not help; as pointed out by my thesis committee, it would be a better idea to engage in a prototyping process with form, interaction, and sound all in play. The process I've followed in the past month certainly helps and shouldn't be abandoned, but it relates only to form of the instrument—not so much its function. An instrument that looks nice doesn't mean much when it doesn't sound very good or isn't usable.

As I mentioned in the introduction, I'm working toward an instrument that sounds, interacts, feels, and looks right. What I've learned from this month-long process, and from my thesis committee's insight, is that these elements all inform one another. To focus on one element in isolation is a mistake, and I made a big mistake by focusing so narrowly on feel (and look) of the instrument. I got bogged down by my obsession with form.

It's easy to look at this time as "wasted," but that view only holds within the scope of this master's thesis timeline. Yes, it would've been more efficient to engage in a more holistic instrument prototyping process given my dwindling time left to complete a thesis, but this experimentation also serves the bigger picture. By no means will the String Accordion be finished with the conclusion of my master's thesis; these experiments, and the skills built through engaging in the process, are critical to the larger arc of the String Accordion's evolution. That said, now is the time to step away from the idea of perfect form and pursue imperfect but combined form and function.

I hope this documentation of my experimentation is useful to anyone with access to a laser cutter interested in bending wood in very particular and curved shapes. My work here is far from done, but perhaps it will speed up the process for anyone new to laser kerf-bending techniques.

http://www.deferredprocrastination.co.uk/blog/2011/laser-cut-lattice-living-hinges/

http://www.deferredprocrastination.co.uk/blog/2012/lattice-hinge-design-choosing-torsional-stress/

http://www.instructables.com/id/Curved-laser-bent-wood/

HAMMOND M3 REBUILD

BY MITCHELL GRAHAM

Introduction

A Hammond M3 organ was donated to the audio studios in the Duderstadt Center at the University of Michigan. A team of students led by Mitchell Graham is working to restore the M3 to working order as well as adding modern functionality like Musical Instrument Digital Interface (MIDI) control. Many facets of engineering, design, and creativity are at play, as this sort of rebuild hasn't been done before. The organ must first be restored to working order and made easier to repair in the future, and then each key must be turned into a MIDI trigger, and buttons, knobs, and drawbars will be added for extended MIDI control. This must all be accomplished while maintaining and expanding the playability of the instrument without hindering the opportunities for creative expression that it presents. These goals raise questions of what defines an instrument and how one can be enhanced and redesigned without drastically interfering with its interface.

Inspiration

In the summer of 2016, a Hammond M3 organ was donated to the Duderstadt Center at the University of Michigan. It was a “chopped” organ, which means that the legs, foot keys, and built-in speaker were removed to make it more portable. Additionally, the organ was in poor condition, with many keys not functioning properly.

See figures 1 and 2, which show an original Hammond M3 and a "chopped" M3 on a stand.

Figure 1

Figure 2

Initially, the plan was for the Duderstadt Center audio staff to restore the organ to working condition for users to play in the audio studio. Dave Greenspan, the managing producer of the audio studios, asked if I would be interested in leading the project, and I accepted. I immediately got to work trying to figure out all the issues with the organ.

A couple of days later, Dave showed me a video of someone playing a Wurlitzer theatre organ, which has four keyboards and can make the sounds of a full orchestra. This performer is able to control an entire orchestra of instruments while sitting at the keyboard. The vast number of opportunities for creative expression when one has virtually unlimited instruments at his or her fingertips is a very exciting concept to both Dave and me. He asked how we could make that happen with the M3. I thought about it for a while and concluded that a similar effect could be achieved through adding MIDI functionality to the organ.

MIDI is a protocol that allows many electronic musical instruments and computers to communicate with one another. Adding MIDI functionality to the keys of the M3 would allow it to control electronic musical instruments or trigger samples in a computer, thus allowing a player to play simultaneously the organ and any other sounds imaginable. Adding MIDI functionality turned the initial restoration project into a complete rebuild of the organ.

Restore/Redesign

Our goal was twofold: first, to restore the organ to working order, and second, to make it easier to maintain in the future. The organ we received was originally built in 1956, so it has lasted more than sixty years, and we want to make sure it can last at least sixty more. The first step was probably the least fun: cleaning. We had to remove every key and scrub them individually to remove the residue from years of use and storage. We also had to remove rust from almost every metal surface on the organ. Figures 3, 4, and 5 show a disassembled key, the keys removed from the organ, and the organ outside of its cabinet with one manual's keys removed.

Figure 3

Figure 4

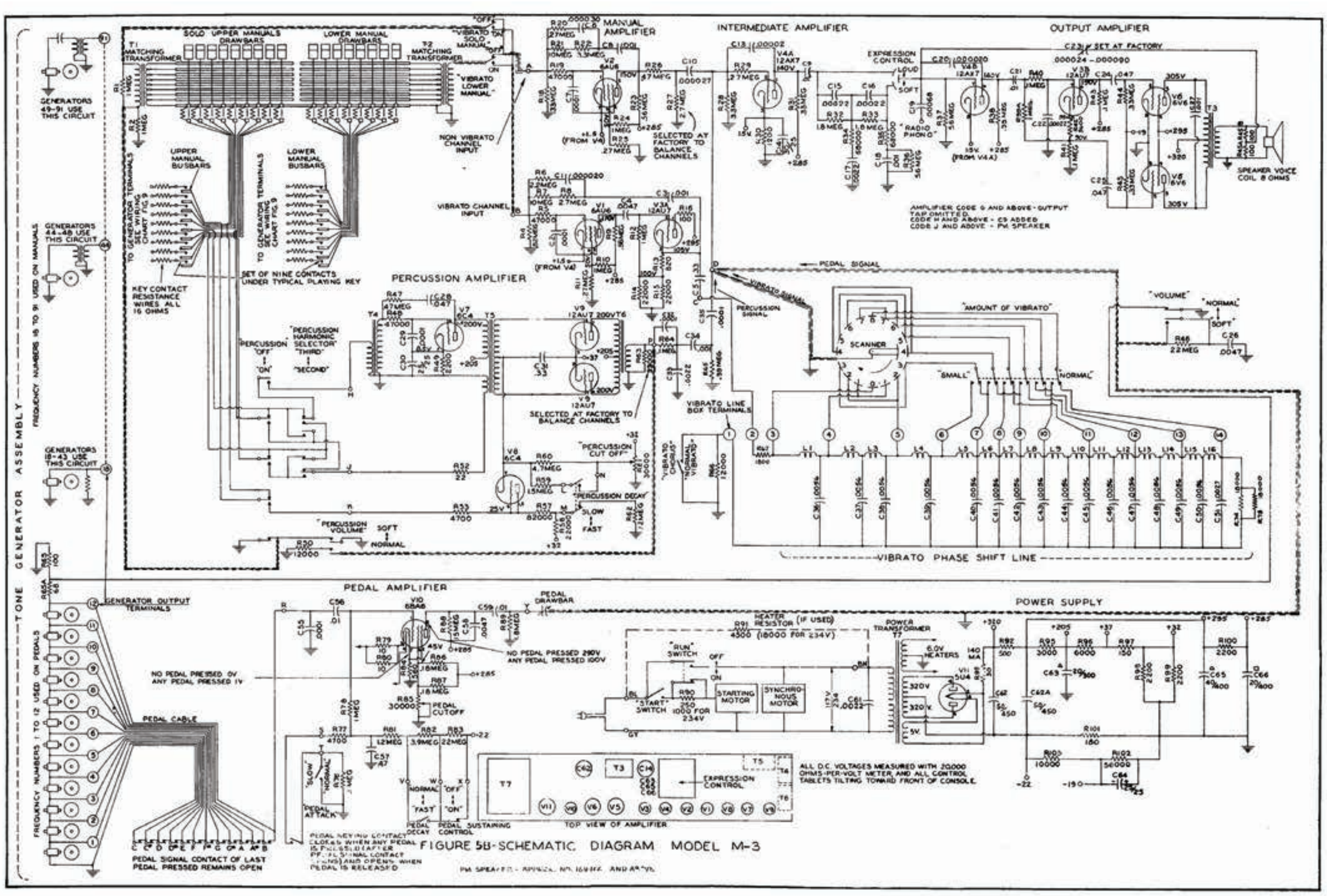


Figure 5

The second step proved to be tedious as we rewired the connections between the manuals and the tone generator in a way that will be easier to maintain. This is achieved by adding breakaways, or connectors, to the cable snakes that connect the manuals and tone generator. Photos show the wiring before any improvements were made and after the newly wired and organized connections were installed.

Figure 6

Figure 7

It's easy to see the disorganized jumble of wires connected to the organ's manuals. In order to remove a manual for maintenance, they all must be either cut or desoldered, both of which are extremely time-consuming and tedious options. We decided to make it easier to separate the organ for maintenance by adding breakaways and connectors to the snakes of cables between the manuals and tone generator.

Picking the type of connector to use is a tricky process in itself because we need to use connectors that have many pins so that we don't need hundreds of connectors, but they have to be sturdy and stable enough to last a long time while potentially being connected and disconnected multiple times. Each key has a contact that has a wire attached, so instead of having a mess of individual wires, we will use wire snakes, which are essentially bundles of individual wires. Each wire will then be connected to a pin on a connector. Immediately, three-pin connectors like XLR are out of the question, and less sturdy connectors like ELCO (although they can have many pins) would not be a good choice either. We settled on DB-25 connectors because they have twenty-five pins and seem to be the most stable relative to the number of pins.

Since the M3 we received is a "chopped" organ, we decided to add the original foot keys and volume pedal back into the final design. I was able to track down an original schematic diagram of the M3 from Hammond's online archive of wiring diagrams. This image was printed in the Duderstadt Center Media Lab on a large poster, and we have it hanging in our work area to refer to when needed.

GroundWorks Media Lab is a collaborative facility that supports the production, conversion, and editing of digital and analog media. Aside from editing stations, the lab also includes several other resources, including the poster shop and the reservable recording booth and multimedia rooms. GroundWorks provided our team with digital workspaces for design and poster printing.

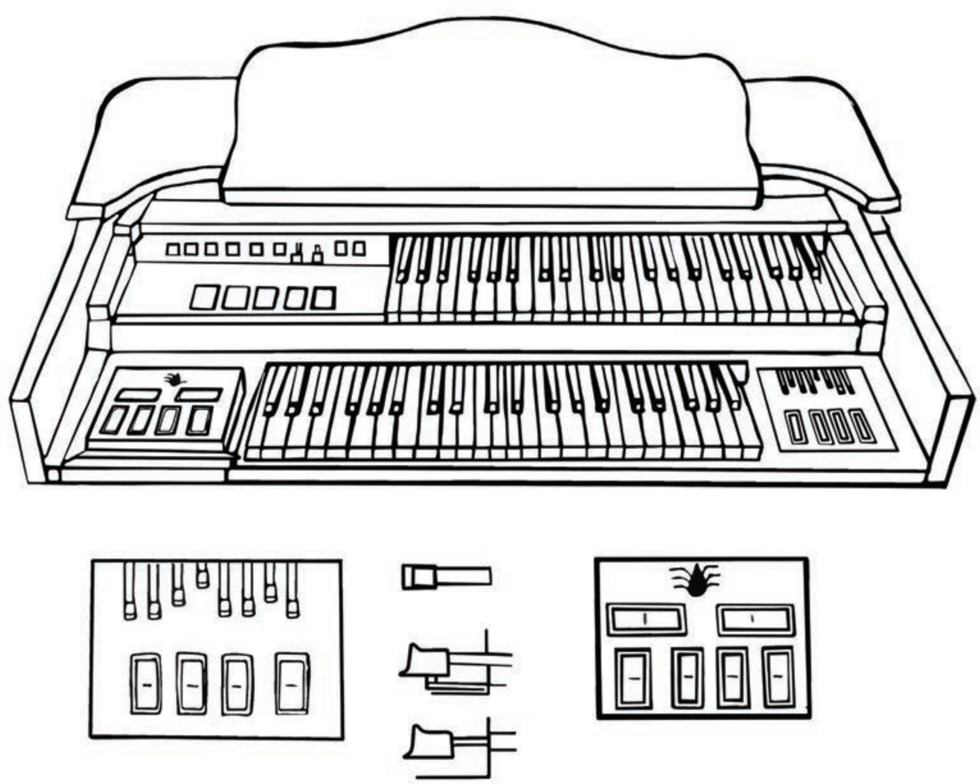


Figure 8

In the bottom left corner is the octave of footkeys, and the schematic shows how they are wired into the tone generator and the rest of the organ. The only original aspect of the organ that we are not bringing back is the built-in speaker, because upon completion, we will purchase a Leslie speaker to connect to the organ. Leslies are combined amplifiers and speakers that modulate sound with rotating speakers, where the player controls the rotation speed. We will add a control panel for the Leslie to the organ as well as several direct-out options from the built-in amplifier.

Additions

In addition to the restoration and improvements to the original M3 functionality, a few major improvements will be made.

Each key will be a MIDI trigger. This means that the keyboard will be able to send MIDI signals that can control other electronic instruments. A great deal of thought and discussion accompanied this decision. Do we use optical sensors? Pressure pads? Thinking about this led me to discuss what defines an instrument with my colleague Kevin Allswede. We concluded that an instrument is defined by its limitations. For example, you can't play a melody by blowing into a violin, and you can't make a piccolo sound like a timpani. Electric organs have limitations too, especially when it comes to the function of the keys. When a key is pressed on the M3, it pushes down nine contacts corresponding to the nine different harmonics that make up a tone. The volume doesn't change based on how hard you press the key, unlike a piano or many MIDI keyboards; instead the volume is controlled by a foot pedal. In order to maintain the limitations that the M3 presents and to maintain the feeling of performing on an M3 when using its added MIDI functionality, the keys will not be velocity sensitive, and the velocity will be controlled by a foot pedal next to the one used for the organ volume. This also makes it easier to add MIDI functionality, because each key essentially serves as a button when the contact is made. We are able to piggyback off one of those contacts to trigger MIDI on/off signals.

There are two crucial control surfaces for MIDI keyboards that the M3 does not have: octave up/down controls and a pitch-bend wheel. Typical octave up/down controls are buttons with some sort of feedback, usually LED lights or a display, to let the players know what octave they are playing in. How octave up/down works for MIDI is that each note has a MIDI number corresponding to it, and going up or down octaves adds or subtracts an octave's worth of values. Aesthetically, it wouldn't fit to have buttons with LEDs or an LCD display for feedback, so we will use a rotary switch as the control surface. That way the switch will point toward something labeled with the octave the keyboard is playing in, and it will maintain the vintage aesthetic of the organ.

The pitch-bend wheel will be mounted horizontally, instead of the typical vertical orientation. We made this decision because with most MIDI keyboards, players frequently use the pitch-bend wheel with their thumb while holding the side of the keyboard. Since the organ will be much larger than a typical MIDI keyboard and will be enclosed in a large cabinet, a performer would be unable to hold the side of the keyboard and use the pitch-bend wheel simultaneously. To achieve the optimal interaction, the pitch-bend wheel will be horizontal to utilize the momentum from the player's hand moving horizontally from a manual toward the wheel.

In addition to the MIDI keyboard features, there will be MIDI switches, buttons, and drawbars added. The switches will simply be modified switches from an M3, optimized for turning effects on and off. The buttons will also be based on M3 switches. The plan is to use three-way switches (with forward, neutral, and backward positions). The switches will be spring-loaded so that they always return to the neutral position, essentially turning the forward and backward positions into buttons.

These buttons will either be modified M3 switches or be 3-D printed to match the organ's aesthetic appearance. Usually, 3-D printing is an intimidating process because it can be difficult to find facilities that offer 3-D printing and design to students, but the Duderstadt Center has the UM 3-D Lab.

The UM 3-D Lab provides the entire University of Michigan community access to the tools, expertise, and collaborative opportunities needed to support cutting edge research, academic initiatives, and innovative uses of technology in the general areas of teaching and learning, visualization and simulation, 3-D printing and scanning, motion capture, modeling, animation, and design, and custom tool and application development. The 3-D lab provides our team with 3-D printing and design for custom parts for the organ.

The MIDI drawbars will be modified drawbars from a Hammond organ. The drawbars are sliding variable resistors, so there are several options for using these for MIDI messages. One option is to utilize the variable resistors and link resistance to the MIDI values outputted by the drawbars. Another simpler option is to use prebuilt MIDI faders and physically attach them to the drawbars in one of a number of ways. Both options pose their own difficulties, so prototyping and testing will be crucial at this stage. Fortunately, the Duderstadt Center has a perfect space for prototyping and testing: Design Lab 1.

Design Lab 1 is a creative learning environment that supports initiatives to bridge disciplines, build networks, and discover new contexts for scholarship. Design Lab 1 hosts an academic community centered in making, with an emphasis on aesthetics. Animators, videographers, musicians and sound engineers, motion scientists, robotics engineers, programmers, gamers, and designers collaborate to explore the practical and expressive potential of new tools, technologies, and aesthetic directions at the convergence of digital and physical space. Design Lab 1 provides our team with collaborative space for design and fabrication.

Sketches as of mid-February show the design for the M3. The additions of pitch-bend and modulation wheels, as well as the octave up/down rotary switch, are visible to the left of the lower manual. To the right of the lower manual are the added MIDI buttons and switches, as well as the MIDI drawbars and potential ways for MIDI faders to be attached to the drawbars themselves.

Collaboration

From the beginning, I knew I could not accomplish this project alone, not just because of the amount of work it required, but also because I did not have the necessary skills, knowledge, and resources to make it happen by myself. Fortunately, the Duderstadt Center at UM facilitate all the collaboration necessary to make this project come to fruition.

People Involved

Kyle Katynski is a sophomore from Troy, Michigan, studying sound engineering. He is interested in recording studio work and car audio. *Kyle provides hands-on work.*

Christopher Walker is a sophomore from Lake Forest, California, studying performing arts technology. He is interested in audio design and composition, specifically audio design for video games. *Christopher provides hands-on work and design ideas.*

Avery Bruni is a senior from Plymouth, Michigan, studying sound engineering and engineering physics. He is most interested in recording and mix engineering and model-based explorations into

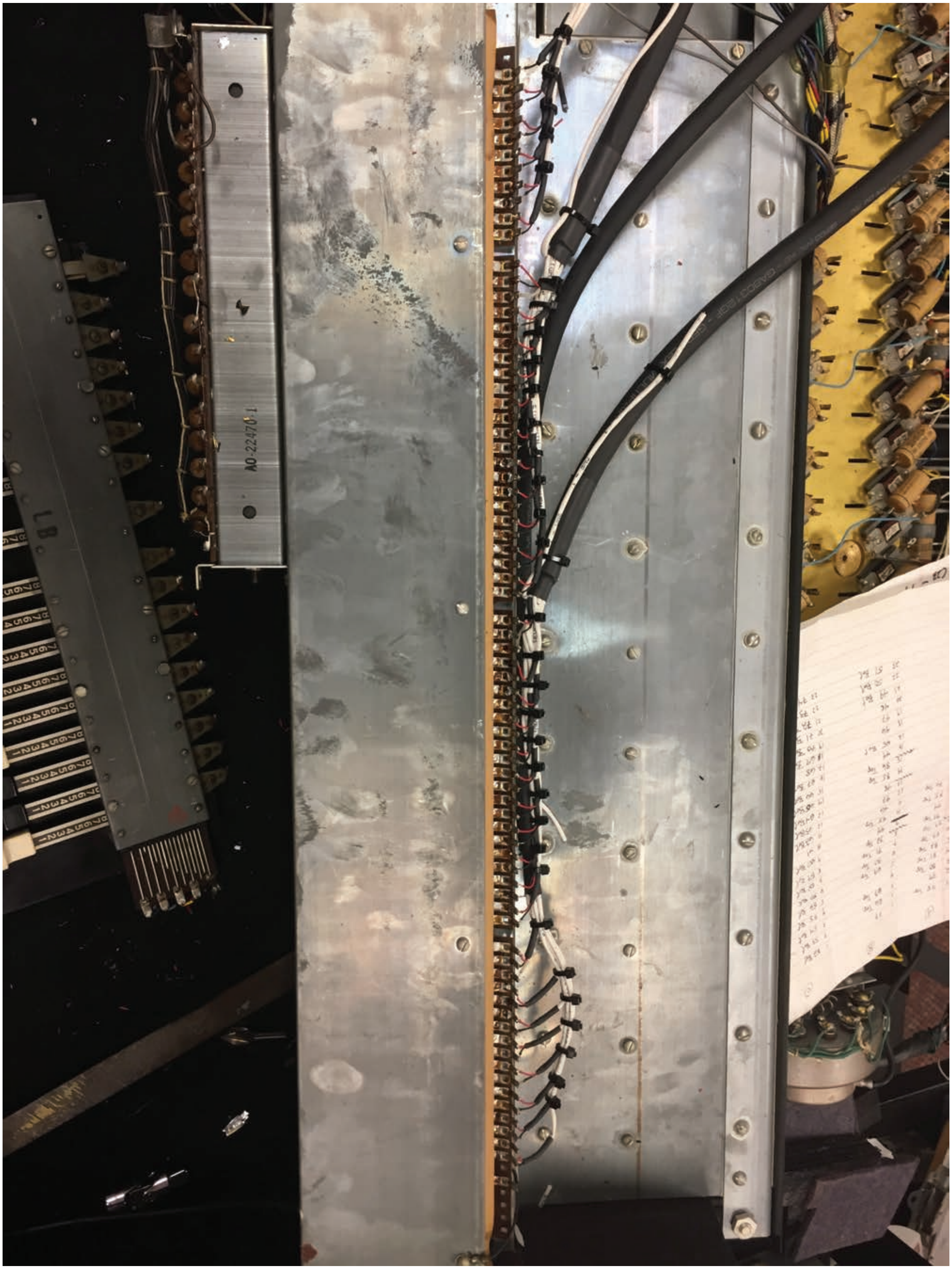


Figure 9

acoustics and sound synthesis. *Avery provides hands-on work and design ideas and is leading the hardware/software integration aspects of the rebuild.*

Anna Brooks is a junior from St. Joseph, Michigan, studying interarts performance. Her areas of focus include pedagogical design and bio art. *Anna provides design and visualization expertise.*

John DiNunzio is a junior from Berkley, Michigan, studying electrical engineering. He is a transfer student from Albion College and has research experience in analog amplification modeling. *John leads the rebuild of the organ's vacuum-tube amplifier.*

Joey Panlertkitsakul is a junior from Bangkok, Thailand, studying sound engineering. *Joey provides hands-on work and design ideas.*

Kevin Allswede is a second-year graduate student in media arts from East Lansing, Michigan. He has an undergraduate degree in performing arts technology from UM and is interested in performance and design of digital musical instruments. *Kevin has provided insight and advice throughout the design process.*

Dave Greenspan is the managing producer of the Duderstadt Center's audio studios.

Jeff Gazdacko is an audio resources media consultant/audio assistant.

Dr. Michael Gurevich is an assistant professor of music and the chair of the Department of Performing Arts Technology in the University of Michigan School of Music, Theatre, and Dance.

As the project manager for this endeavor, I have learned how crucial it is to delegate tasks, utilize resources, and ask for advice/assistance. I have also seen the value in communication within a team, because everyone needs to constantly be on the same page in order for a tedious project like this to come to fruition when there are so many moving parts (both literally and figuratively). I feel that I've found my place as a project manager, and I hope to use the skills that I've learned in communication, design, leadership, and fabrication to continue exploring the intersection of creative and technical work.