University of Ottawa
Fall2021 - GNG2101
Deliverable F: Prototype 2

Lab Section A04 Team_18

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Introduction

A lot of prototype 2 was constructed over the reading week from October 24 to the 30th as we were anxious to get iterating as soon as possible. This proved to be wise as we ran into some unforeseen issues as will be discussed later. Another reason we wanted to begin promptly was because our third client meeting was scheduled for the Tuesday after the break and we wanted to ensure we would have lots to discuss. This was our last meeting and so it was important that we had an array of talking points to get our client to share any last thoughts, feedback, concerns or ideas with us. The interview went well and some surprising things noted will also be discussed later on in this report. This document also includes numerous pictures of our second prototype, broken down into its subsystems, for which each team member was responsible for one: grid, hinges, straps, sound system. Testing results are tabulated as well.

Client Meeting Three Feedback

This client meeting was focused on presenting and receiving feedback on our prototype 2 test plan. In general the client seemed excited by our progress but had a few questions and comments for us. One of the main goals of this prototype, which will be elaborated upon later, is to determine if the base of our final prototype will be made out of plastic or sheet metal. The client seemed more excited about a 3d printed base and cited three major problems with a sheet metal base. These problems included price, heat conduction, and cutting your finger on the sheet metal. We asked about what kind of locator symbols would be appropriate, braille, simple shapes with a legend, or a mixture of the two. The client suggested a uniform braille locator system because the combination of the two would be confusing. For longer words we were told that shortening it to the first 2 or 3 letters would be prudent. We discussed with the client about the depth of the grid and came to the conclusion that a shallow grid would be better since it saves on material and accommodates smaller hands. In the end the client did not have any questions for us as we made sure to be very in depth with our description.

Purpose & Form of Prototype 2

The purpose of this prototype is to test the essential subsystems. We are debating on if the final prototype will be made of 3D model or sheet metal, depending on the results of the prototype 2 tests, the material of the final prototype will be determined. This prototype will be physical and comprehensive (as shown with the list of subsystems tested below) and will be moderate to high fidelity. Visually, it will look like our vision of the final product however in terms of functionality, some things such as 40/40 hinge activation will still be lacking.

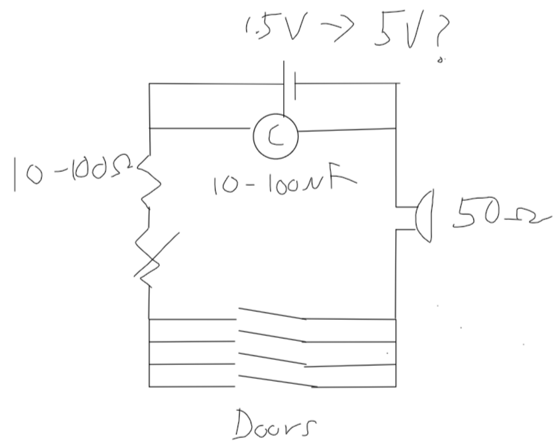
Test Plan

Subsystem	Grid to Grid Attachment	Hinge	Grid to Stove Attachment	Heat	Sound
Team Member	Lauren	Muiz	Patrick	Lauren (3D material) Muiz (sheet metal)	Azan/Kyle
Type of Test	Multiple sections of the grid will be modeled using solidworks and 3D printed to be assembled into the full grid. Verification at the store will be performed with the physical prototype to verify dimensions. Types of attachments - screwing sections together - Taping sections together - Dimension testing at the store - Comparison to design criteria	Different types of hinges and hinge configurations will be tested to see which work best Types configurations - screwing a store bought hinge to the 3D printed base and door -screwing 1 hinge into a sheet metal base and printed door -glueing 1 hinge to a sheet metal base and printed door -glueing a hinge to a printed base and printed door - Comparison to design criteria	Use multiple different types of straps to see what the max weight each type of strap can handle Types of strap: - Nylon straps with quick release buckles - Lashing straps - Strong string/twine - Comparison to design criteria	The maximum heat that can be withstood by a 3D printed piece will be tested. Different 3D printing configurations for example in fill and nozzle size will be tested in case maximum heat varies with configuration. - Comparison to design criteria	Feasibility of the sound system will be tested. Tests/areas of analysis: - Unbounded volume of buzzer at various voltages - Lifespan on single battery (mix with calculations and observations) - Maximum size to be used when integrated - Comparison to design criteria

Test Results

Sound System

The Design:



The above circuit diagram was the final goal of the prototype. But different circuits were used to evaluate if this was feasible in general. The price of the circuit would bring the price to around $6.50 in material (but actual cost is $0 since for the prototypes, materials that were already owned were used to test the proof of concept).

<u>Test 1: Unbounded Volume of buzzer at 1.5, 3.3, and 5 Volts.</u>
The Circuit below was used in this test. An Arduino Uno and a battery (for 1.5 V) was used to achieve the required power input.

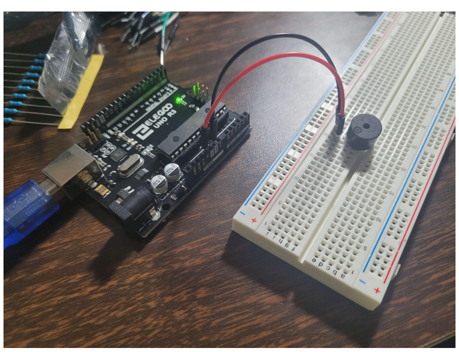


Table 1: Results for the unbounded volume of buzzer test

Voltage	**Volume**
Expected/desired	50-80 db
1.5 V	Too low to measure

3.3 V	Too low to measure
5 V	Approx. 10 db

The above results were unexpected for multiple reasons. The buzzer used was for lower voltages and online sources suggested this would work. It was initially thought the buzzer used was not working, but changing to another buzzer (including an active piezoelectric buzzer instead of a passive one) the circuit did not seem to allow for higher volumes. Although the buzzer did not make much sound, the faint sound from the 5 V test suggested that it was only a lack of power that resulted in the above results. This would mean in order to make the system work, higher voltages would be needed.

Test 2: Lifespan of the circuit

The same circuit above was used with the exception of a current measuring device in series. The test was not able to be conducted since it would be an unfair test to test the current used when the device is not even functional at the required voltages. It was decided to skip this specific test but a few observations were observed that did contribute to the lifespan of the circuit. The following is assuming the use of AA batteries of a capacity of 2500 mAh as suggested by this blog.

It was noted in the previous test that a higher voltage would be required. This would mean that higher currents would be used (because of the relationship of Ohm's law shown below) which would decrease the battery life of the circuit.

$$V = I R$$

It was also noted that the buzzer (when making a faint small sound at 5V) showed a significant increase in temperature in a short amount of time. This suggests two major points: a large amount of current is being sent through the buzzer while producing a small amount of noise; and that temperature after relatively short amounts should be expected to rise which in turn reduces the total lifespan of the device. This is problematic if the user would leave the door open in a state where the buzzer may be on for a short amount of time or frequent use that results in frequent bursts of sound. These two observations suggest a lower lifespan than expected.

Test 3: Size required to implement

As parts came in, their sizes were recorded to evaluate whether or not they would fit in a reasonable size when placed inside the grid. It was noted that many of the parts could be slightly cut or adjusted to fit. These adjusted sizes were what was measured. Also note that variations are included for different circuit choices.

Table 2: Results for the size requirements of the buzzer.

Device	Target Dimensions (L x W x H)	Measured adjusted dimensions (L x W x H)

Single AA Battery (For 1.5 V)	7x3x2 (for battery compartment)	5.5x1.6x1.6
Double AA Batteries (3V)	7x3x2 (for battery compartment)	5.5x3x1.6
4x AA Batteries(6V)	7x3x2 (for battery compartment)	5.5x6x1.6
9V Battery	7x3x2 (for battery compartment)	5.5x2.6x1.7
Passive Buzzer (Piezoelectric)	1.5x1.5x1.5 (for Buzzer)	1.1x1.1x1
Active Buzzer (Piezoelectric)	1.5x1.5x1.5 (for Buzzer)	1.2x1.2x1.1
Potentiometer	2x2x5 (for volume control knob)	1x1x2

Even though all the above fits within specification, it ignores that better batteries are needed which are unlikely to fit or be too expensive to realistically expect the client to buy/maintain.

Conclusion

It was decided that the sound system was not feasible. The advantages of a marginal safety feature (marginal in the sense that not a lot of safety is gained) when using the stove is outweighed by the additional complexity needed for more batteries, potential problems with cleaning and a shortened lifespan for the circuit itself. Furthermore, when we took measurements at the store, we asked an employee if the stove made its own sounds which in fact it does upon the activation of any button.

Grid to Stove Attachment

For the grid to stove attachment, it is necessary to have a device that is strong enough to support the grid in a stable position (keeping in mind that the grid is not very heavy) as well as to be relatively easy for the user to set up. After brainstorming different attachment options, it was determined that the best option would be some kind of strap to position the grid in place on the stove.

The top three straps we researched are:

1. Nylon straps with quick release buckles

The nylon straps proved to be strong and durable. They were also very user-friendly considering they can be easily extended or shortened as necessary; the nylon straps were 6 feet long in maximum length. However, the biggest concern with using these nylon straps were the quick release clips. Although it was difficult to determine how long it would take for the plastic clips to wear out, these are definitely the weakest part of the product. However, it would also highly depend on the amount that the user is clipping and unclipping.

2. Strong string/twine

Twine was also strong enough for our project in securing our grid to a stove. However, the biggest detriment to twine was that it would be more difficult for the user to attach since it would include multiple knots. It would also require more directions on setup than the other strap options would need. Thus twine was not our favourite option.

3. Lashing straps

The lashing straps also proved to be very strong and durable. Similar to the nylon straps above, they are once again very simple to set up, and they are very easily adjustable for different lengths wanted by the user. The biggest difference between these lashing straps and the nylon straps above is the clip. The lashing straps have a steel cast metal clamp that would take significantly longer to break than the plastic clip on the nylon straps. The lashing straps are also 12 feet long and have a break strength of 600 lbs. Therefore, lashing straps are our favourite strap design.

Incorporation of Straps in Prototype 2 and Future Prototypes:

We are incorporating lashing straps into our second prototype as our method of attaching our grid design to the stove interface. The straps will be looped around stoppers on the floor behind the stove, which will reach under the stove to hold the straps and grid in position (Figure 4 in our Deliverable D shows an example of this). The straps will then run up the back of the stove and over the top of the stove to where they will connect to the grid. The adjustable clamps and excess strap length could be wherever the user desires, but would most likely be out of sight behind the stove. On the front of the stove, the straps will attach to our grid design by looping through 2 strap slots on the top of the grid (one on each side of the grid). See the figure below for a demonstration of the strap-to-grid attachment.

Figure 1: Visual of the Strap-to-Grid Attachment (Using Cardboard and Paper)

Velcro (Part 2 of the Grid to Stove Attachment)

Our group also determined it would be beneficial to have a secondary accessory, besides the straps, that attaches the grid to the stove. This is a safety feature in case the straps were to give way, or if the straps were not secured appropriately. For this feature, we originally planned on using velcro as a connection. However, while researching and testing, we decided to also test Command Strips since they cost approximately 4-5 times less than velcro. After testing, we determined we would continue using velcro. Our reason for this was that velcro can be attached and detached on a frequent basis, whereas we would need to use new Command Strips each time we take the grid on or off the stove. This becomes a major problem because we want our design to be easily cleanable since it will be used in a kitchen. Thus, we will be using velcro as our secondary attachment for our grid to the stove.

Base Grid Template

Purpose

This prototype was moderate to high in terms of functional fidelity. It is similar to our vision of how the final grid will sit on the stove. Slight variations include some potential measurement adjustments. As this was our first model using real measurements, some details were slightly skewed as will be discussed in subsequent sections. However we are pleased with the development of our concept from this prototype seeing where we progressed from our visual proof of concept.

In terms of the material, we are testing 3D printer plastic versus sheet metal right now so the final product material is still up in the air. The test plan for this prototype was to take it to Last Man's Superstore and attach it to the stove in question, ensuring the dimensions are sized properly. The efficacy of the solution will be evaluated including things like wall thickness and door panel size (things that are still variable). As well, as listed later, design criteria such as set up time, visual set up requirements and installation will be measured.

The Design

We began with a CAD model. The 3D printers accessible at uOttawa makerspace print 23.0 x 22.5 x 20.5 cm and seeing as our design was 10.3 x 41.2 x 2.0 cm the first step was to decompose the grid into components in preparation for printing. Although two pieces would have been suitable, we decided to go with three as this would keep the pieces symmetrical and easily connectable.

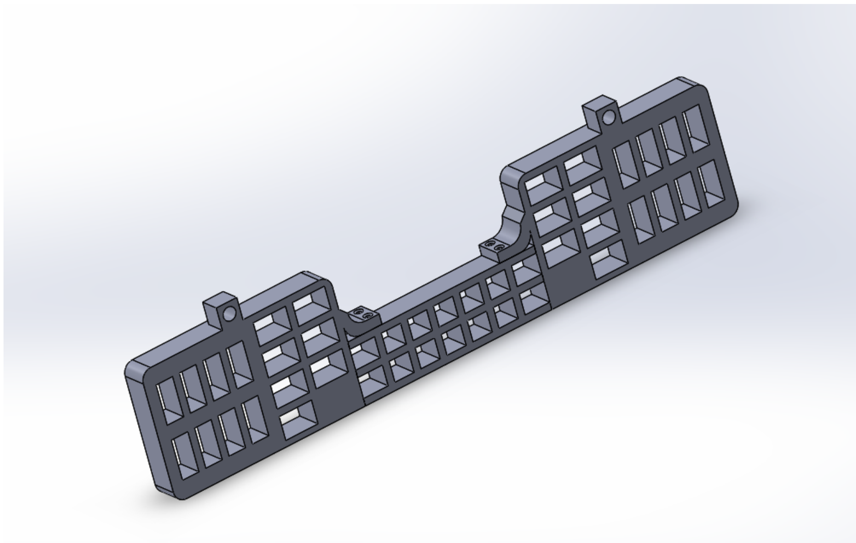


Figure 2: The three grid pieces, left, centre and right assembled in Solidworks.

To attach the three pieces, four holes were incorporated into the prints, two respectively on the left side grid tab. M0.6 x 1.00 x 12 chamfered slight bubble headed (Quantity: 4) were used for the attachment and thin strips of adhesive electrical tape were used along the bottom.

Once our files were converted to .stl, we were ready to print. Originally, we had tried to print Sunday October 24 however despite the website information, the makerspace was closed. As well, even using the largest nozzle size of 0.8 mm for the three components, the 8 hour print time (for all 3 parts) made it difficult to print and collect the parts during the makerspace hours (adjusted to Monday and Thursday only for reading week). Testing of this prototype was performed on Friday, October 29, 2021 in the Last Man's Bad Boy superstore to evaluate the efficacy of our design.

As can be seen in the pictures the straps were not included in this test. This is because we had originally planned two iterations for the week of October 25 however because of the limited makerspace hours and the unexpectedly large print times, only one iteration was managed and this did not include the upper tab dimensions and hole diameter needed for the straps. Therefore, the different straps were tested and explained separately as seen above. We are clear as a group on how the incorporation of that subsystem will work however.

<u>Door Panels</u>

For all of our team members, this was our first time using a 3D printer. When modeling the door panels, I had no idea what dimensions were feasible to print accurately. One problem the client specified (that occurs across many tools used) is that the stick on locator dots tend to lose their adhesive properties and fall off rendering the tool useless for a person who is blind. Our solution to this was to simply make the braille a part of the door panel in one piece. According to Pharmaceutical Braille [1], the dot diameter is 1.3 mm to 1.5 mm with 2.5 mm spacing from dot centre to dot centre as per the braille standard. These are arranged in panels of 6 dots, 3 high and 2 across to be felt by the index finger. Dot height is 0.2 mm. I was not sure however if the printers could do such precision without marring the dots. As well, as to the available room on the door panels. In comparison to real braille (we compared with braille panels outside the makerspace, our dots are actually large and tall. This was good news for us as it meant the client, who is adept at reading braille could still accurately read the button function beneath each door panel with smaller dots which allows more room for the hinge mechanism, wall thickness and the door hook. In the end, the 3D printer was setup to print using the 0.25mm nozzle for a print time of an hour.

Design Criteria Tested and Results

Although a tabular format is helpful for viewing testing results, the tests were specific to each design criteria and using a table to display the information would not be efficient.

1. **Cleaning time (resistance to spills)**

For the grid itself, it was easy to clean and wipe moisture off of its surface. The numerous holes made drying a little more difficult but definitely not unreasonable compared to other kitchen apparel.

2. **Usability B: % of total usable stove functions while visually impaired**

Once the grid is set up on the stove control panel centred on its backboard, all the features are available via the braille covered door panels. There are four panels in each corner which visually display the level (1 - 9) of heat for the given element. These in addition to the clock will not be accessible to a person who is blind. Therefore, out of a total of 45 features (40 button choices and 5 display panels) 40 are accessible giving the grid an 88.89% rating of total usable stove functions for the visually impaired.

3. **Usability D: required visual-based tasks for first time setup and set up time**

It took about 5 minutes to set up the device. I would say being able to see the grid placement, ensuring the buttons are correctly aligned to the slots and making sure the velcro command straps attach properly made the process faster. While it may take longer and be tedious for a person who is blind to set up the grid, it is still feasible albeit not ideal.

4. **Surface area**

The braille dots and test conclusions have been explained above. The surface area of the four door panels printed is 25.5 mm by 18 mm giving a surface area of 459 mm^2 or 4.59 cm^2. The hook was a suitable height of 7.5 mm and proved easy to grab with one's fingers. As stated above, the word OFF written in braille was able to fit on the door panel with adequate spacing and our dots were bigger than they needed to be. Therefore, the surface area will meet our ideal design specifications of less than 10 cm^2.

5. **Mass**

Grid mass: 0.244 kg (this includes the 4 screws but does not include any door panels). However a single door panel has a negligible mass (doesn't even register with a scale) so we estimate including all 44 door panels will add at most 2 - 3 grams of mass, for our purposes with the straps, this doesn't matter. The user is expected to be feeling along the grid applying downward pressure anyways so the straps must be able to handle this in either case. Note as well that this is greater than our marginal target specification of 0.2 kg however we overestimated how heavy things were with our original thinking and so 0.244 kg is reasonable and feasible for our design.

6. **Price**

In terms of cost, this prototype cost nothing. The screws were from home. The printer plastic was also free of charge as was the use of the printers. The lashing straps for the grid-to-stove attachment are $11.49 for a 2-pack. If we decide to go with 3D printed grid template for our final product, the main drivers of our price would be the hinges and straps.

7. Heat

We did not want to destroy our prototype in case further tests are needed so for the heat test, we used a scrap piece of plastic from a failed print. The purpose of this test was to monitor at what temperature melting of the plastic would occur at. A similar test is performed for the sheet metal as described below however the end condition is when the metal becomes too hot to touch as opposed to melting. This test was more of a confirmation of approximate melting temperatures because the Ultimaker printers in the makerspace print at around 200°C and so it is expected the PLA can melt and harden quickly at this temperature [2]. Tools for this test included a heat gun, a temperature monitor and a vise grip to hold the plastic. Although the rest of the piece does not conduct the heat, the heat gun can give upwards of 500°C with a strong air flow and it goes without saying that one does not want to have their fingers near that. The heat gun (blue device) had two main settings: a switch for low or high air flow and a dial at the back for monitoring temperature. Firstly, a high air flow was used with the lowest temperature setting for the dial. Interesting results were that although the surface being heated rose in temperature, the backside of the grid did not. The temperature delta was about 140°C to 40°C as measured by the heat monitor for the front surface to the back surface. Finally, I tested the piece with high air flow and high temperature in order to ensure plastic deformation. The gun reached temperatures of around 180°C according to the heat monitor. In terms of our target specifications, we are within the bounds for our ideal level at 100°C. This is important because for boiling something on the stove, 100°C is a crucial point to have safe usage of the grid.

Figure 3: Failed print held in the vise clamp (left), heat gun and temperature monitor used to perform the PLA heat test (centre), resultant deformation of the grid (right)

<u>Changes to be made</u>

- The depth of the grid can definitely be reduced. As of right now, it is 20 mm thick and sits comfortably on the backboard. It doesn't look strange or stick out an awkward amount. However this much thickness is unnecessary and may cost more for unneeded material. As well, the larger the thickness becomes, the more difficult it is for someone with large fingers to use the grid.

- The outer wall on all four sides needs thickness reduced as the outer buttons are halfway cut off by the grid wall. This misalignment is the result of a 2 mm discrepancy between measurements and the actual lip width of the physical stove control panel and it extends for the outer four buttons, top and bottom on each side respectively.

Some Images

Figure 4: Wide view of the grid sitting on the control panel, all buttons are covered and sequestered in the slots.

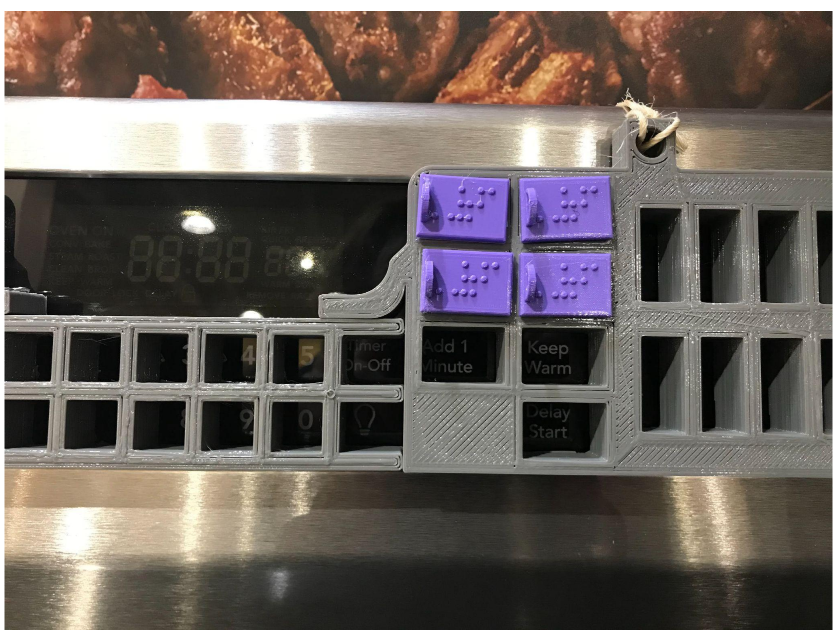


Figure 5: Door panels fit nicely over the slots for some buttons, orientation of each panel is the same with the hook on the left and the hinge on the right.

Figure 6: Images above showing how the grid is dimensioned so it sits flush to the control panel set into the backboard.

Figure 7: Difficult to see however velcro tabs are placed on the stove underneath the "Quick Preheat" and "Add 1 Minute" functions to lock lateral motion.

Figure 8: Misalignment of dimensions with the outer eight buttons (4 top and 4 bottom), this problem is repeated for the right side.

<u>Some Surprising Problems</u>

- I (Lauren) tested the grid at the store. An unforeseen problem was that my fingernails are longer and with the smaller slots such as those over the central numbers, I was unable to get my skin on the button. Since the surface is activated by touch/heat of my skin, being unable to make contact makes the grid unusable.

- Another problem that wasn't considered was finger size. Smaller fingers can pass through the slots snugly however larger fingers are too thick which renders the grid inaccessible for certain people. This is something that we need to discuss with our client and potentially make changes to the prototype. Some potential solutions though are to reduce the wall thickness, and with a sheet metal base this would not be an issue.

- As a team, we are struggling for ways to test design criteria such as Usability A: Time to locate an element of the interface and Usability C: Error rate of accidental triggers. These are dependent on a person being blind and we are not sure how to accurately test this. We feel it would be more beneficial in an in person meeting where our client could physically touch the prototype. In fact in our third client meeting, this was briefly discussed and our client seems open to the possibility of an in-person meeting at the store.

<u>Sighted people using the grid</u>

- A separate problem we discovered when discussing with our client during our second interview was the ability of the grid to be used by a sighted person. This need was introduced to us later than the first round of client needs and so we weren't sure how to solve it quite yet. However with the testing of this grid prototype on the actual stove, the solution is that a sighted person can simply pull the grid off the control panel by detaching the velcro stickies preventing lateral motion. In this way, they need no knowledge of braille and they can avoid the inconvenience of opening each panel in the hopes to find the desired one.

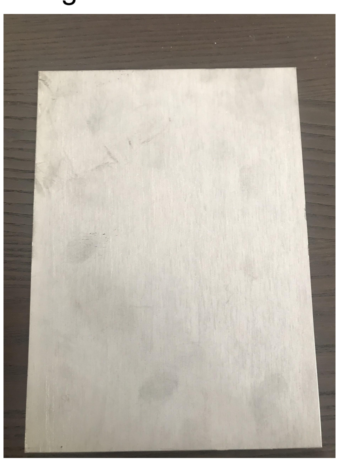
Words becoming too long for the door panels upon braille translation

- We printed four identical doors for hinge testing and panel placement for this prototype. On the door, we included braille dots to test our idea of printing the dots as one component with the door. This was important for us as an issue the client mentioned was locator dots falling off appliances with moisture or repeated use. If they were physically the same part as the door, this problem would be negated. The word OFF was transcribed into braille. It fit nicely with adequate spacing. For our next iteration, we will be following the standards more closely for how wide, tall and positioning wise the braille dots should be from one another. Our client solved the problem of length in our third interview. She suggested we only transcribe the first two letters of each function onto the door panel. For example, the door giving access to the “Bake” function would have “Ba” in locator dots on the panel. This would be consistent across all doors and would solve our surface area concerns. In order to avoid confusion as to what the abbreviations mean, a translation tablet will be printed with the grid so the client can match the door panel locator dots to those on the tablet which will have the full word written out expressly in braille.

Hinges

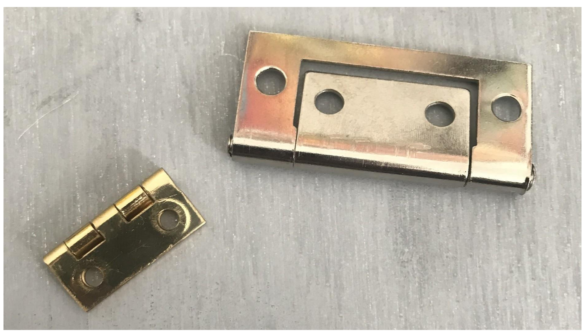
Materials and costs

Sheet metal plate (free): this will be used to test the sheet metal base to 3d printed door configuration.



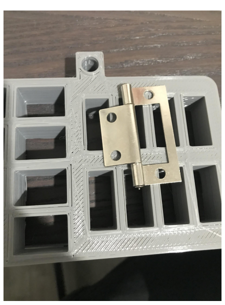
Modes of attachment($23.25): nuts and bolts, glue, and screws will be used to determine which kind of attachment style works best for the sheet metal base to 3d printed door configuration and the 3D printed base to 3d printed door configuration.

Two types of hinges ($10.42): the final dimensions of the various doors and slots have not been finalized. As such two hinges of different sizes have been purchased to be tested.



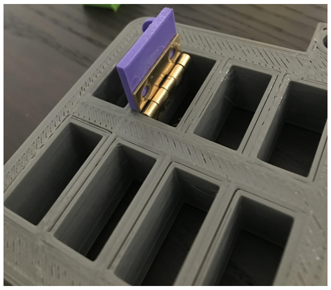
<u>Test Results</u>

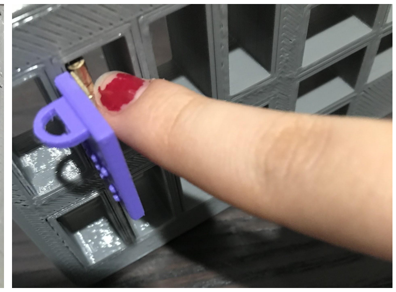
- The larger of the two hinges was completely unusable. They were too large for the size of the slots in the grid and also the size of the doors



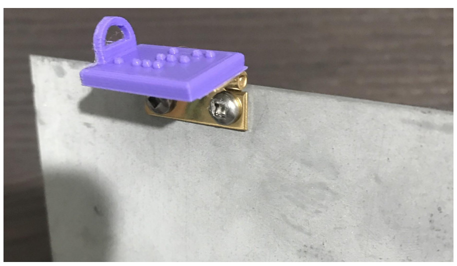
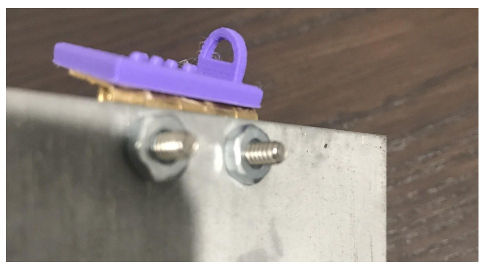
- Drilling into the doors with screws or bolts to attach the hinges does not work because the screws or bolts would stick out of the top side of the door. This would likely interfere with whatever locator symbols are printed on the doors or confuse blind users that are feeling around for symbols
- It was infeasible to drill the hinges to the 3d printed base simply because a drill could not be found that would fit into the slots, so the only 3D base to 3D door configuration is with glue

- 3D base to 3D door configuration (Glue): this system is feasible although there are a few problems. First, with the hinge in the slot even smaller fingers cannot fit through the hole. Second, some of the holes even the smallest hinge does not fit in. Third, the orientation of the doors may vary depending on how best the hinge fits into the hole and this may cause confusion for the user. Finally, this is obvious but the door size must be measured for the specific hole. In this test the wrong door for the wrong hole was used and we can see how it hangs over into one of the other holes.





- Sheet metal base to 3D door configuration (nut&bolt): This design is feasible with only one major problem being that the bolt sticks out of the other side of the sheet metal distinctly and if a user was to put their finger into the hole they could scratch or cut themselves on the bolt

- Sheet metal base to 3D door configuration (Glue): This system is feasible with no obvious problems detected so far

Potential solutions

- The thickness of the walls would be reduced if the base was made of sheet metal allowing for more room on the hinges

- Originally we thought to orient the doors and hinges so that they would all open the same way, the geometry of the holes will not allow this so some of the doors will have to open left to right while others will open down to up
- With the 3d base the main problem is with the width of the hole, the only solution is to make the walls thinner. We will have to test different wall dimensions with different infill parameters to see the thinnest we can make the walls while maintaining structural integrity.
- We can also research into finding smaller hinges

Sheet metal heat test

At the highest heat on a traditional stove the sheet metal did not experience any structural failure.

Conclusion

After our extensive testing of the subsystems and the grid we feel we have gained more insight as to the direction of our final product. Must of our research is complete now and what remains is to ensure accurate dimensions and seamless integration of the different subsystems for our final product. We are considering one more iteration before committing to our final prototype to verify dimensioning and some of the finer points explained above. In terms of the material to be used, as a group we decided to go with 3D printing the base and doors. This decision is a result of client feedback including the worry of burning one's fingers on heated metal as well as our own concerns about how to accurately manufacture a sheet metal grid to the millimetre so it fits flush and snug as the 3D printed model. Overall, we are excited to continue with this project in preparation for our final presentation and design day pitch.

References

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