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Semester project: Prototyping

https://mystifying-hodgkin-9f12a6.netlify.app/

CART 360

In making prototypes, I am first seeking to understand the difficulties tied to building the product. I start by decomposing the functionalities that go into making the product so that I can test each one individually and understand the constraints and concerns that I should address in future versions. I test each functionality using low fidelity prototypes that only perform one functionality in a simple way.

Once the first round of prototypes is complete and each has been tested, I analyze how each went to learn from mistakes and improve with future versions. I identify which aspects are most difficult so I can prioritize research time and testing effort. I can reiterate steps one and two until I feel I have gained enough understanding of each problem and found a working solution.

When a prototype seems to work in the way I intended it to, I build higher fidelity prototypes that will convey more meaning to test users and help me gather more accurate information as to how they use the artifact. A higher fidelity prototype helps me communicate my intentions better with test users so that they can imagine the final artifact.

Because this is a school project, I am not too concerned with using prototypes in order to advocate for the need for my artifact or product. However, if I were building a product so that it would be used in an industry or sold, I could use highest fidelity prototype to convince the people in charge of funding the project that my solution is worth further investing in.

I prototyped each functionality of the habit builder as follows.

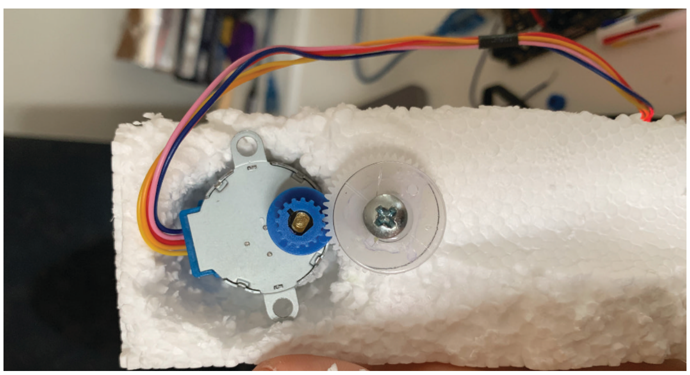
Task progress viewer

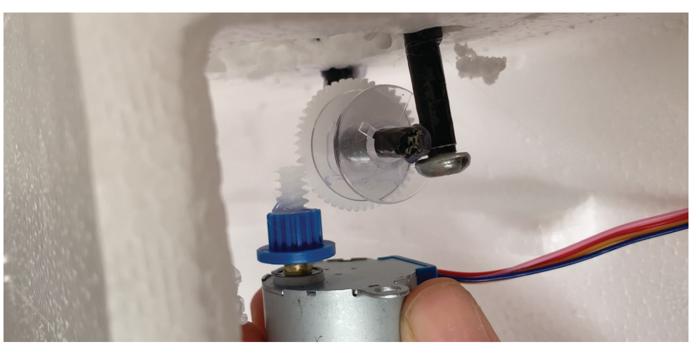
This allows the user to know what they should be doing and how long they still have to do it for. This is implemented through a series of parallel lines which in a way similar to clothes line, rotate a string so that a clothespin attached to the string moves along the horizontal axis. The clothespin is used to hold pieces of paper where the user writes instructions.

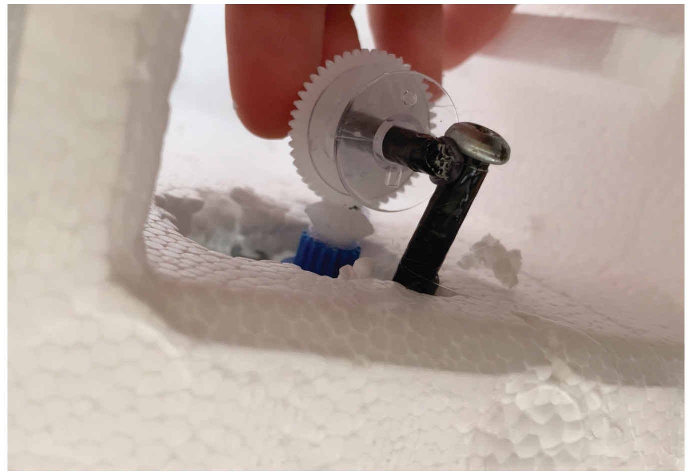
As a low fidelity prototype, I build a small pulley system with chopsticks, string, and sewing bobbins. I attach a clothespin to the thread and place a piece of paper in the hands of the pin. I can rotate the sewing bobbins manually with the chopsticks to see the piece of paper moving from left to right. Already, I am able to confirm my assumption that seeing the piece of paper effectively affords me with both of the functions I was originally looking to implement: conveying which task to perform, and seeing how long I should perform it for.

I then build a higher-fidelity prototype by incorporating a stepper motor and plastic gears to the pulley system. I replace the cardboard encasing with polystyrene as the cardboard was not solid enough and was bending as I turned the chopsticks.

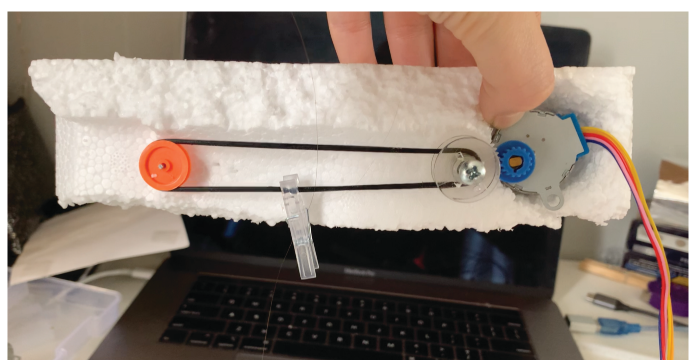
Through this iteration, I was able to confirm my suspicion that the mechanical portion of this product is a complicated aspect that requires precision, and that I will need to spend a lot of time on in the future. All components need to be perfectly aligned for the system to work. In addition, attaching pieces to hobby motors turned out to be extremely complicated without proper materials. The gears I purchased came without any attachments or axels, so I have to experiment with hot glue, sticky tack, chopsticks, popsicle sticks, tape, and nails to attach everything together, which takes a considerable amount of time for very little reward.

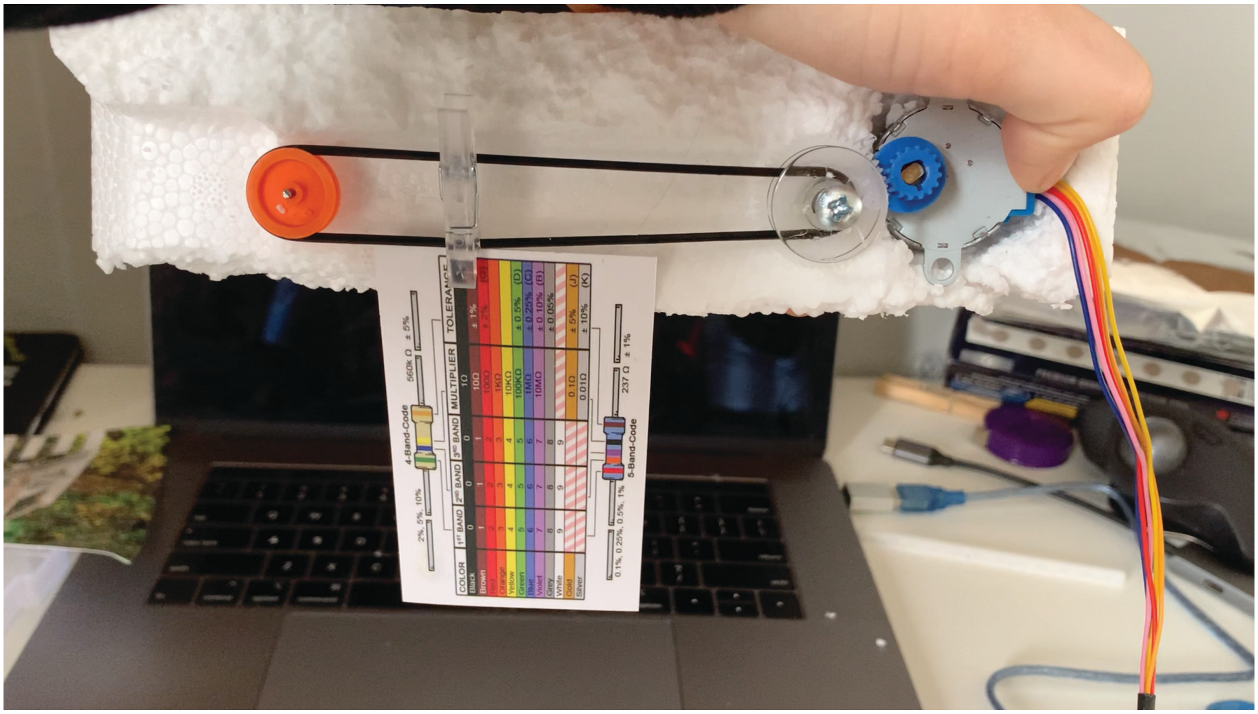






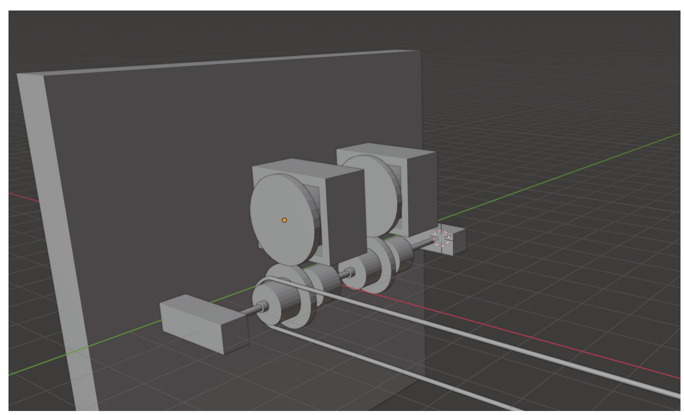
I test two gear alignments, one where the motor rotates in the same direction as the gears, and one where bevel gears transfer the motion of the motor by 90 degrees. While the bevel gears in theory would allow me to better hide the motors in the final product, the ones I have are too small to be reliable, and I do not have access to precision tools to ensure that the gears are placed precisely where they need to be. I elect to move forward with parallel gears. I notice that while the small plastic gears work, I would have more room for misalignment if I had access to thicker gears. Because I need to move the clothespin further than the angular rotation of the stepper motor, which does not turn very fast at maximum speed, I learn that I need to select a gear ratio where the first gear is smaller than the second.

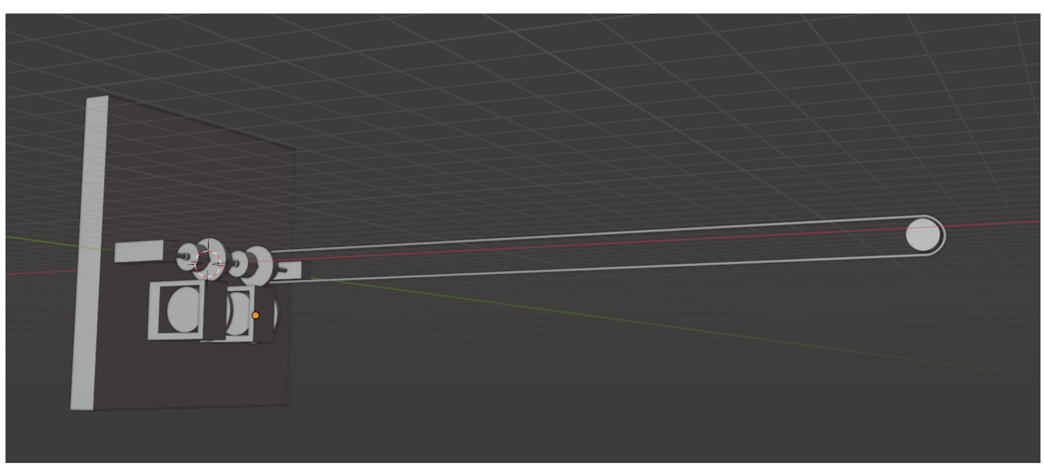




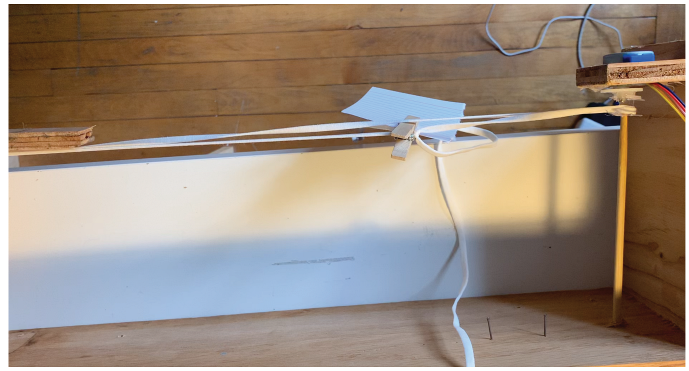
I also test the material of the string and learn that few materials guarantee that the string will always move with the pulley. A rubber band works better than yarn or string as it has more friction and is slightly elastic, but the weight of the paper and clothespin makes it stretch downwards, which I do not want. I learn that making a loop around each of the bobbins with the thread makes it work better that simply tying the thread around both bobbins.

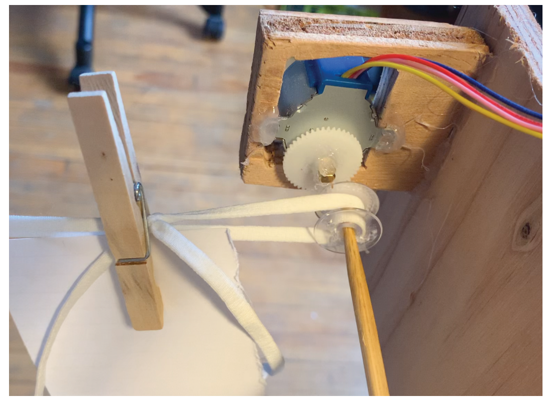
At this point, I build a 3D model of the pulley system in order to find a way for the motors to take as little space as possible in the finished product.

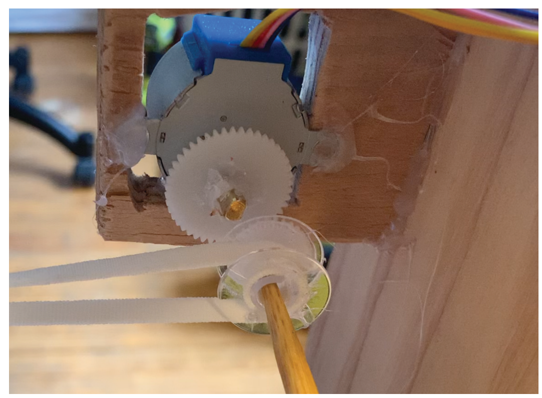


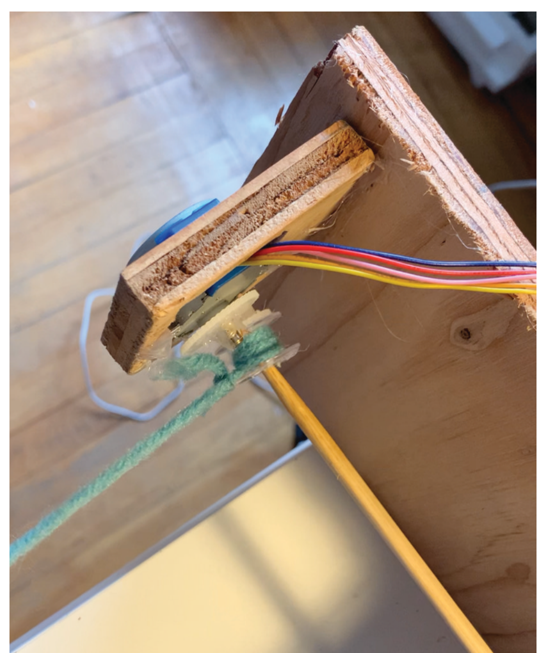


Finally, in order to test the system at scale, I build a similar system out of wood so it is more solid than the polystyrene and space the pulleys by about 50cm. As I expected, at scale, the imprecisions become important enough that it is very difficult to get the string to rotate at a precise speed. The elasticity of the string material needs to be reduced to that the clothespin does not dangle too low, but needs to be enough that the string catches on the pulley as it is spinning and does not slip.









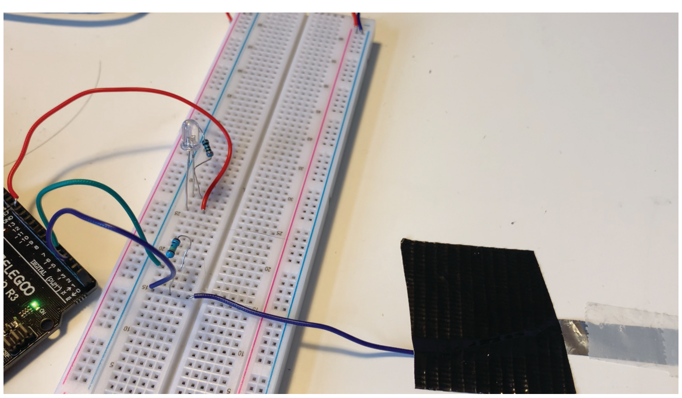
Task setup mechanism

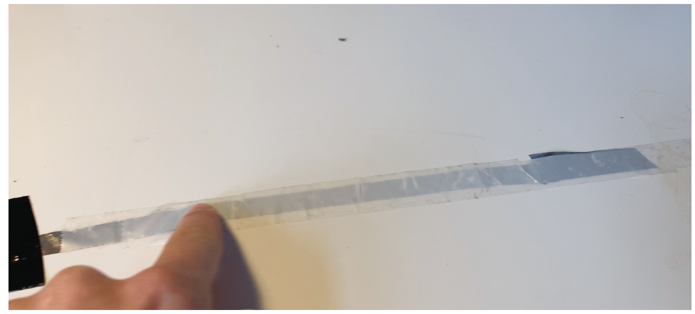
This allows the user to configure which task they are should be doing and for how long. To configure each clothesline, the user places their finger on a touch sensor on the side of a clothesline until the led display indicates we are in setup mode. The user then uses a touch sensor or a simple potentiometer to increase or decrease the amount of time to be spent on that part of the task.

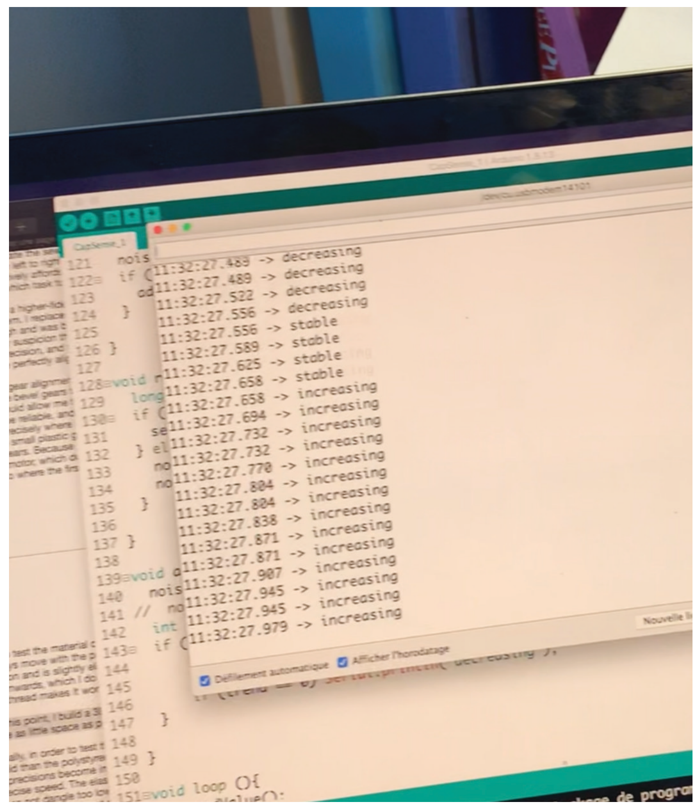
I test this part by building a circuit with two capacitive touch sensors. When they are both touched, the program enters setup mode for that line.

I then control the time with a simple potentiometer and have the result display on an LCD. I notice that the potentiometer, which detects rotation, does not match as well with the general « direction » of the artifact, which his to convey information through left-right motion.

In order to test left-right motion, I build a touch sensor out of a large resistor and aluminum foil covered with different numbers of plastic tape layers. I am able to detect whether I am moving my finger from right to left or left to right, and can therefore increase or decrease the time value.







Reward mechanism

This allows the user to obtain a reward every time they complete the activity. This is built with a lockbox that opens with a stepper motor when the user completes a task.

Because this system is common and already exists, I leave its prototyping for the end, as I believe it will not be as tricky as the other two systems. At the time of writing this document, the lock box has not yet been prototyped.

Affordances evaluation of sensors

- Simple Capacitive touch sensor: They only detect that the user has touched a the artifact in a given location. They allow me to detect which pulley line the user is wanting to set up. They also allow me to detect that the user is wanting to start with the activities.
- Capacitive touch motion sensor: allows me to detect the user's finger swiping left and right in order to increase or decrease a value. Built with aluminum foil, tape, and a 10K ohm resistor. Used with the CapSense Arduino library. Cannot detect exact location, as value of the input differs depending on the amount of pressure exerted on the aluminum foil, but can be used to detect variation.

Evolution of Thought throughout the Prototyping Process

As I built incrementally more involved versions of the prototype, the project's intension and meaning did not change a lot. Through experimentation, I confirmed that seeing information analogically move along the x-axis intuitively represents time passing. I also confirmed that I did not need to display information on a screen or have it spoken through voice commands in order for it to be understood by the user. I was able to convert meaning without technologies that I find more intrusive.

However, I had to change some of my expectations as building mechanically moving parts turned out to be difficult. I also understood the difficulty of building small objects without access to precision tool and with very DIY materials. I at times felt daunted by the task and disappointed by the lack of rigour of my prototypes. This forced me to come up with the easiest way of doing things, and work incrementally, only moving towards a more involved version of a functionality when I knew I would be able to implement a functional one before the due date in December.

In addition, having a 3D artifact at scale to play with made explicit some design concerns that I had not though about before. If the final artifact is the underside of a bookshelf, I need to make sure it is easy for the user to access each of the clothespins without having to slip their hand uncomfortable in a tiny space. I also need to make sure the artifact works at eye-level. Overall, I intend to build a static prototype of all the parts at scale, so that I can get a feel for the artifact as a whole which I haven't gotten yet from looking at the individual functionalities.