Design of a Cotton Wisp Generator for Prototype Testing of iRobot's Roomba

Team 4: MOVMent

(Michael Abadjiev, Orion Strickland, Van Harting, Mayia Mitchell)

By: Michael Abadjiev

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Introduction

This report details the process by which a device was developed to create hair-like wisps of cotton for use with testing of iRobot vacuum cleaner prototypes. This system should be mounted, along with other debris-generating machines, to a conveyor belt that can be used to simulate a robotic vacuum cleaner traveling along a rug or carpet-like surface. It will be used to generate a hair analogue to imitate human and pet hair for the robot to collect. This requires a hopper to hold a bulk amount of raw cotton or cotton balls, a processing mechanism to separate the cotton into wisps, and a dispenser to deposit the cotton onto the conveyor belt.

Background

iRobot is a consumer robotics company that currently specializes in robots to help with day-to-day chores. Their flagship robot, the Roomba, is a fully autonomous vacuum cleaner featuring automatic docking, programmable start times, and automatic dirt disposal. The most recent iteration of the Roomba features a smart home base where the dirt and debris collected by the robot is automatically siphoned out and into a garbage bag for easy disposal. In order to test these devices, the company needs a quick and reliable way to fill Roomba dust collection bins. The focus of this particular project was generating a substitute for human or pet hair by separating wisps from cotton. A reach goal of the project included pressing the fibers into the carpet in order to simulate human footsteps. This task was broken down into the more detailed goals shown below in Table 1. The priorities assigned to each of the sub-tasks was based on the requirements provided by iRobot.

Table 1: Project Needs

Priority	Type	Requirement
1	Function:	The device must be safe to use, i.e. no pinch points, exposed wiring, sharp edges etc.
2	Function:	Wispocity between 1 and 2, as shown in Figure 1
3	Function:	even distribution of dispersed cotton over 4 grams of dispersal
4	Function:	150mm +/- 15mm dispense zone
4	Function:	0.5 grams/m^2 per 3 minutes dispense rate, i.e.: dispense 0.5 grams over 1m^2 every 3 minutes
5	Function:	hopper must hold 0.25kg of cotton (either bulk cotton or cotton balls)
6	Function:	avoid damaging/shortening fibers
7	Size & weight:	must fit within a 50cm cube
8	Size & weight:	weight limit: 10kg
9	Function:	free standing device
10	Function:	document mounting on a .5m wide conveyor belt (no need to implement)

11	Reach function:	add the ability to impart some downforce to the conveyor (5-40 lbs) with zero relative movement to carpet
12	Reach function:	adjustable feed rate of cotton +/- 0.2 g/m^2 per 3 minutes

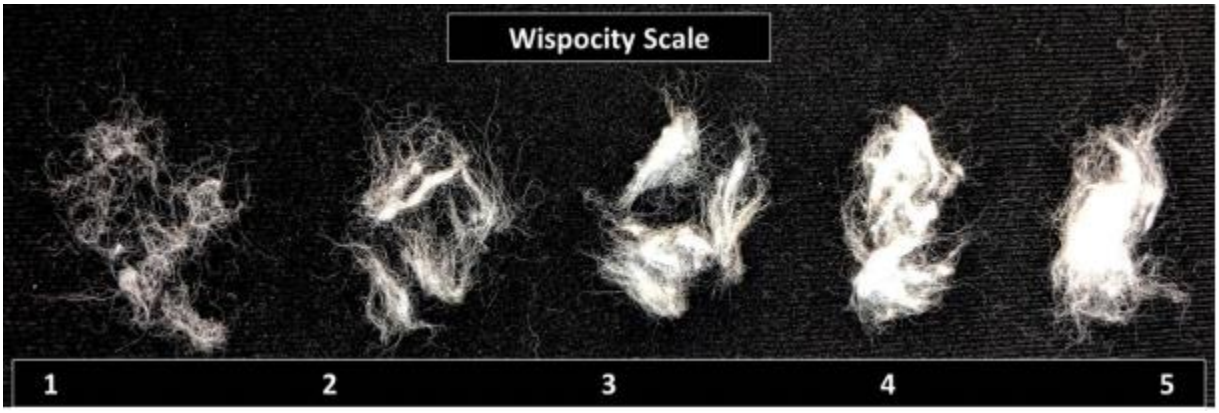

Figure 1: Wispocity Scale

The “wispocity” scale shown in Figure 1 was developed by iRobot for the purpose of this project, and indicates the desired separation of the cotton strands in order to more accurately represent human and pet hair.

Methodology

Ideation

The ideation for this project began with a few brainstorming sessions, where visual devices like mind maps and circle sketches were employed. An example of the results from one circle sketching session can be seen in Figures 2 below, and additionally in the appendix section

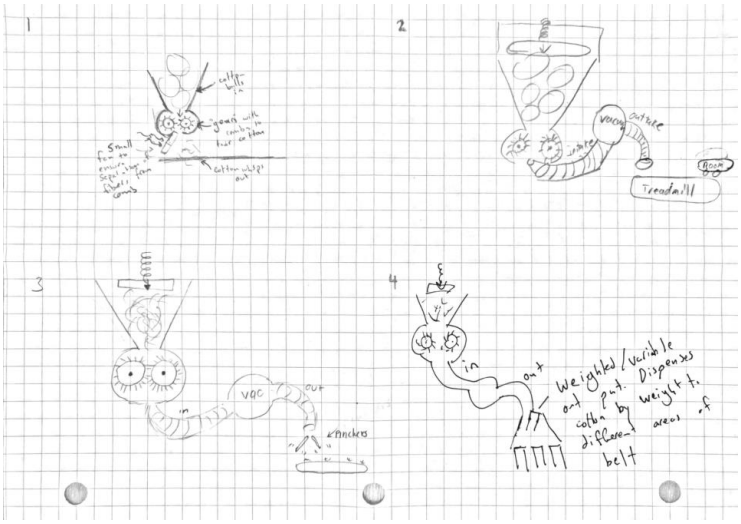

Figure 2: Circle Sketch Example

Most ideas revolved around using traditional cotton processing methods, such as carding cloth or rollers to dismantle the cotton. These ideas posed a few serious problems; first carding cloth is very expensive, and second, the aim of the carding process is to consolidate cotton fibers, rather than dismantle them, which makes it less ideal for our application. During one brainstorming session, while playing with some cotton balls, it was noted how well they stuck to abrasives materials, and one team member voiced the idea of trying to use sandpaper to separate cotton wisps. A quick experiment showed this idea held some promise, and a more detailed experiment was then conducted. Multiple different grits of sandpaper were tested to determine which, if any, would yield a suitable wispocity, while also keeping the adhesion between the cotton wisps and the sandpaper to a minimum.

Grit	wispocity	remove difficulty (1-5)
50	2 to 3	2
80	1 to 3	2
120	1 to 2	4
200	0.5 to 2	5

As can be seen in Table 2 above, higher grits of sandpaper resulted in a better wispocity rating, however they also resulted in too much adhesion between the cotton and the sandpaper to be able to easily separate the wisps. It was determined that a design involving a simple belt sander, along with a fan to blow air and separate the wisps of cotton from the sanding belt would be pursued.

Design Iterations

The belt sander design underwent several design iterations, which are described below chronologically.

Iteration 1: Belt sander

This first design (Figures 3-4) simply had a sanding belt running along the inside of the hopper. The intended result was to for wisps of cotton to be dragged off the main clump and down through the small slit at the bottom.

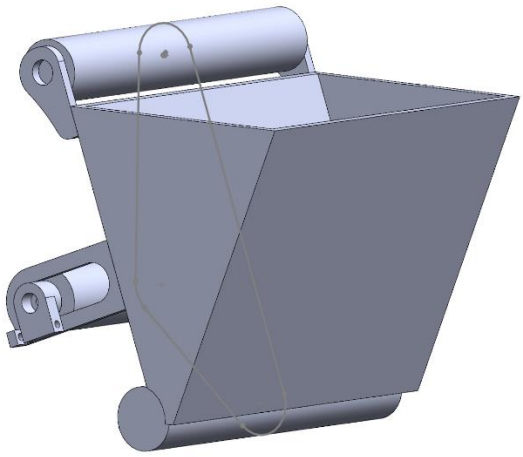

Figure 3: Iteration 1 isometric view

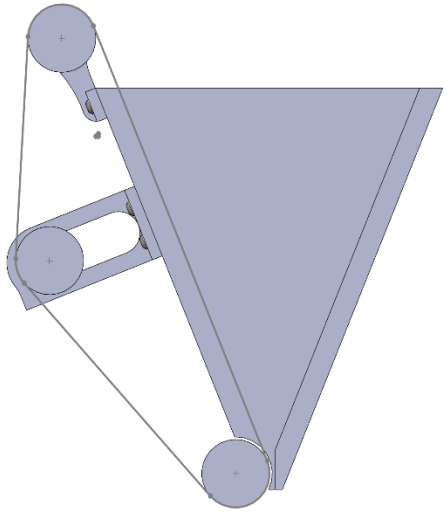

Figure 4: Iteration 1 Side Section View

This design did not account for the adhesion within the cotton fibers, and jammed very quickly upon testing with bulk cotton. The prototype, as well as the clogged cotton, can be seen in figures 5 and 6 below.

Figure 5: Prototype 1

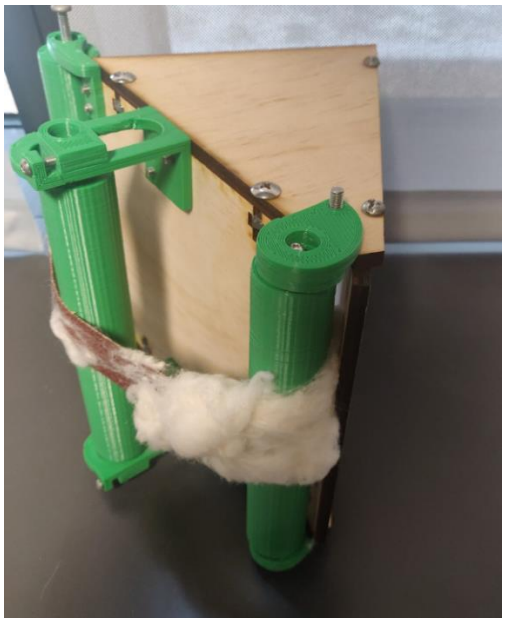

Figure 6: Clogging cotton problem

Iteration 2: Adding a mesh and fan

Several attempts were made to prevent the clumping of the cotton, from shrinking the opening to changing the belt grit, but none were successful. Eventually it was decided that some method had to be employed to forcibly separate the bulk cotton from the sanding belt. This wound up being a mesh that allowed the belt to grab wisps of cotton and tear them off the main clump, while preventing the large clump from following through. Several types of mesh were tested to determine which would most effectively keep the cotton in place, while also allowing strands to be pulled through. These meshes can be seen in Figure 7 below followed by a table detailing their respective performance.

Figure 7: Meshes tested (left to right, mesh hat, window screen, aluminum holed cooking tray)

Table 2: Mesh Test Data

mesh type	result
mesh hat	no cotton drawn through
window screen	not enough cotton
holed aluminum	good cotton ratio

From this testing it was determined that the holed aluminum grate provided a good separation of the bulk cotton from the sanding belt, resulting in small wisps being drawn through by the sanding belt. In addition, it was determined that a fan would be needed in order to actually separate the wisps of cotton from and a fan with a high air velocity was selected to be used.

Iteration 3: Finalized prototype

The finalized design added a motor with a belt drive to power the belt sander part of the mechanism. A 12 volt power supply was used to power both this motor and the fan for blowing wisps off of the sandpaper. A final render of this design can be seen in figure 8 below, and Figure 9 shows the final result assembled. The hopper itself was constructed primarily of 1/4" plywood, as this was readily available and easy to cut using a laser cutter.

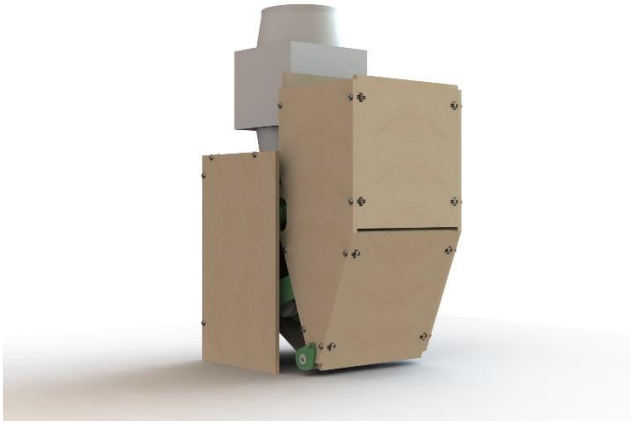

Figure 8: Final Render

Figure 9: Final Assembly

The belt sander roller mechanism was manufactured primarily from 3d printed PLA plastic, again due to ease of access and the ability for rapidly iterating between prototypes. The belt sander component can be seen in Figure 10 below. The top roller is slightly crowned, in order for the belt to automatically center itself on the device, and not rub along the sides. The belt sander also features a tensioner in order to be able to adjust the tension the belt via screws. Figure 10 also shows a section view describing the flow of material in the device.

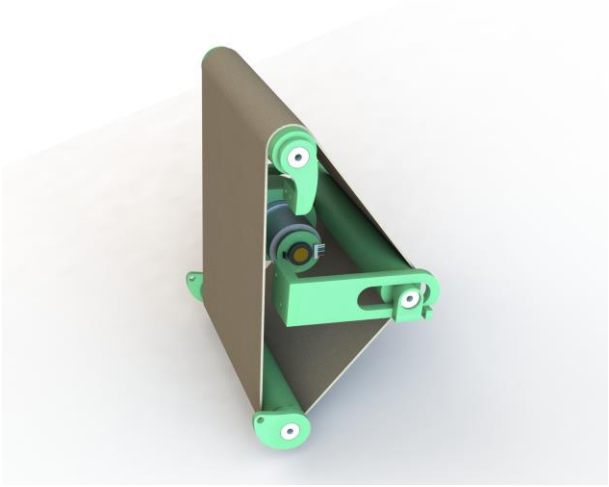

Figure 10: Belt Sander

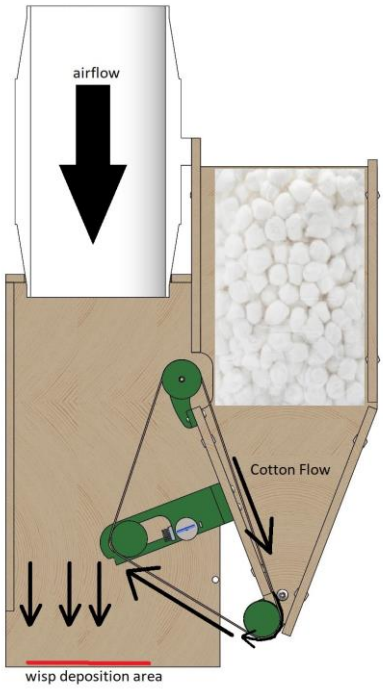

Figure 11: Section View

Results & Conclusions

This device serves as an adequate proof of concept for a wisp generation device. The sandpaper is able to consistently pull strands of cotton through the aluminum mesh, resulting in a wispocity of between 1 and 2. The fan successfully removes the cotton wisps from the sanding belt, but the lack of any airflow control resulted in cotton being blown everywhere, rather than simply landing on the ground below the device. This can be addressed by more shrouding around the fan, in order to better contain the cotton wisps and land them over the deposition area. In addition, some sort of ducting would be advisable to control the airflow and have it more precisely located on the sanding belt, rather than just randomly blowing air around it. Another consideration for future iterations is for the belt sander itself. Our team chose to buy a longer belt than needed, and then shorten it to the desired length. This resulted in a belt that was difficult to drive consistently, as the seam where the belt was cut and re-attached caused a binding point in the rotation. In the future, the sanding belt should be appropriately sized to begin with.

Overall, this project resulted in a device that was successfully able to separate bulk cotton into hair-like strands that satisfied the customer's "wispocity" requirements. The sandpaper solution worked very well for separating bulk cotton into wisps, which the fan as then able to remove and deposit onto the conveyor belt. The device can easily be placed on a platform, or have extended legs attached to the side in order to be able to fit over any size conveyor belt necessary. The design can even be extended to deposit over a larger area with relative ease, by simply extending the rollers to be longer, along with the corresponding sides of the hopper. In the case of extending the deposition area, it may also be necessary to add an additional fan. Overall, this project and resulting prototype serve as an effect proof of concept for creating a device to simulate hair in the testing of iRobot's products.

Appendix

Appendix A: Ideation Pictures

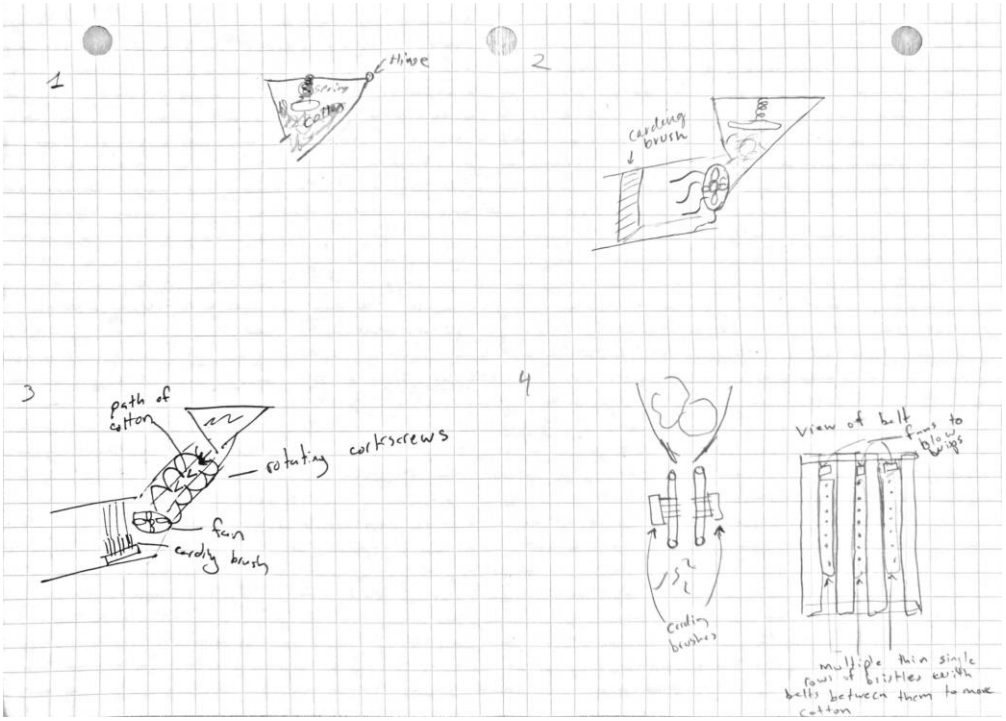

Figure 12: Circle Sketch Drawing 1

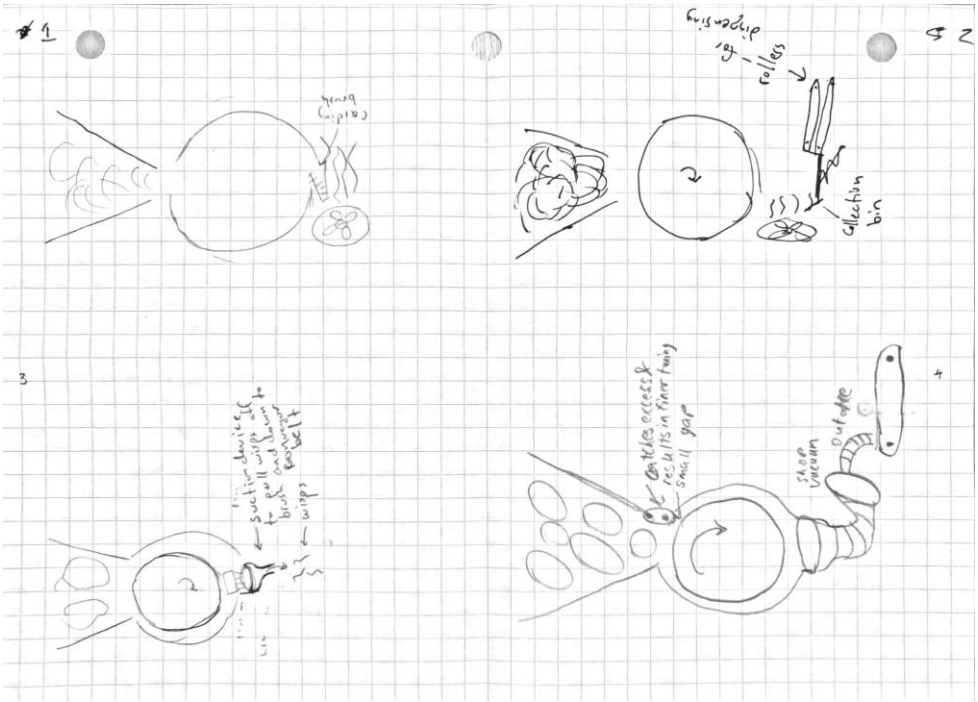

Figure 13: Circle Sketch Drawing 2

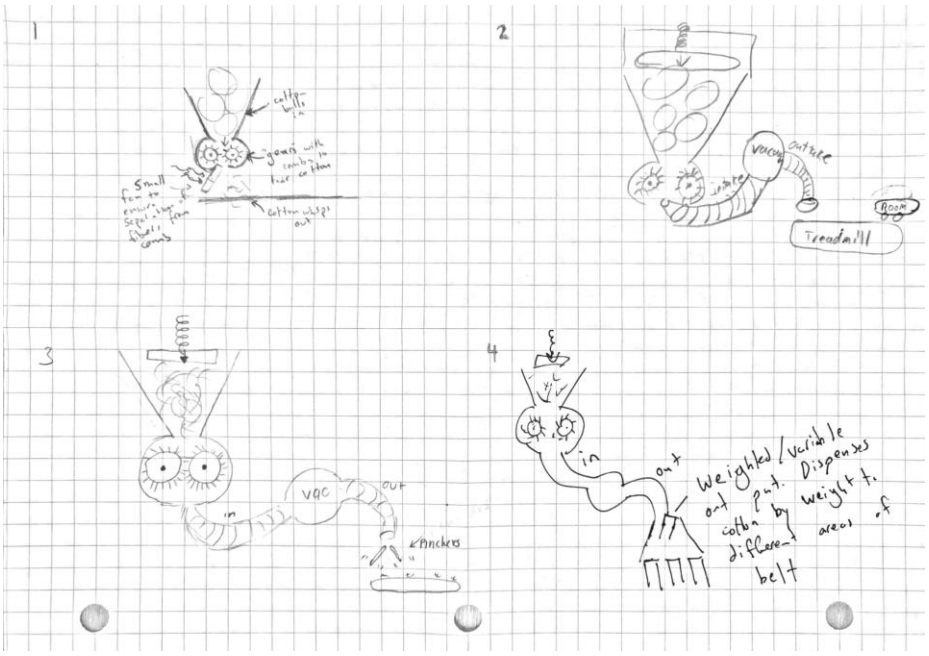

Figure 14: Circle Sketch Drawing 4

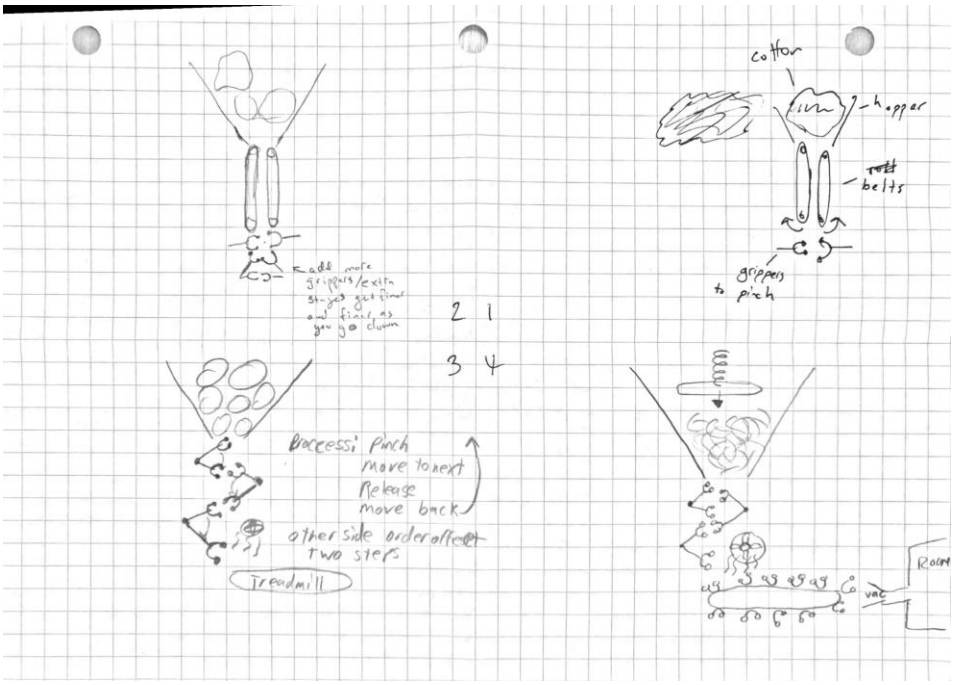

Figure 15: Circle Sketch Drawing 3

Appendix B: Bill of Materials

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	driven wheel	driven belt sander drum	1
2	m4x12 bearing	bearing for rollers	6
3	driven wheel hanger left	hanger for driven wheel	1
4	driven wheel hanger right	hanger for driven wheel	1
5	undriven roller	top crowned roller	1
6	undriven mount left	top roller mount	1
7	undriven mount right	top roller mount	1
8	tensioner rail left	tensioner wheel static rail	1
9	tensioner carriage	tensioner wheel carriage	2
10	tensioner roller	tensioner roller	1
11	tensioner rail right	tensioner wheel static rail	1
12	Pololu 50:1 motor	purchase - pololu 50:1 geared DC motor	1
13	sanding belt	6" wide sanding belt	1
14	hopper-2	hopper wall	2
15	hopper-1	hopper wall	2
16	hopper-3	hopper wall	1
17	hopper-4	hopper wall	1
18	SBHCSCREW 0.164-32x0.75-HX-N	socket button head cap screw 8-32x0.75	24
19	SBHCSCREW 0.164-32x0.625-HX-N	socket button head cap screw 8-32x0.625	2
20	MSHXNUT 0.164-32-S-N	8-32 machine screw nut	25
21	B18.3.4M - 3 x 0.5 x 12 SBHCS --N	socket button head cap screw M3x12	14
22	Blower	purchase - blower motor	1
23	shroud-1	fan shroud wall	2
24	shroud-2	fan shroud wall	1
25	shroud-3	fan shroud wall	1
26	motor pulley	motor drive pulley	1
27	drive belt - 10" vbelt	purchase - 10" v-belt	1