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Foldibot the Autonomous Clothes Folder

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Foldibot the Autonomous Clothes Folder

By

Braden Glasgow

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Final Report for 4600:471 Senior/Honor Design, Spring 2021

Faculty Advisor: David Peters

3 May 2021

Project No. 49

Abstract

As society becomes more technologically advanced, so does the demand for innovative products that save time; products like the Roomba have revolutionized household chores. Our teams' vision was to develop a solution for another time-consuming household chore: folding laundry. The goal of this project was to conceptually design a marketable "robot" capable of autonomously folding clothes and explore a potential design by prototyping and testing it. Our team utilized our culmination of knowledge acquired over five years of engineering studies to turn a "pen and paper" sketch into a functioning prototype; this project used engineering tools such as a Weighted Decision Matrix, Functional Decomposition Diagram, 3D CAD models, and Python coding. The results of this project were: a robot that was under budget, a complete mechanical folding system design and construction, and coding to control the robots x and y axis.

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1. Introduction

In the modern world, our everyday lives have become simpler and simpler thanks to autonomous engineering solutions. Don't feel like vacuuming the house for half an hour, we have the Roomba. Don't want to use half an hour mowing the lawn, get a MowRo robotic motor. Tesla is taking driving out of the equation, your model 3 can drive you home on its own. As society becomes more technologically advanced, so do our household appliances. Time saving, state of the art, inventions like the Roomba, an autonomous vacuum, have changed the way we live; providing convenience and eliminating the need to do daunting chores such as sweeping. This project, Clothes Folding Robot, aims to solve another daunting household chore: folding laundry. There are a few publicized prototypes that seek to solve this same issue. One prototype seeking to enter the market is a product known as the FoldiMate, which can be seen below in Figure 1.0.

The FoldiMate can fold numerous articles of laundry but requires user interaction and therefore fails to properly meet the growing demand for autonomous appliances. The product is also very large and has a proposed purchase price of $1,000. An ideal, marketable robot product would be able to sort through a pile of laundry, identify and fold each article of clothing accordingly, and then place them into a laundry basket. In order for a new product to be marketable and compete with the Foldimate it must have the following criteria: a universal architecture which allows for numerous articles of clothing to be folded, some sort of camera imaging system which allows for clothing articles to be identified/sorted, and the ability to perform with very minimal user interaction. Some other important factors to consider when doing a market comparison are cost, size, look, ease of use, etc. Due to the time and monetary constraints associated with this project the engineering team of this project will be focusing on the "universal architecture which allows for numerous articles of clothing to be folded".

With our senior project, we wanted to address the elementary task of folding clothes. After coming up with the idea, we did find that there are folding robots out in the market already; however, most of the commercialized products are either remarkably expensive or not very autonomous. In our project we hoped to create a low cost and nearly autonomous design. The overall goal of this project is to develop an innovative way to fold clothes that can compete with existing publicized prototypes. Due to the complexity of this project the team has decided that the ideal device will be conceptually designed and only the folding portion will be detail designed and prototyped. To be more specific, the group will be tasked with designing one mechatronic system that can fold three types of clothing: a standard sized T-shirt, a standard sized pair of jeans, and a standard sized bath towel. Ultimately, this project will produce a simple, low-cost mechatronic system that can be further developed into a marketable product.

1.1 Design Brief

The overall goal was to design and manufacture a machine or robot that will autonomously fold 3 articles of clothing (t-shirts, pants, and bath towels) successfully for under $1,000. This is a future goal that will take years to accomplish and with only a semester to work with we made the decision to design a mechanical robot and conceptually design the autonomous portion. So, the goal for this semester was to develop the mechanical portion of the robot.

2 Conceptual Design

The most important process and initial development of the project was the research and brainstorming. The first part of the research was discovering current devices already on the market or being produced which included foldimate and examined the pros and cons of these devices and how we could develop a better product.

We concluded that this would take years to accomplish and decided that for the limited time we have that would develop a simple mechanical folding device.

- "Grab" the article – identify, analyze
- "Orient" – move to recognizable position (i.e. flip inside out, rotate, etc)
- "Fold" – multiple steps to get clothes to desired shape/size

Our device would focus on the folding function of the machine.

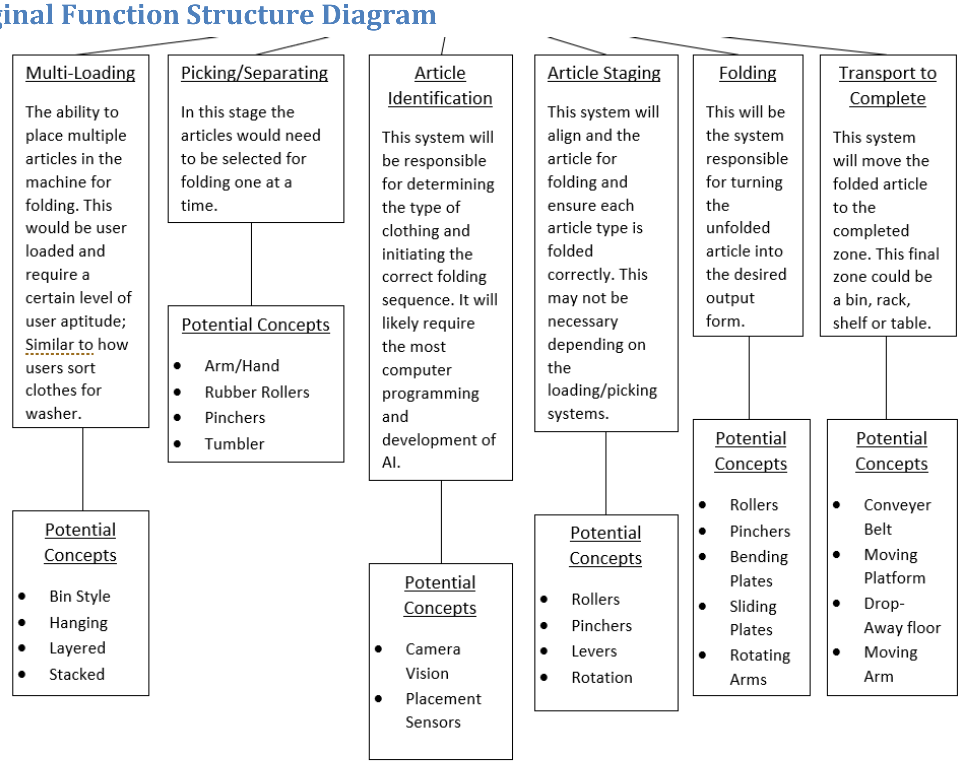
2.1 Expanded Design Brief

Build an autonomous moving robot utilizing either stepper or servo motors, that will grab and fold 3 articles of clothing t-shirts, 3pants, and towels. After preparing the article, the user will be able to select which article of code the machine will run. This function should also be aesthetically pleasing and cost less than $1,000 not including our time to design and build it. Must be Safe to use, Strong and Reliable in function, and Quick.

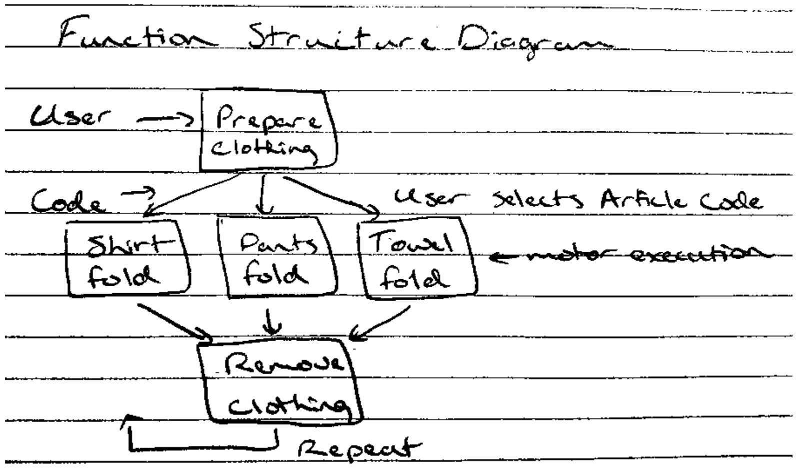
2.2 Function Structure Diagram

In the Function Structure Diagram, the overall function (clothes folding) is broken down into smaller sub-functions.

2.2.1 Original Function Structure Diagram



2.2.2 Modified Function Structure Diagram



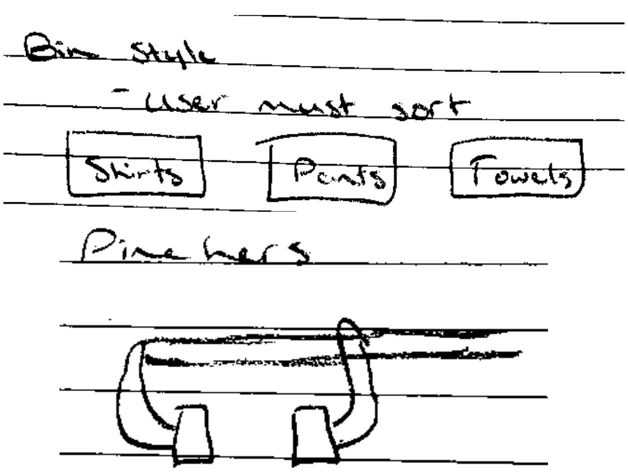
Initially we wanted the device to be able to prepare and identify the clothing but shortly after realized that would be very ambitious and unreasonable, given the budget and time frame we were working under.

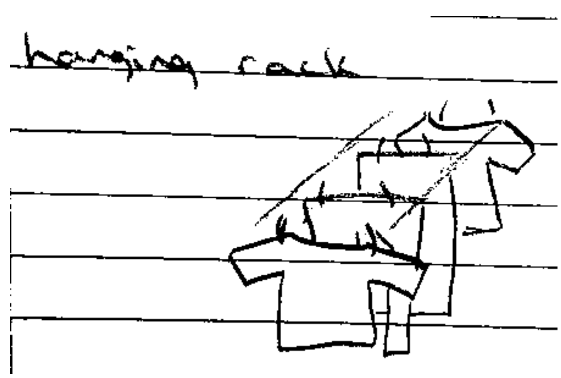
2.3 Morphological Chart

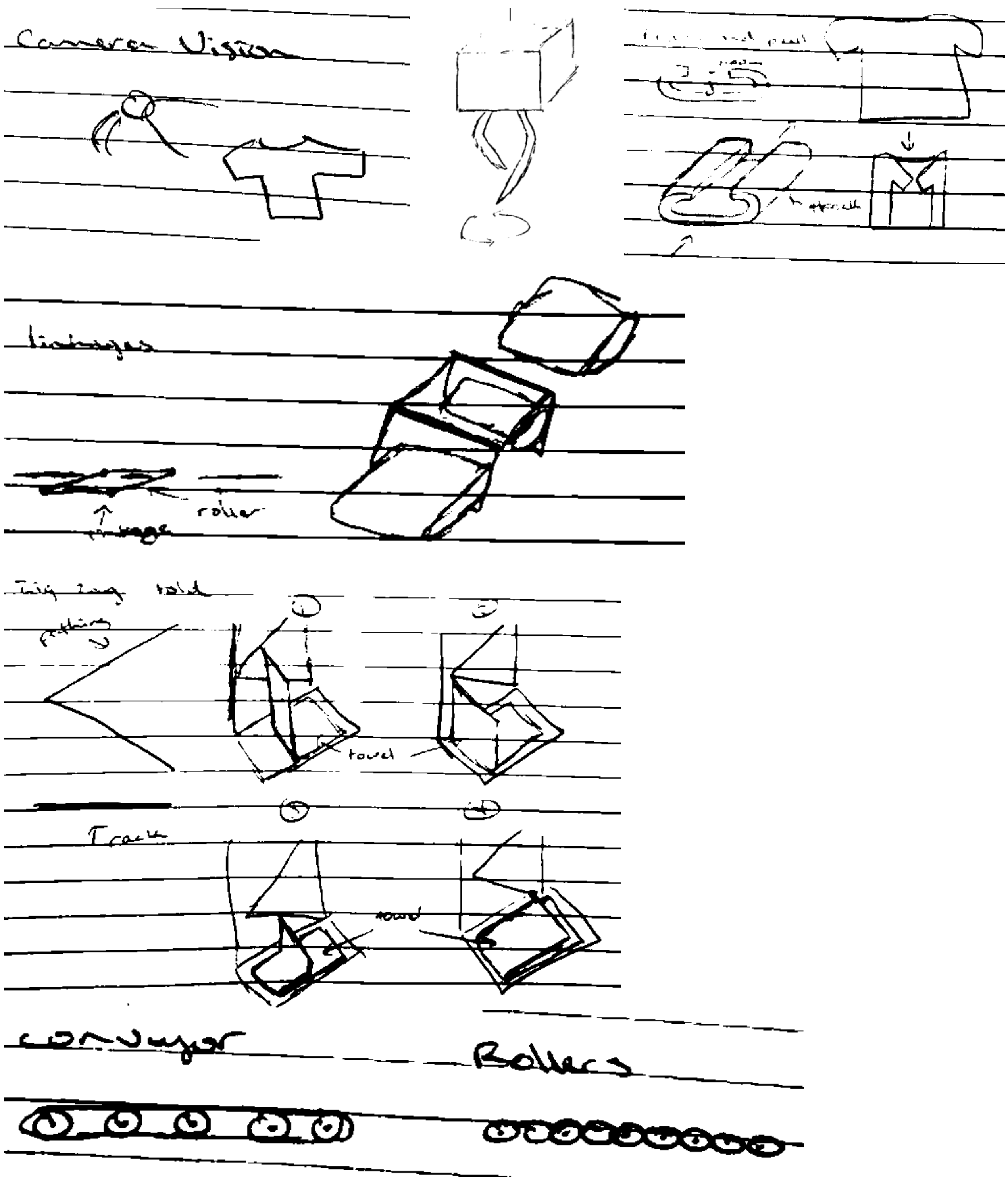
A Morphological Chart allowed us to structurally generate ideas that would accomplish each function.

Folding Device Morphological Chart									
Sub-Function	**Function Solutions**								
Multi- Loading	Bin Style	Hanging Rack	Layered Stack	Compartment Seperation			Filing Cabinet		Seperated "Wads"
Picking/ Separating	Arm/Hand	Gripped Rollers		Pinchers	Tumbler		Achieved in Multi-Loading		
Article Identification	Camera Vision	Placement Sensors		User Dependent		Achieved in Multi-loading (Compartment Seper.)			
Article Staging	Rollers	Pinchers	Levers	Sensors	Platform Movement			Achieved in Multi-loading	
Folding	Rollers	Pinchers	Levers	Arm/hand		Bending Plates		3D Printer Concept	
Transport to Final	Conveyer	Moving Platfrom		Drop Away Floor		Moving Arm			Rollers

2.4 Concept Sketches

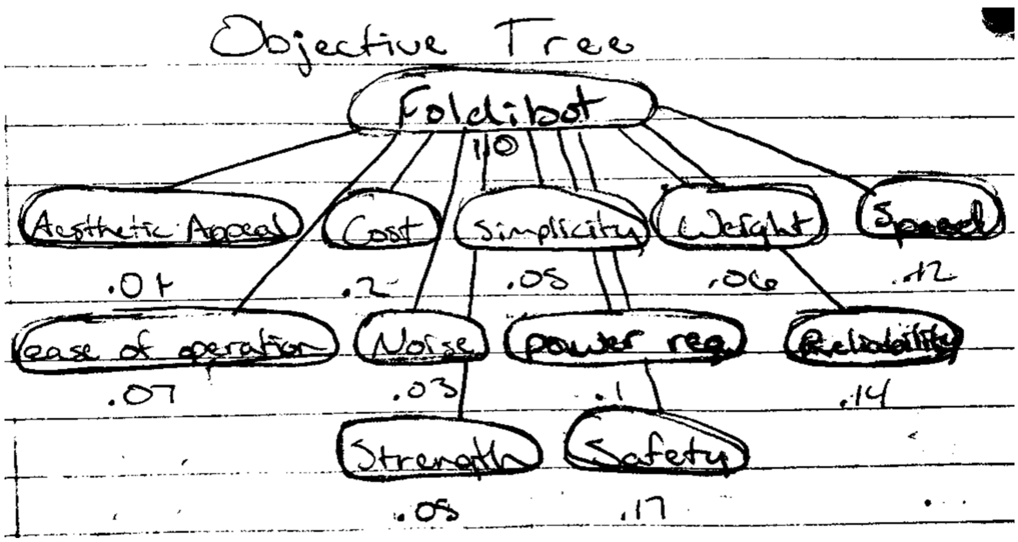





Camera Vision
linkages
roller
towel
Track
towel
conveyor
Rollers

2.5 Objective Tree

Utilizing an objective tree would aid us in determining which design would be the best the qualities we were looking for.



2.6 Weighted Decision Matrix

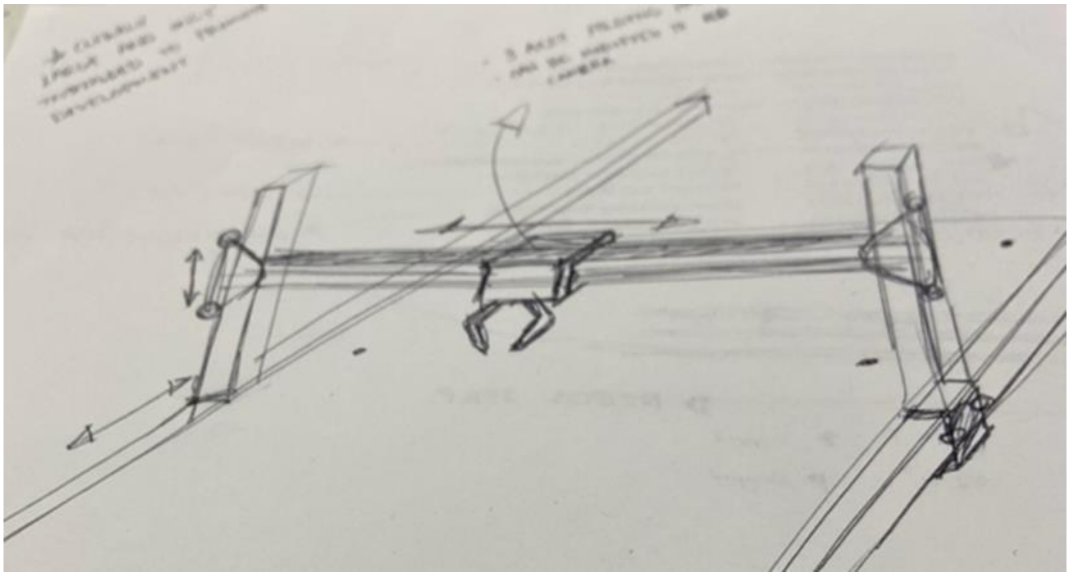
The weighted decision matrix is the scorecard of each design. Highest score wins.

Weighted Decision Matrix

	Weighting factor	Concept A		Concept B		Concept C		Concept D		Concept E		Concept F	
1. Aesthetics	.01	3	.03	4	.04	2	.02	5	.05	2	.02	5	.05
2. Cost	.20	2	.4	2	.4	3	.6	1	.2	1	.2	1	.2
3. Simplicity	.05	5	.25	3	.15	4	.2	4	.2	2	.1	4	.2
4. Weight	.06	2	.12	3	.18	4	.24	4	.24	2	.12	2	.12
5. Time to Crush	.12	5	.6	3	.36	3	.36	3	.36	3	.36	2	.24
6. Ease of operation	.07	4	.28	4	.28	4	.28	4	.28	4	.28	4	.28
7. Noise	.03	1	.03	3	.09	2	.06	3	.09	3	.09	2	.06
8. Power Req	.10	4	.4	3	.3	2	.2	2	.2	2	.2	1	.1
9. Reliability	.14	4	.56	4	.56	4	.56	3	.42	3	.42	2	.28
10. Strength	.05	3	.15	3	.15	3	.15	2	.1	2	.1	2	.1
11. Safety	.17	4	.68	4	.68	2	.34	4	.68	5	.85	2	.34
Σ	1.00		3.50		3.19		3.01		2.82		2.74		1.97

3. Embodiment Design

In this phase of the design we would paper prototype what the model would look like and how it would function.

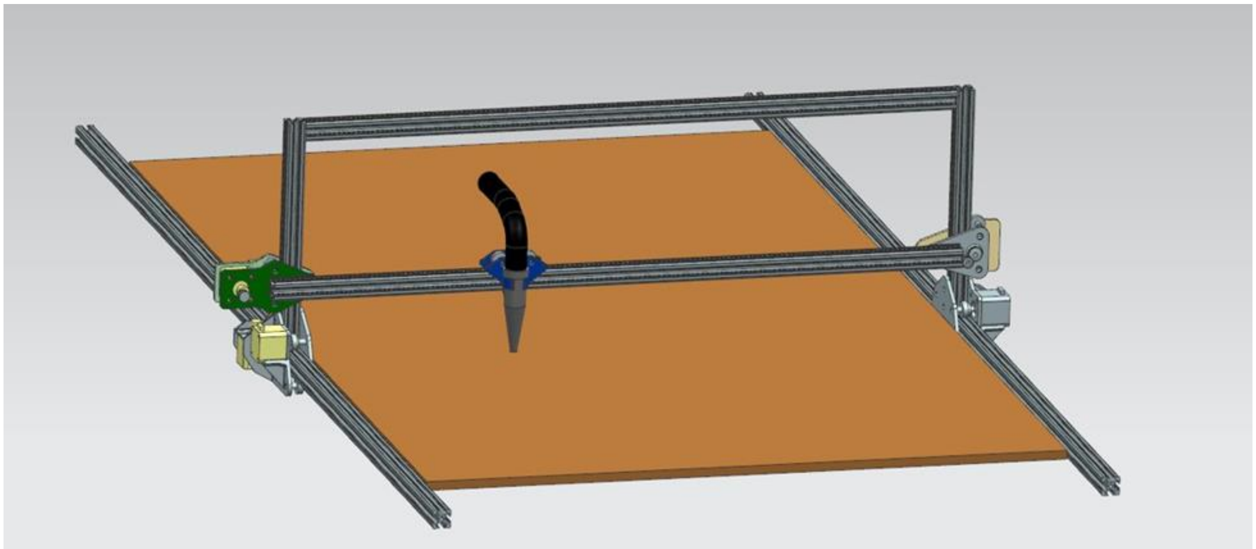


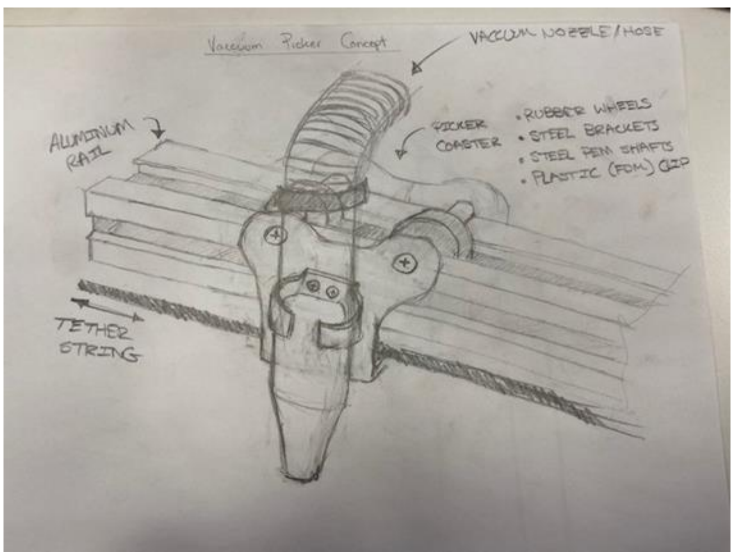
Concept A was the highest scoring design of the weighted decision matrix and would be the design we continued with.

- This would be a Gantry Style robot where it has 3 axes of movement between X, Y, and Z using stepper motors to initiate movement.
- Stepper motors would be located where the rails intersect and control their axis of movement.
- Brackets, either sheet metal or plastic would hold the rails together.
- Bottom platform would be made of MDF or wood.
- Head will be moved left and right using a single motor to give it a push or pull.
- Grabbing head will be a claw that can move clothing with ease.

4. Detailed Design

In this part of the design, we moved our paper prototype into a real world 3D model so we could get a better idea of what things would look like, create individual stl files for parts that needed to be 3d printed, and math out the sizing of the design.





- The claw was changed from a claw to a vacuum head. This was due to budget, using a vacuum head that we already had was much cheaper than buying or constructing a claw. Could be some strength concerns depending on the suction of the vacuum. Simple solution would be to manipulate the nozzle to give it a smaller area.
- 17 frame stepper motors that would be used have been added.
- Largest article of clothing was the towel, used ¼” plywood 30”x60” for the base.

5. Manufactured Design

6. Costs

$$Total\ Cost = Material\ Cost + Labor\ Cost = \$543.00 + \$10{,}095.00 = \$10{,}638.00$$

6.1 Parts

Bill of Materials				
Part Name	**Manufacturer**	**Retail Cost ($)**	**Quantity (#)**	**Actual Cost ($)**
Mechanical Components (Hardware)				
Rubber Rollers	N/A	$ 0.50	32	$ 16.00
2"x2" Wood Frame	Home Depot	$ 2.54	2	$ 5.08
T-Slotted Aluminum Rails	McMaster-Carr	$ 17.48	4	$ 69.92
Rubber Cogged Tooth Timing Belt	N/A	$ 8.99	1	$ 8.99
Cylindrical Screw Shaft	N/A	$ 9.32	2	$ 18.64
1" Ball Bearings	N/A	$ 2.32	32	$ 74.24
6mm Machined Steel Shafts	N/A	$ 1.37	32	$ 43.84
M4 Machine Screws	Home Depot	$ 0.11	60	$ 6.60
1/4" Plywood Board	Home Depot	$ 4.73	1	$ 4.73
3D Printed Brackets	N/A	$ 2.50	10	$ 25.00
17 Frame Stepper Motors	Minebea	$ 30.00	5	$ 150.00
				$ -
Electronic Components (Software)				
Raspberry Pi 3 B+	CanaKit	$ 59.99	1	$ 59.99
DRV8825 Stepper Motor Driver	Waveshare	$ 19.99	3	$ 59.97
Total				**$ 543.00**

6.2 Labor

Employee Payroll				
Employee	**Position**	**Number of Hours Worked**	**Hourly Rate**	**Actual Cost**
Braden Glasgow	Mechanical Engineer	100	$ 33.65	$ 3,365.00
Jacob Kittinger	Mechanical Engineer	100	$ 33.65	$ 3,365.00
Steven Shimko	Mechanical Engineer	100	$ 33.65	$ 3,365.00
Total				**$ 10,095.00**

7. Conclusion

7.1 Accomplishments

1. Mechanical device finished
2. Under Material Cost goal
3. Developed code to move in the x and y directions
4. Solid progress to carry into future development

7.2 Uncertainties

1. Is a completely autonomous device possible?
2. Will the mechanical design be compatible when completely autonomous?
3. Will it be cheap enough to be a household appliance?
4. How much time will it save the everyday person?
5. Will it be marketable to households?

7.3 Ethical considerations

This product will only take away a minor number of jobs. If the Foldibot is for personal use only, no jobs will be lost. If taken to retail, there are a small number of jobs where people simply fold clothes all day. Clothes manufacturers fold the clothes before packing and shipping them and retail stores need someone to fold clothes that were tried on or didn't arrive to the store perfectly.

7.4 Future work

We or a future team can work on making the device more autonomous. Currently, the user must choose which motor script must be run and place and prepare it accordingly based on the article of clothing. During our brainstorming phase, we had the idea of a camera system that could identify an article and prepare it to be folded. We didn't know how we would go about this nor could afford the time.

Another enhancement to our design could be an aesthetically pleasing casing and orientation. Our design is somewhat primitive and takes up a lot of space. If you could turn the design vertical while accounting for gravity affecting the orientation of the clothing, you'd have a much more real-estate efficient design.

8. Engineering Standards and Multiple Constraints

Engineering standards were developed by engineers so that it would ensure safety, reliability and operational efficiency in machine design and mechanical production. The manufacture of gun parts, sewing machines, locks, typewriters, bicycles and the like, leading up to the manufacture of steam engines, machine tools and locomotives, had made it clear that commercial success lay in sale of large numbers of duplicate units - uniform, safe, and standardized. There are few ASME engineering standards and multiple constraints that applied to our design. The main standard that was used by us in the design was dimension and tolerancing (Y14.5). This was used when designing our final design and developing our cad models. The Y14.5 is a language of symbols used on mechanical drawings to communicate geometry requirements efficiently, and accurately for features on parts and assemblies.

Another standard we followed had to do with material used in building our device. This included plastic, electrical, and metal material involved in the final design. The NM.3 Standard provides specifications for nonmetallic materials (except wood, nonfibrous glass, and concrete) and, in conformance with the requirements of the individual construction standards, methodologies, design values, limits, and cautions on the use of materials. B46.1 – 2009 is concerned with the geometric irregularities of surfaces. It defines surface texture and its constituents: roughness, waviness, and lay. It also defines parameters for specifying surface texture. The terms and ratings in this Standard relate to surfaces produced by such means as abrading, casting, coating, cutting, etching, plastic deformation, sintering, wear, erosion, etc. We considered these standards when deciding what material and surface finish to use for each section of the device.

References

- ISO/ASTM 52900: 2015(E)
- https://www.asme.org/codes-standards/find-codes-standards?type=Standards&page=1&perPage=100&sortBy=bestselling&sortByDir=desc
- ASME-BPE
- NM.3
- B46.1 – 2009

Appendix

Schedule

Week 1 (1/27 – 2/3): Sub-system Detailed Design

Jake: Frame/Folding Table

- Hand Sketches (Brainstorm)
- Concept Finalization
- Dimensions, System Layout, etc

Braden: "Picker"/Roller Brackets

- Hand Sketches (Brainstorm)
- Concept Finalization
- Dimensions, System Layout, etc

Steven: Explore electronics

- Research Arduino or Raspberry Pie Boards
- Digest 3D printers (Can mimic their design)

Weeks 2 - 3 (2/3 – 2/17): CAD Design

Jake: Frame/Folding Table

- Part Models for frame components
- Frame/Table Assembly model

Braden: "Picker"/Roller Brackets

- Part models for "picker"
- Part models for slider brackets
- Assembly model for picker and sliders

Steven: Complete electronics B.O.M

- Identify # of motors and type
- Finalize coding base (Arduino or Raspberry Pie)
- Identify programmable card
- Conceptual layout of electrical components

Week 4 (2/17 – 2/24): Part Ordering/Pre-fabrication

Jake/Braden/Steven:

- Create B.O.M
- Purchase parts
- Construct based on availability (3D printing)

Week 5 - 6 (2/24 – 3/10): Buffer Weeks

Jake/Braden/Steven:

- Construct based on availability (3D printing)
- **Design Reworks**

Week 7 - 8 (3/10 – 3/24): Build/Assembly/Testing

Jake/Braden/Steven: "Make it work"

- Complete Build
- Emphasize Coding (Group effort)
- Test, Test, Test
- **Design Reworks**

Weeks 9 (3/24 – 3/31): Presentation/Videos/Testing

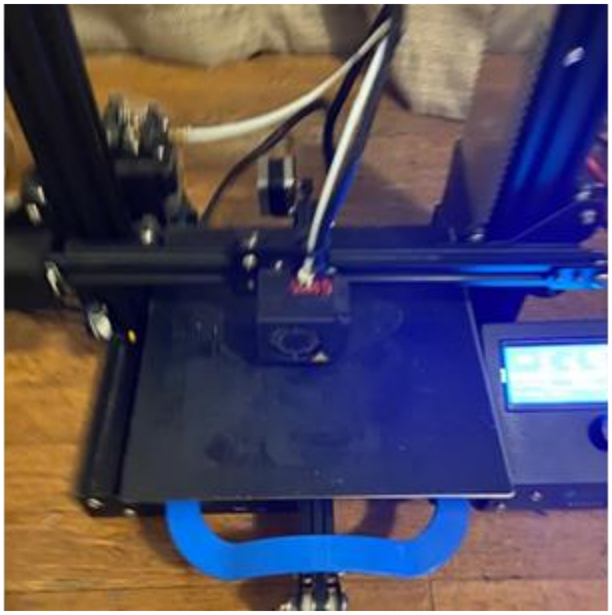
Jake/Braden/Steven: Prepare Presentation

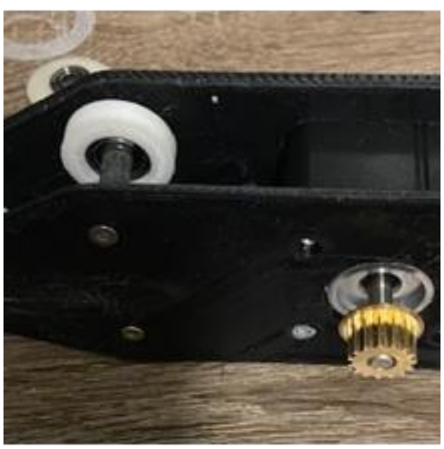
- Powerpoint
- Videos
- Device Cosmetics

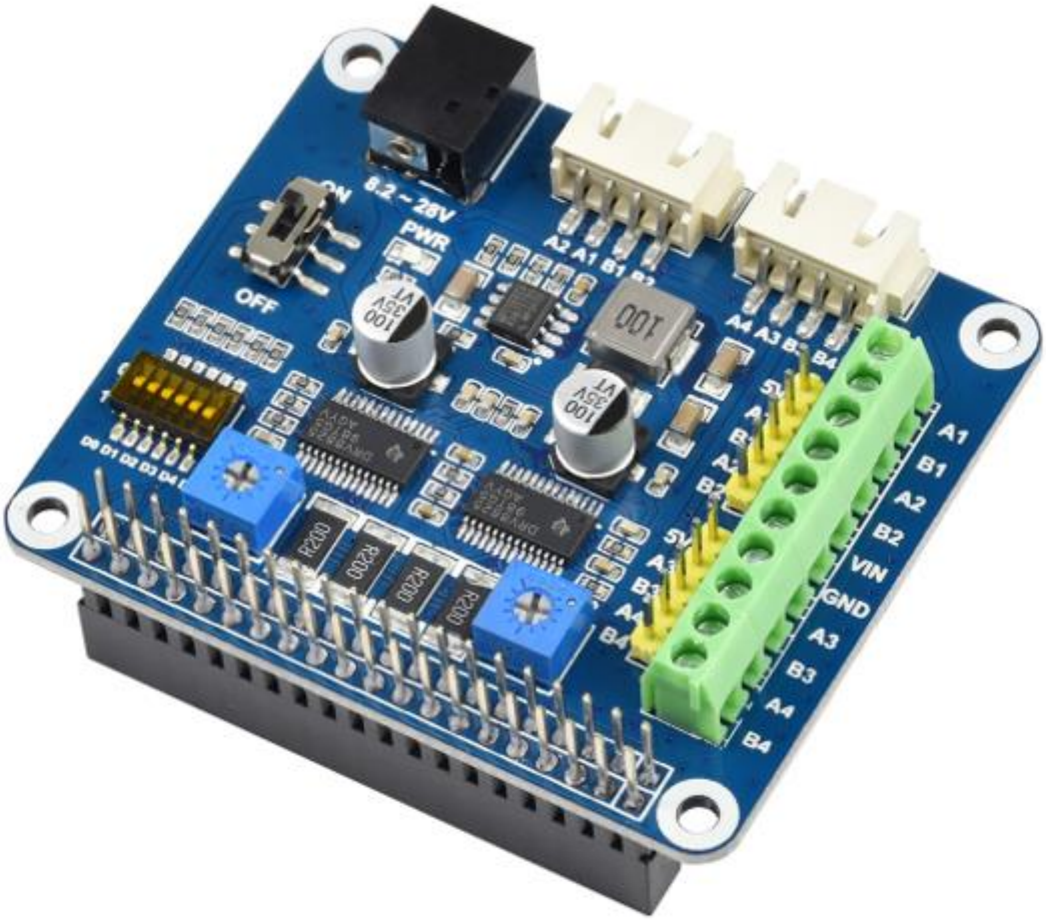
Weeks 10 (3/31 – 4/9): GET'R'DONE (Report)

Jake/Braden/Steven: Write report

- Word Doc
    - Outline - https://deepblue.lib.umich.edu/bitstream/handle/2027.42/62449/me450?sequence=1







8.2 ~ 28V
PWR
ON
OFF
A1
B1
A2
B2
VIN
GND
A3
B3
A4
B4