GNG 2101

Design Project User and Product Manual

Quick Fold – Switch Adapted T-shirt Folder

Submitted by:

QuickFold Group D1.2

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Table 1. Acronyms

Acronym	Definition
MDF	Medium Density Fiberboard
PLA	Polylactic Acid
UPM	User Product Manual

1 Introduction

This User and Product Manual (UPM) provides the information necessary for students, designers, and interested individuals to effectively create and use Quick-Fold – The automated T-shirt folding machine. This UPM provides a comprehensive documentation of everything to do with the prototype.

Bethany Children's Health Center[1] provides health and rehabilitation services to children and young adults. To encourage some of their patients with independence, they have hired them for work in the center's store. Currently the center has a manual T-shirt folder that some patients may use with aid, however, it presents a challenge to those with severe mobility challenges. The client has requested that the team design an automated T-shirt folder that may be activated with the push of an accessible button.

The design of the device uses three motors each connected to one of the flaps that folds. These motors are mounted below the T-shirt folder in an enclosure and are connected to the folder via 3D printed flaps. These motors are coded such that when they receive the signal that the button was pressed, they will rotate in consecutive order to fold a T-shirt.

This UPM first details the overview of the system as a whole and provides any warnings related to system use. Instructions are provided for how to operate the assembled machine and details are provided for troubleshooting any common problems that may arise. A detailed breakdown of each subsystem is provided along with instructions of how to build each one. These instructions are meant to go along with the documents that are uploaded to MakerRepo.

[1] Note: The client is a business, not an individual user. Their name is listed in the project background and is therefore not a privacy concern

Instruction on how to connect the subsystems so that they interface correctly are provided as well.

2 Overview

Problem

Many devices are not built with accessibility in mind and so there are many tasks that those with mobility challenges or physical disabilities have trouble completing. The client is a rehabilitation center that serves children to young adults with complex medical and physical disabilities. To increase their independence, the health center has provided jobs to some of the long-term patients folding T-shirts in the staff store. Due to the mobility challenges, the client requested an automated t-shirt folder to help the patients complete this task. The problem statement we used throughout the course to guide this design was:

Develop an automated T-shirt folding device that can be activated with an accessible button for individuals with mobility issues.

Needs

The fundamental needs of the user are that:

- The T-shirt folder be automated.
- The folding mechanism be triggered by an accessible switch.
- The switch preferably connects to the machine via a 3.5mm audio jack.
- The material is durable and is not cardboard.
- Battery powered device is preferred.
- The t-shirt folder is safe for child use.
- The folder can accommodate adult sized T-shirts.

Product Differentiation

Quick-Fold is better than other competitors because it is one of the most cost-effective options. This machine is mounted in an enclosure that is semi-portable, and the enclosure is built such that parts may be replaced easily. The opening in the enclosure base allows the user to reach in and update what is required. This ease of repair increases the working life of the machine.

Quick-Fold was built with children to young adults in mind, so it was designed for safety. Some of these safety aspects are a long cord between the operation button and the machine and an emergency stop button. The machine has also been designed with a slow folding rate, so that if anything ever got stuck in the machine, there is very little risk of injury. As well, there are different colours and patterns on it to inspire creativity and the mechanical and electrical components were left visible to the user to promote an interest in STEM. Figure 1 shows a top view of the final assembled prototype.

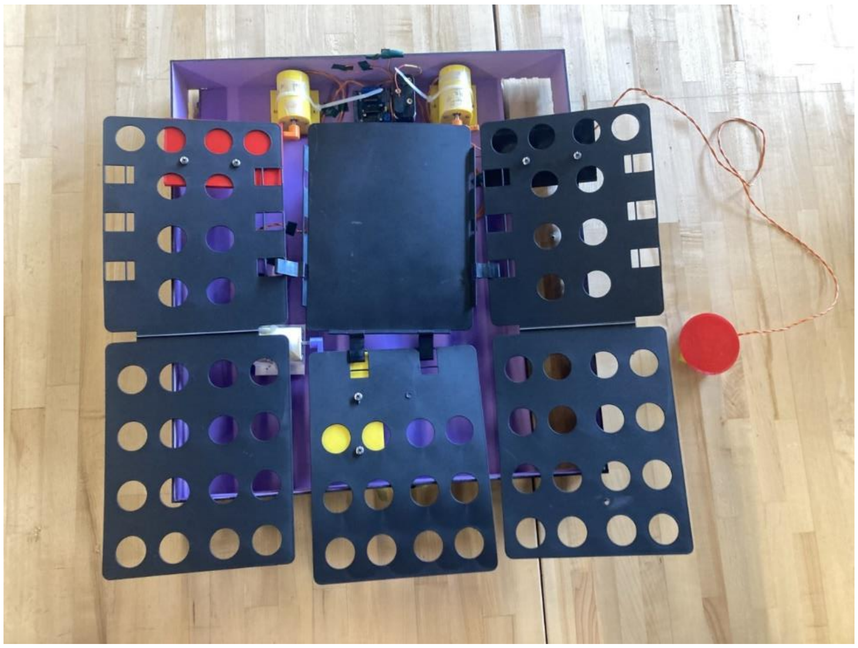

Figure 1. Final Prototype of Quick-Fold T-shirt Folder

Key Features

The main function for Quick-Fold is to fold T-shirts. The design consists of a store-bought manual t-shirt folder that has been adapted to be automated. The machine is turned on with a small switch button that connects to the power source and then the folding mechanism is activated with the push of the large accessible button.

System Architecture

The system is mounted into an enclosure made of MDF and then an Arduino and motor shield act as the "brain" of the system. A 12V battery pack provides the power to the Arduino and the Arduino communicates with the motors to tell them when to rotate. The motors are held in place in 3D printed holders which are attached to the MDF enclosure. 3D printed motor attachments have been attached to the motors and these are screwed into 3D printed motor flaps. These motor flaps have been screwed into the t-shirt folder so that the motors transfer the torque through the motor attachment to the flap, which rotates and causes the t-shirt folder flap to rotate. The rotation of the flap creates the folding motion. Figure 2 shows the overview of how the system functions and Figure 3 demonstrates how the torque is transferred from the motors to the t-shirt folder.

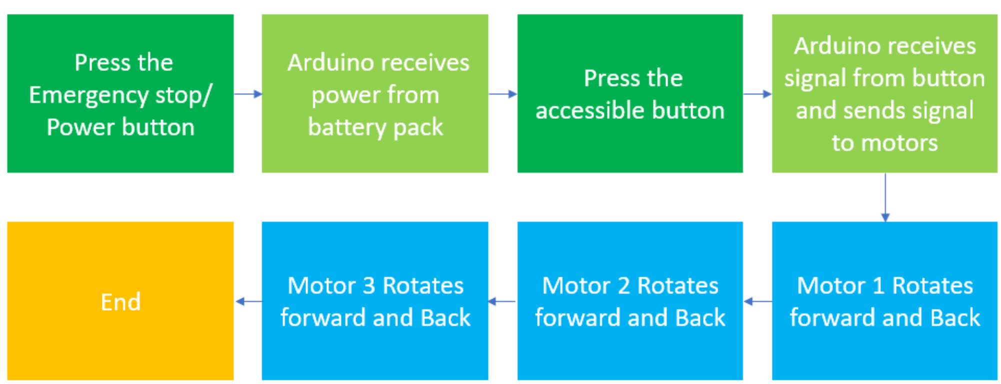

Figure 2. Bloc Diagram of Overall Function of System

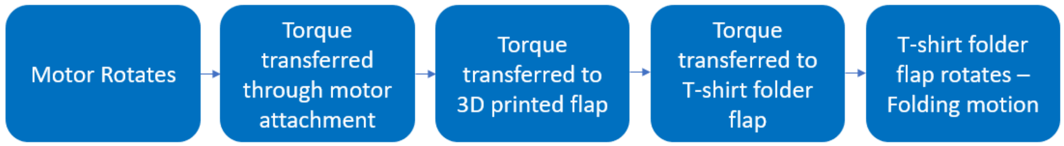

Figure 3. Bloc Diagram of Transfer of Torque from the motor to the T-shirt Folder

2.1 Cautions & Warnings

This article discusses various safety precautions and considerations that users should be mindful of when operating the machine.

1. Ensure the machine is placed on a stable, flat surface to prevent potential damage or malfunction.
2. Adhere to the manufacturer's guidelines regarding the appropriate size and thickness of clothing that the machine can handle.
3. Ensure that clothes are laid flat and positioned correctly on the machine to achieve optimal folding results.
4. Remember to turn off the power when the machine is not in use.
5. Handle this product with care; avoid bumping or dropping it, as this may damage the internal circuitry or cause the battery to rupture and ignite.
6. Maintain a safe distance while the machine is operating, and exercise caution to avoid getting caught in the machine. If your fingers are caught, promptly press the power/emergency stop button to stop the machine.
7. Regularly inspect the machine for signs of wear or damage, and update the batteries as needed. If necessary, contact our after-sales service department for assistance.

8. Do not attempt to disassemble or modify the machine, as this may void the warranty and create safety hazards.

This machine uses batteries, an Arduino, a motor shield, motors, and various other electrical components. Care must be taken when using the machine to avoid the risk of short-circuit. When electrical components are used there is always a risk of fire due to arcing, so adhere to the machine instructions and operate the machine away from hazards such as water or extreme heat.

3 Getting started

Quick-Fold is a barebones simple system designed to do one task. To use the prototype, place a T-shirt flat on top of the folder and press the toggle switch to allow the batteries to provide power to the Arduino. Take a few steps back from the system and when ready, push the accessible button. Wait approximately ten seconds for the folding sequence to occur and end. Press the toggle switch again to power off the system and remove the folded T-shirt.

3.1 Configuration Considerations

The system consists of three different subsystems, mechanical, electrical, and code. The mechanical subsystem consists of flaps that are attached to the t-shirt folder with screws. These flaps, along with 3D printed motor accessories connect the motors to the t-shirt folder so that they are aligned with the hinges and can cause rotation (Figure 4, 5). The mechanical subsystem consists of:

- T-shirt folder [1]
- 3 High torque 12V DC motors [2]
- 3 3D printed flaps
- Screws (size, M5x12)
- 3 motor attachments
- 3 motor cases

Figure 4. 3D Printed Motor Attachment and Flap

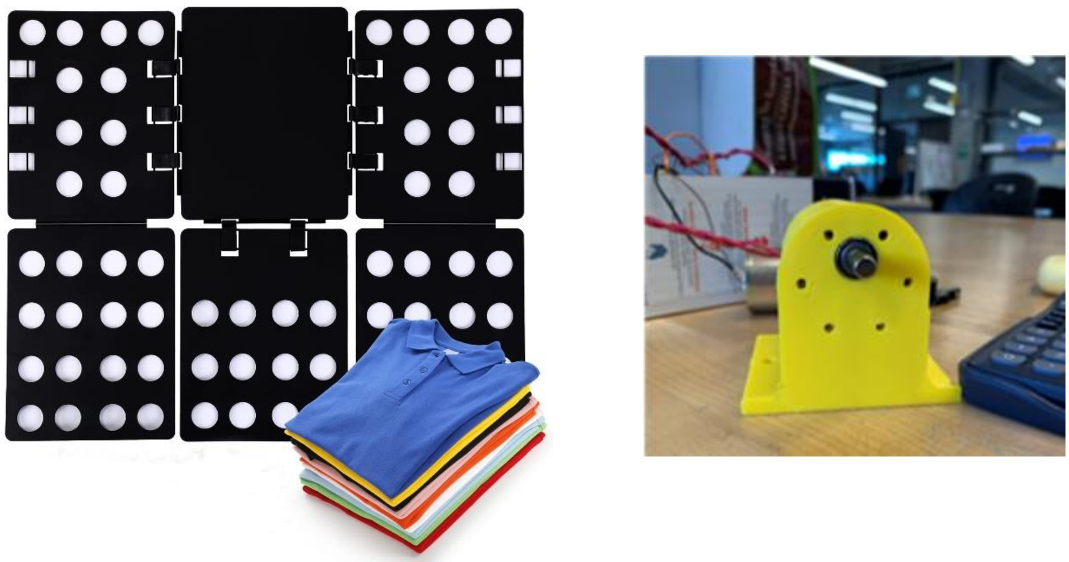

Figure 5. Manual T-shirt Folder and Motor Case

The electrical subsystem is the connection between the code and mechanical systems. This system connects the power source to the Arduino to the motors. This system is also connected to the button. The button sensor is the input, and the motors are the output of the system. The components of the electrical systems are:

- Arduino Uno
- Motor Shield [3]
- Wires

- Button Sensor [4]
- Battery Pack
- Switch Button [5]

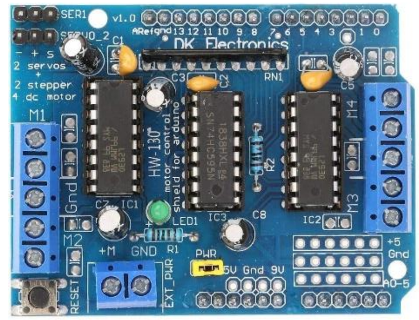

Figure 6. Arduino and Motor Shield

Lastly the code subsystem is the brain (along with the Arduino) of the operation. The code subsystem receives and reads a signal from the button sensor. Once this sensor is received, a loop begins where each motor one by one is rotated approximately 180 degrees toward the center of the folder and then 180 degrees back to its starting point. This system comprises of the Arduino IDE environment.

3.2 User Access Consideration

As this t-shirt folder was designed to be as accessible as possible, it enables individuals with mobility issues to fold a t-shirt with a press of a button. An individual can use QuickFold's product if they can place the t-shirt on the product and press a large button.

For those with major mobility challenges, a second user may be required to place the T-shirt on the machine and remove it afterward.

Currently, there are no audio signals integrated into this system, so those who are visually impaired may require aid locating the button and operating the machine.

3.3 Accessing/setting-up the System

To set up the product, place Quick-Fold onto a flat surface, and place a t-shirt atop the folder. After ensuring the location is clear, press the power button to turn on the machine. Then press the accessible button to start the folding procedure.

The accessible button may be mounted wherever needed for each individual user. For example, if the user uses their head to push the button, the button should be attached to the wall at an appropriate height.

3.4 System Organization & Navigation

The system is fairly simple, as the user only has to interface with button. The button's input will trigger the sequence of t-shirt folding.

Quick-Fold's subsystems (mechanical, electrical, code) are detailed in section 3.1. connections between then subsystems to make them interface properly are detailed in section 6.

3.5 Exiting the System

The product runs one cycle at time. Once the user presses the button to start the folding cycle, they will not need to do anything other than take the t-shirt away after the cycle is complete. To put away the machine, the user must turn off the power by pressing the power button. There are no steps required for exiting the system as it automatically runs only one cycle and then stops.

For emergency stop functions, every time the user presses the emergency button, they will have to reset the board to the original position before the next cycle. Currently this entails disconnecting the flaps, resetting the motors and then reconnecting the flaps.

The system is semi-portable, however it should be stored on a flat surface. It is recommended to place the system on a small table with wheels so that it may relocated or stored away with ease.

4 Using the System

The system has only one function, folding T-shirts. To operate the assembled Quick-fold T-shirt folder, please adhere to the following step-by-step instructions.

4.1 Regular Use

1. Place the T-shirt folding machine on a flat surface, such as a table or the floor, ensuring that there are no obstructions or tangled items between the plastic boards, and that the wires are not intertwined.
2. Lay the T-shirt on the machine. It should be laid flat on the machine with the collar facing the motors at the top of the machine. It is alright if the fabric overhangs the machine, however, for a cleaner fold, it is best to fold the overhanging sections onto the board.

Figure 7. T-shirt Placed on Quick-Fold machine

3. Press the power button.

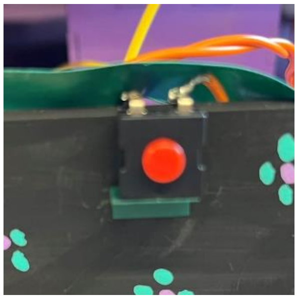

Figure 8. Power Button

4. Press the Accessible button to begin the folding sequence.

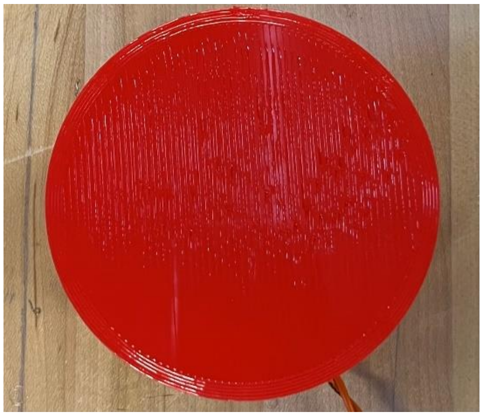

Figure 9. Accessible Activation Button

5. Wait for the plastic boards to fold. Three flaps will fold in consecutive order, right, left, bottom. Only remove the T-shirt after the flaps have fully reset.

4.2 Sudden Stop

If an unexpected situation occurs while Quick-Fold is in operation, including but not limited to fingers being caught by the plastic boards, immediately press the power button. The machine will stop instantly, allowing you to address the issue.

4.3 Built-in Power Supply

Quick-Fold features a built-in power supply, allowing users to move it to any desired location for use. However, please note that the machine is not waterproof, so it should only be used in dry indoor environments. If you notice the machine slowing down, the motor struggling to lift the plastic boards, or the machine ceasing to operate, check the battery and determine if a replacement is needed.

5 Troubleshooting & Support

While our product boasts a simple and reliable design, certain failures may still occur during regular use. This guide aims to describe proper maintenance procedures and highlight common hardware issues, along with their respective solutions. It is important to follow the provided instructions as device malfunctions resulting from misuse or intentional damage by users are not covered under the warranty. Should the user experience problems such as the device ceasing to function, the motor operating at reduced speed, or running in the incorrect direction, they may consult the guide below for troubleshooting or send the product to our after-sales service center for professional repair.

5.1 Incorrect Behaviors

This guide discusses how to address common abnormal behaviors that may occur with the machine:

1. Single motor stops working: If a specific motor in the machine ceases to operate, meaning one of the boards no longer moves, please check if the motor is properly connected to the wires. If the motor is disconnected, ensure the power is off before reconnecting the wires to the motor. Be sure to connect the wires according to the positive and negative markings on the motor interface as the image shows. If connected improperly, the motor may rotate in the opposite direction as desired and cause damage to the device.

   To ensure a secure connection, please solder the new connections in place.

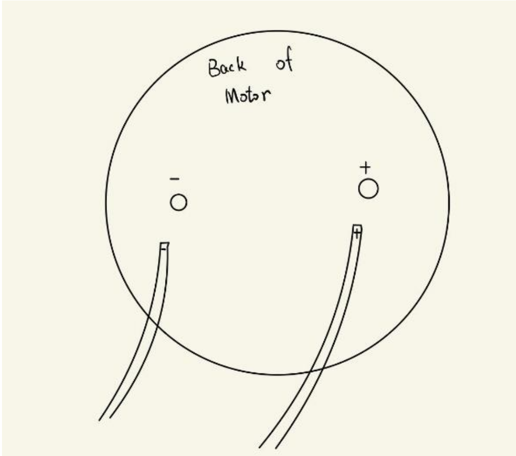

Figure 10. Illustration of Positive and Negative terminals of motor

2. Machine stops working (Motors are not turning): Verify whether the machine is powered on. If you are using a battery-powered version, make sure the batteries are installed and charged. If the machine still does not operate, check that all wires are connected. If machine continues to fail, disconnect each motor and check if it functions or if it has been burned out. Check for burning smell to determine if there was a malfunction with the motor shield or Arduino.
3. Machine stops working (Motors turn): Please check the motor attachments to determine if the attachment pieces have warped, or if any screws have popped loose. If this is the case, reprint those components and reinstall.
4. Motor speed is slow: Replace the batteries or ensure that the voltage is sufficient. If the problem still exists, please disconnect the power and take the product to our after-sales service center.

5.2 Special Considerations

This section outlines the procedures for handling unexpected situations when users are maintaining the product.

1. If you find damaged wires while maintaining the product, immediately disconnect the power. Replace the damaged wires with spare ones. Solder the wires together to ensure proper connection.
2. If you notice damage or abnormal behavior in the motor during maintenance, power off the product and send it to our after-sales department.
3. If you encounter a blinking yellow light or other anomalies on the Arduino board while maintaining the product, consider replacing the Arduino board or resetting it by pressing the reset button and re-uploading the code.

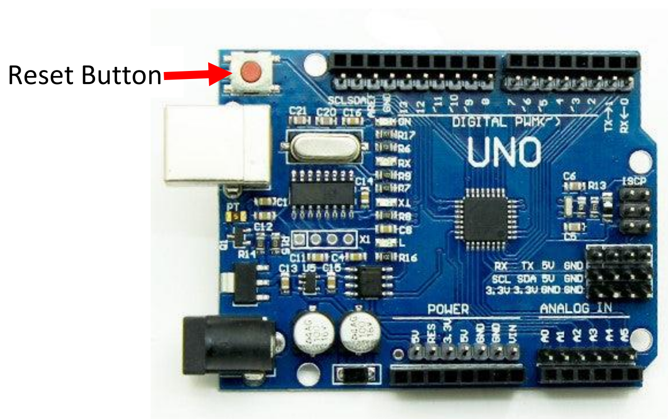

Figure 11. Arduino Reset Button

4. If you find broken or disconnected plastic plates during product maintenance, disconnect the power. Please reprint the broken- or worn-down parts and attach them to the machine.

5.3 Maintenance

The prototype should be disconnected from power when not in use. Every three weeks, or forty uses, one should run the machine with the enclosure open and check for burning smells to determine if any damage has occurred to the electrical components. After every twenty uses, the user should check and try to tighten the screws on the flaps as these may loosen with use.

5.4 Support

This article will discuss how to obtain after-sales service assistance and system support. If you encounter difficulties during the use of our product, require after-sales service, or are dissatisfied with the product and need to return or exchange it, please feel free to contact our after-sales service department.

Below are the contact details for the after-sales service department. Please note that the marked time zones are based on Toronto Time (GMT-4). Reach out to us by phone or email, and our technical staff will be more than happy to provide you with technical support.

- After-sales Service Phone (English): +1 604-778-1234 (8:00 AM – 4:00 PM, Monday to Sunday)
- After-sales Service Phone (French): +1 605-788-4321 (8:00 AM – 4:00 PM, Monday to Sunday)
- After-sales Service Email (English): HelpRequestEN@QuickFold.com (Replies within 24 hours)
- After-sales Service Email (French): HelpRequestFR@QuickFold.com (Replies within 24 hours)

Please note these are not real emails or phone numbers. If you are recreating this project, please contact one of the five creators (Listed on the title page) by using their UOttawa Emails.

6 Product Documentation

Overall Bill Of Materials

Table 2. Bill of Materials - Whole Project

Item	Quantity	Price per Unit	Total price ($)	Source
Mechanical Subsystem				
T-Shirt folder	1	$16.99	16.99	Ohuhu Tshirt Folding Board
PLA	200g	40 (free for UOttawa student)	40	PLA Filament
MDF	2	$3.00	6.00	Maker store - MDF Sheet
Fasteners	1	$39	39.00	Ottawa Fastener Store
Coding Subsystem & Other Required Software				
Libraries	N/A	0	0	Arduino Libraries
SolidWorks Standard (3 months)	N/A		860.20$/quarter Note: Not purchasing for GNG 2101 class	Solidworks Pricing
Electrical Subsystem				
Arduino Uno	1	$17	17	Maker store-Arduino
Hook-up wires	1	$1.60	1.60	Maker store-HOOK-UP WIRE
Battery holder	4	$2.50	10	Maker Store - AA Battery Holder
Push button switch	1	$2.25	2.25	Maker store - Push Button Switch
DC motor	3	$20.67	50.94	AliExpress-HighTorqueMotors
Motor shield	2	$15.52	31.04	Amazon - Motor shield
Toggle Switch	1	$2.25	2.25	Maker store-Toggle Switch
Zipties	1	$1.50	1.50	Dollarama
Battteries	2	$2.99	5.98	Best buy
Total Price (CAD)				**$197.87**

6.1 Mechanical Subsystem

6.1.1 3D Printed Attachments

6.1.1.1 BOM (Bill of Materials)

Table 3. BOM for Mechanical Subsystem - 3D printed Attachments

Item	Quantity	Price per Unit	Total Price ($)	Source
T-Shirt folder	1	$16.99	16.99	Ohuhu Tshirt Folding Board
PLA*	200g	$40 (free for uOttawa student)	40	PLA Filament
MDF	2	$3	6	Maker store - Acrylic Sheet
Fasteners*	1 set	$39	39	Ottawa Fastener Store
Total			$101.99	

**Fasteners include 6 M5x16 Phillips head screws, 6 M5 wingnuts, 3 M2X12 CSK screws, 3 M2 nuts, 6 M3x10 (note that not all fasteners belong to this subsystem)*

Table 1 details the bill of materials used for the mechanical system of this project. The total amount spent on the mechanical subsystem was $101.99, out of the $200 available budget. Quick-Fold chose to adapt a manual t-shirt folder [1] instead of manufacturing one from scratch due to budget constraints. Quick-Fold then designed attachments on Solidworks to 3D print out of PLA to minimize cost. These attachments (described below) transmit the torque from the motor and to the adapted manual t-shirt folder to enable rotation.

6.1.1.2 Equipment list

The following resources were required to create the final prototype:

- 3D Printing Machine (Ultimaker 2+)
  - 0.4mm Nozzle Size
  - 0.8mm Nozzle Size
- Hand Drills (~0.28" Drill bit)
- Phillips Head screw drivers

6.1.1.3 Instructions

To assemble the mechanical subsystem, the following components are needed:

- 3X 3D Printed Flaps
  - 1X Right Side Flap
  - 2X Left Side Flap
- 3X 3D Printed Motor Mounts
- 3X 3D Printed Motor Attachments
- 3 sets of M2x12 CSK screws and M2 nuts.
- 3 sets of M5x16 Phillips head screws and M5 wing nuts.
- Access to screw drivers corresponding to previously mentioned screws
- Access to hand drill
- Access to 3D printing machine.

Assembly Instructions:

1. 3D Print three motor attachments on a 0.4mm nozzle size. (STL/CAD files are provided in MakerRepo-UM2_Motor Attachement_V2.gcode).

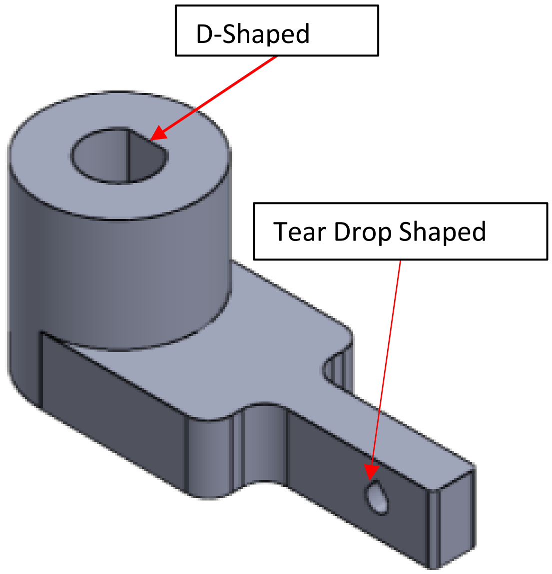

Figure 12. Motor Attachment Design.

2. 3D Print two of the "Right Side Flaps" and one of the "Left side flaps" on a 0.8mm nozzle size (STL/CAD files are provided in MakerRepo- UM2_RightSideFlaps.gcode).

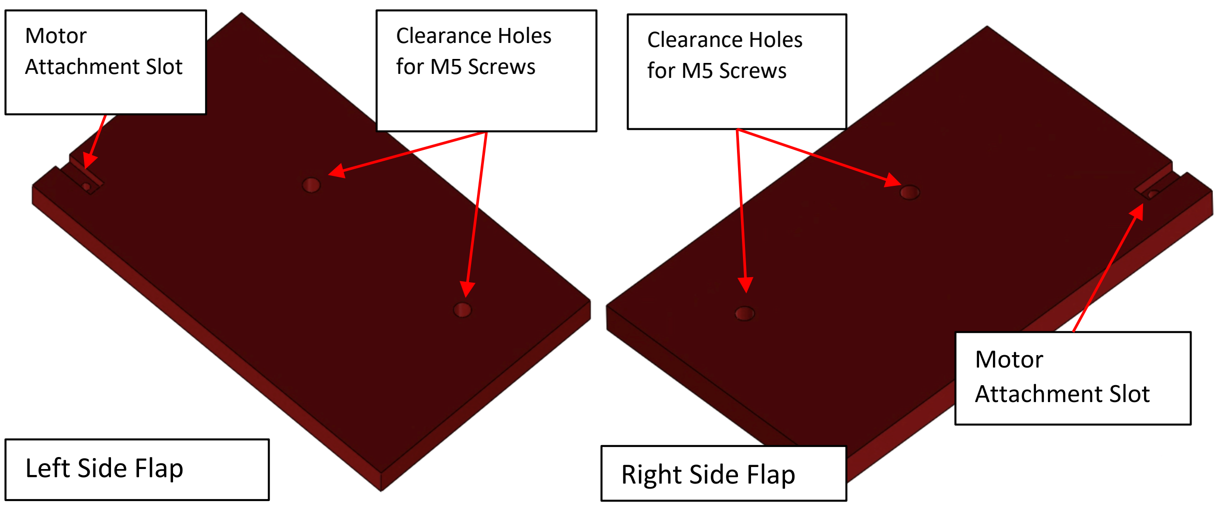

Figure 13. Right and Left Side Flaps

3. Place each motor attachment into its labelled slot on each flap and use an M2x12 CSK screw to fasten the attachment in, with the M2 nut in contact with the motor attachment

piece. Ensure that the motor attachment piece is placed so that the D-shaped hole is facing the shorter side length, as seen in the image below.

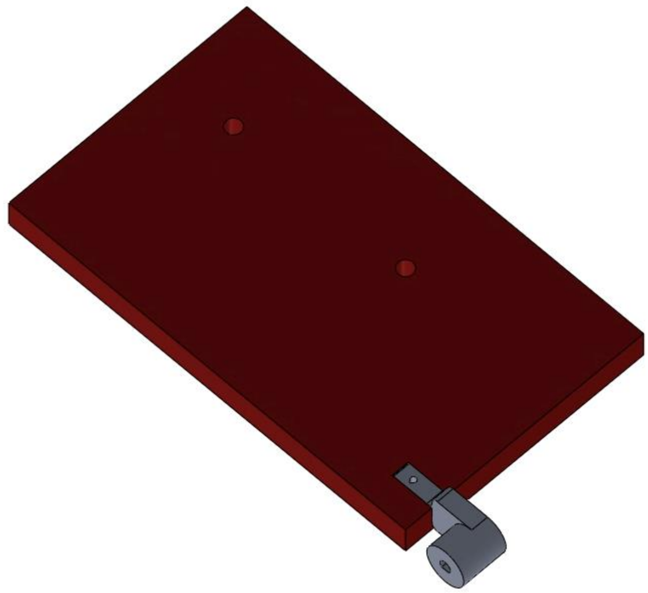

Figure 14. Connection of between motor attachment and flap

Now that all the side flaps are assembled, it is time to attach them to the manual t-shirt folder.

4. Mark the points in the following image onto the t-shirt folder and drill holes using a –0.28” drill bit (a little bit larger than a diameter of 5mm).

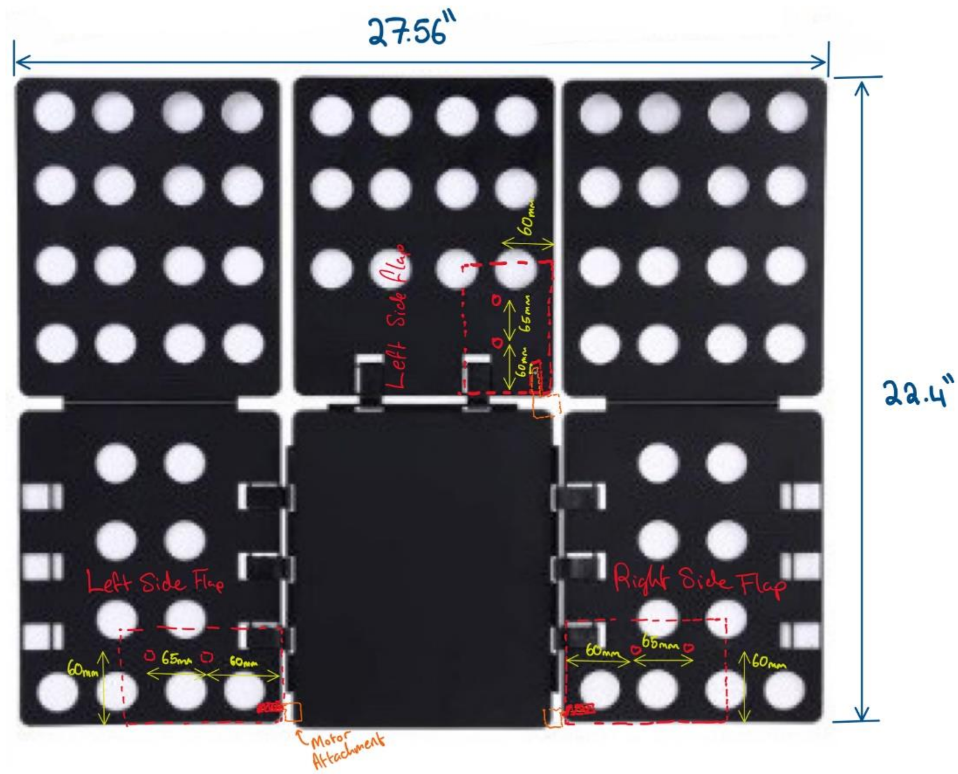

Figure 15. Location to drill holes on the T-shirt folder

5. Align the assembled side flaps to the newly drilled holes, and secure with the M5x16 screws, with the wing nuts on the side of the 3D printed flap.
6. Once the motors are secured in the 3D printed motor mounts (detailed in the following section), press fit the motor attachments to the motor shafts.

The manual t-shirt folder to motor connection is now secured.

6.1.1.4 Testing & Validation

It is important to note that the product can be significantly optimized by manufacturing the motor attachments, and the interfacing flaps out of a stronger metal, as the strength of PLA is low and reduces the lifetime of the product. Due to budget constraints, Quick-Fold was unable to experiment with these options. However, several iterations of the motor attachments were printed and tested, each test varying the 3D printing settings of the piece. It was found that the product's critical failure was the motor attachment. Increasing the infill to the maximum (100%) helped increase the rigidity and lifetime of the motor attachment piece.

It is also recommended to follow the convention outlined for selecting the nozzle size of the printer, as it was found that the nozzle sizes selected are the optimal sizes that maximize strength of the piece without having an excessive printing period. All prints should be less than five hours.

6.1.2 Motor Casing & Enclosure

6.1.2.1 BOM (Bill of Materials)

Table 4. Bill of Materials for Mechanical system - Enclosure

ITEM	Quantity	Price per Unit	Price	Source
MDF (1/8" thick)	2	$3	$6	Maker store - Acrylic Sheet
Fasteners *	1 set	$39	$39	Ottawa Fastener Store
Zip-Ties	1 pack	$1.50	$1.50	Dollarama

**Fasteners include 6 M5x16 Phillips head screws, 6 M5 wingnuts, 3 M2X12 CSK screws, 3 M2 nuts, 6 M3x10 (note that not all fasteners belong to this subsystem)*

***Motors not mentioned here since they are included in the electrical subsystem. The materials shown in this subsystem are to hold them in place only.*

6.1.2.2 Equipment list

- Laser Cutter
- Gorilla Glue
- 3D Printing Machine (Ultimaker 2+)
  - 0.4mm Nozzle Size
- Hand Drills (~0.28" Drill bit)
- Screw drivers

6.1.2.3 Instructions

Motor holder instructions:

1. 3D Print three motor holders on a 0.8mm nozzle size. (STL/CAD files are provided in MakerRepo – UM2_motor_holder.gcode).

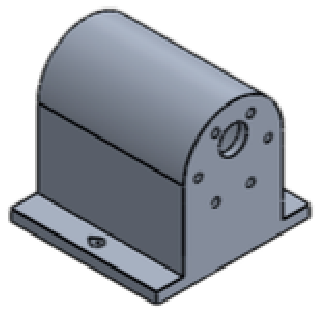

Figure 16. Motor Holder/Case

2. Insert each motor into a motor holder. Note that the motor should have the wires connected (soldered) to its terminals already (refer to electrical subsystem).

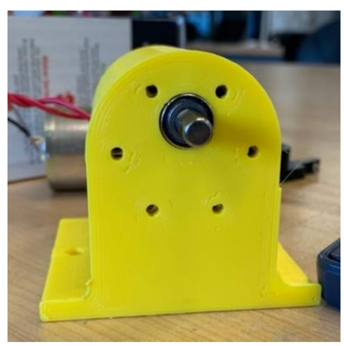

Figure 17. Motor held in case

3. Use two M3 x 10 screws to secure the motor in place to holder. Secure the screws onto the front face of the holder and motor, placing each screw directly opposite of the other. Repeat for all holders.

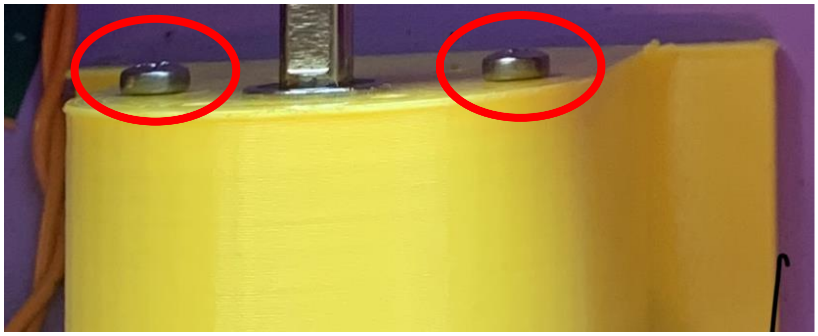

Figure 18. Fastening the Motor to the motor holder

Enclosure assembly instructions:

1. Use provided pdf´s to laser cut the enclosure components using one sheet of MDF for the base, and another sheet for the walls (files are provided in MakerRepo – Base for enclosure.pdf & Enclosure wall.pdf).
2. Drill holes into the enclosure base at the locations where the motor holders will be placed. Verify that the motors properly align with the center of rotation of the flaps. You may use the following diagram as reference, but adjust location if necessary.

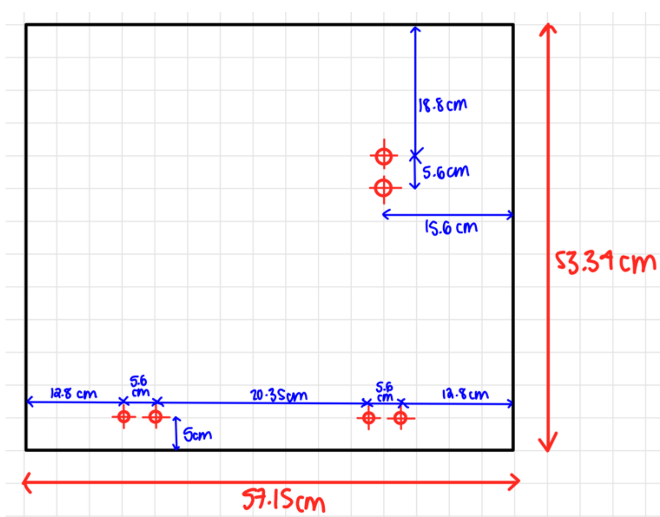

Figure 19. Approximate location of drilled holes in enclosure base

3. Assemble the enclosure by interconnecting the finger slots along the edges of the pieces. Connected corners can be reinforced with gorilla glue.

4. At this step, paint the base and inside walls if desired.
5. Using remains of the MDF sheet used for the walls, laser cut the smaller box (2.8” x 3.8”) parts from the PDF provided.
6. Assemble the box in the same manner as the enclosure. Use gorilla glue to fix box onto the base (refer to picture below for approximate location). This will serve to hold the fixed part of the t-shirt folder at the desired height.

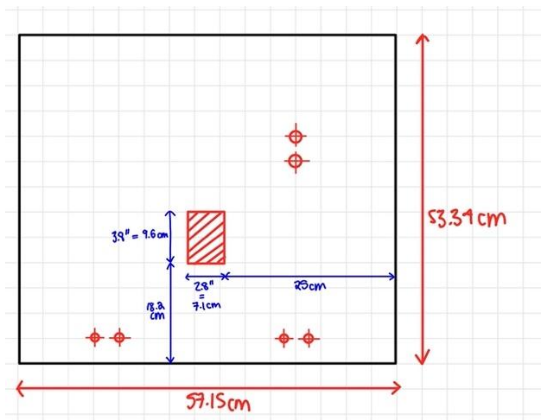

Figure 20. Approximate location of box that supports t-shirt folder

7. Place the motor holders and align their teardrop holes with the holes drilled into the enclosure base. Secure in place with two zip ties going around entire motor holder and the bottom of the base. (Alternatively, a set of screws and nuts can be used).

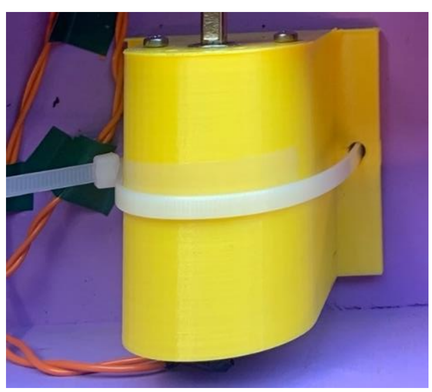

Figure 21. Motor and Case connected to enclosure

6.1.2.4 Testing & Validation

Prior to fixing the motors onto the base, testing was performed by manually holding the motors while the system ran its folding operation. This provided valuable insights into the best location that allows the proper rotation of the folder hinge, as well as determining that the folder required some allowance to move to prevent it from breaking. From these results, the hinges were modified to allow more movement between the folding flaps and the fixed side. In addition, the ideal locations for the motor holders were selected to then we secured them in place. Zipties were used in lieu of nuts and bolts to allow some freedom with the motors to account for potential misalignment from the center of rotation. These changes allowed the final prototype to run smoothly and there was no critical failure from this subsystem.

6.2 Electrical Subsystem

6.2.1 BOM (Bill of Materials)

Table 5. Bill of Materials for Electrical System

Electrical Subsystem				
Items	Quantity	Price per unit	Total Price ($)	Source
Arduino Uno	1	$17	17	Maker store-Arduino
Hook-up wires	1	$1.60	1.60	Maker store-HOOK-UP WIRE
Battery holder	4	$2.50	10	Maker Store - AA Battery Holder
Push button switch	1	$2.25	2.25	Maker store - Push Button Switch
DC motor	3	$20.67	50.94	AliExpress-HighTorqueMotors
Motor shield	2	$15.52	31.04	Amazon - Motor shield
Toggle Switch	1	$2.25	2.25	Maker store-Toggle Switch
Batteries	2	$2.99	$5.98	Best buy

6.2.2 Equipment list

- Soldering iron kits

- Wire stripper
- Multimeter
- Phillips Head screwdriver
- 3D printing machine (Ultimaker 2+)

6.2.3 Instructions

1. Connect motor shield to Arduino uno, as seen in the following image.

Figure 22. Connecting the motor shield to the Arduino

2. Connect the three motor terminals to the motor shield as demonstrated by Figure 23. The orientation of the motor connection is very important as the relationship between negative and positive or negative and negative terminals determines what direction (clockwise or counterclockwise) the motor rotates.

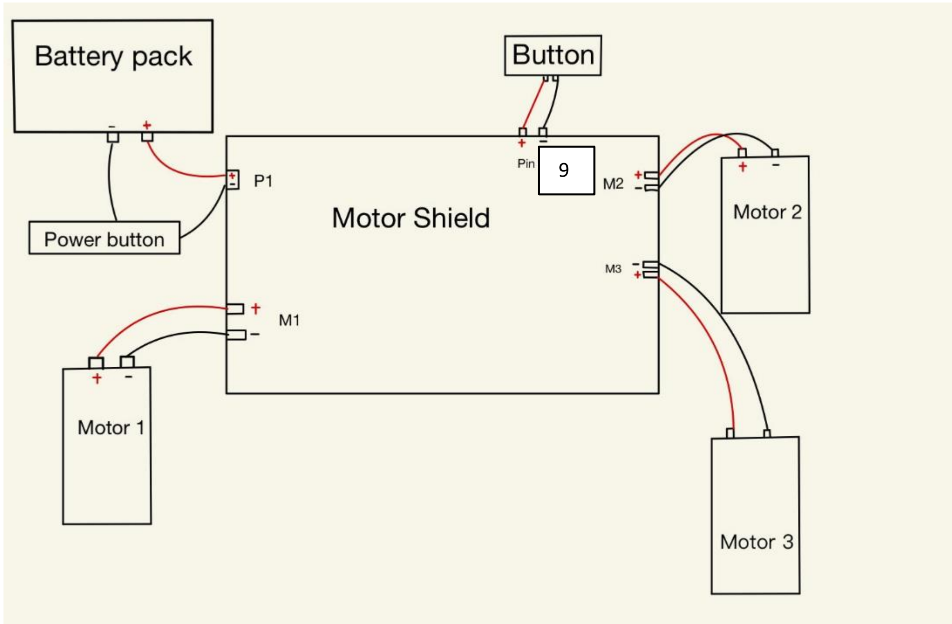

Figure 23. General Configuration of Electrical Subsystem

3. The battery case has two wires, red and black. The red one must be connected to the positive plug for the battery on the motor shield and the black wire must be connected to one terminal of the toggle switch. The other terminal of the toggle switch will be connected to the ground for the battery on the motor shield. (**Note: do not put batteries in before assembling the push button or uploading code!**)

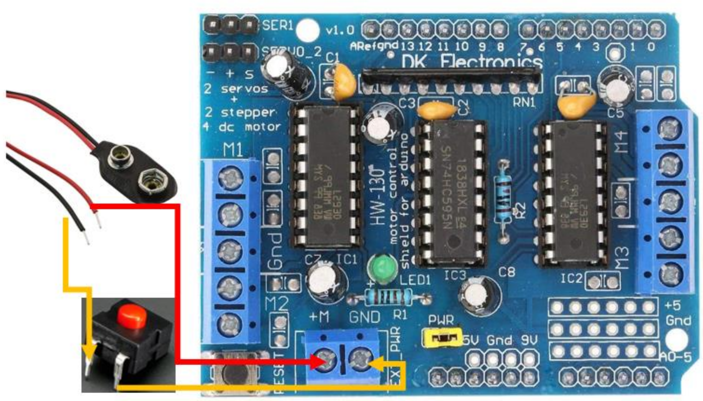

Figure 24. Connection of Battery pack to motor shield

4. Press the 3D printed attachment for the push button (gcode file provided in Makererpo) onto the pushbutton and connect one side of the push button pin to the “servo_1 S” plug on the motor shield and the other side of the push button pin to the “servo_1 -” plug on the motor shield. Notice that there will be two pins that will not be used on the push button.

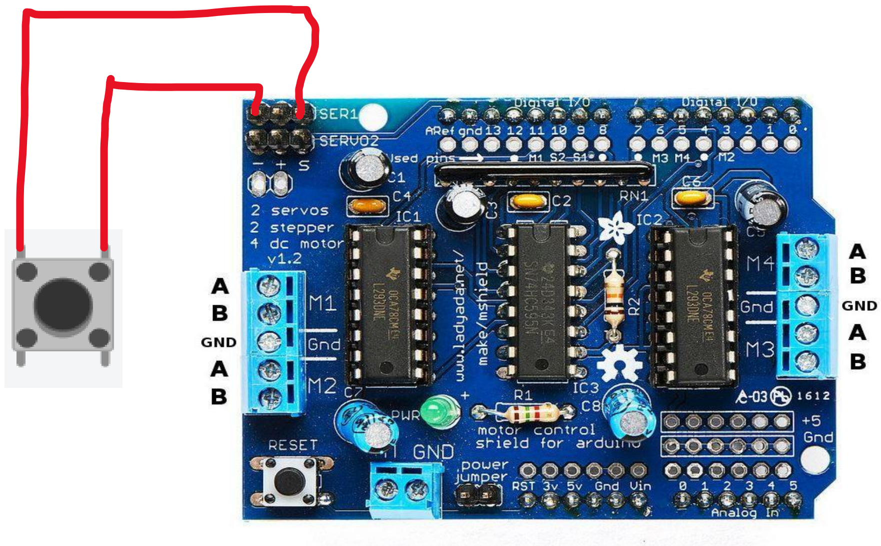

Figure 25. Connection of Push button to motor shield

5. Upload the code from the code subsystem onto the Arduino. Caution: DO NOT PUT BATTERY INTO BATTERY CASE WHILE DOING THIS, MAY BURN YOUR ARDUINO OR MOTOR SHIELD.

6. Solder the wires connecting the motors, pushbutton and emergency stop button.

Figure 26. Solder the wires to the motors

Figure 27. Solder the wires to the Push Button

Figure 28. Solder the wires to the Toggle Switch

7. Put the batteries into the battery case (8 AA batteries in total, each provide 1.5V which sums to 12V).

6.2.4 Testing & Validation

A total of three experiments were conducted, all utilizing the same circuit as depicted in Figure 23, with three motors connected to the shield.

The purpose of the first experiment was to confirm the ability to control the three motors' rotation using the motor shield. Makerlab's DC motors and motor shield were used. By connecting the computer and utilizing Adafruit's built-in test code [6], it was verified that the rotation and direction of the three small motors could be simultaneously controlled through the shield.

The second experiment involved the motors purchased from Amazon. Under the same connection conditions, a custom code (Figure 29, Section 6.3.4) was used. As a result, the motors successfully rotated in the forward and reverse directions in sequence. In this experiment, a pushbutton was added to start the motors. This experiment proved that the design was successful. After this, connecting the motors to the board was the last step to complete the prototype's circuit portion. However, during the test, it was determined that if the battery provided less than 12V (for example 9V), the motors will not able to provide enough torque to operate the system. While if the battery provided more than 12V (for example 15V) the circuit may burn the Arduino and the motor shield.

The third and final experiment entailed connecting all the devices together and driving them using a pushbutton. The motors successfully drove the board and operated in the desired sequence. The experiment was successful, and a power switch was added that also served as an emergency stop button at the beginning of the power supply. The prototype's circuit testing was completed and met the requirements.

6.3 Code Subsystem

6.3.1 BOM (Bill of Materials)

Table 6. Bill of Materials for Code Subsystem

Coding Subsystem & Other Required Software				
Item	Quantity	Price	Price per Unit	Source
Libraries	N/A	0	0	Arduino Libraries
SolidWorks Standard (3 months)	N/A		$860.20/3 months Note: Not purchasing for GNG 2101 class	Solid Works Pricing
Adafruit Motor Shield Libraries	N/A	0	0	Adafruit Motor Shield Library
Official Arduino compiler	N/A	0	0	Official Arduino compiler

6.3.2 *Equipment list*

There was no equipment required other than a computer.

6.3.3 *Instructions*

Pseudo code was initially used to test the overall concept. Once proven functional, the process moved forward to connect the electrical components and complete the C++ code responsible for controlling the motor.

The primary focus lies on two functions: "setSpeed" and "delay." The "setSpeed" function regulates the current flowing into the motor, allowing for control over its speed. Meanwhile, the "delay" function aims to manage the motor's runtime, successfully governing the extent of the motor's rotation. Additionally, the "setDirection" function is employed, enabling the motor to move in two directions—forward and backward.

By leveraging these functions from the library, it becomes possible to coordinate the operation and direction of three motors, ensuring they can effectively fold the T-shirt as intended. The final code to be uploaded to the Arduino is documented on the MakerRepo.

6.3.4 Testing & Validation

A total of two tests were used on the code. The first test used pseudocode in a C++ compiler [7] to primarily verify whether our logic was correct. The motor was simulated by popping up characters in the terminal and the emergency stop button was simulated by entering characters. In the pseudocode test, our results matched our expectations, proving that our coding logic was correct.

```
Enter any number to start
5
Enter 'q' to quit:
motor1 is running positive, angle: 30
motor1 is running positive, angle: 60
motor1 is running positive, angle: 90
motor1 is running positive, angle: 120
motor1 is running positive, angle: 150
motor1 is running positive, angle: 180
motor1 is running negative, angle: 150
motor1 is running negative, angle: 120
q
motor1 is running negative, angle: 90
Stopping...Everything END
Finish.

Process finished with exit code 0
```

Figure 29. Pseudocode used to test logic of system

The second test involved actual motors. Since the code could only set a rotation time for the motors, different numbers were input for the delay and multiple tests were conducted to ensure the motors could perform "clockwise rotation 180°, counterclockwise rotation 180°." The required numbers for the motors to execute these rotations were eventually determined. During testing, code was also added to receive button signals, allowing the motors to start rotating when the button was pressed. Finally, a two-second delay was added between the two motor rotations to ensure the board's rotation frequency wouldn't be too fast and cause safety hazards.

In the end, our efforts paid off, and these experiments achieved the desired results. This proves that our coding system can perform its intended tasks.

7 Conclusions and Recommendations for Future Work

An important thing to keep track of when building this system is time management and ensuring that parts are connected properly so that the subsystems interface together properly. The major lessons we learned when designing this product were the importance of choosing the right splicing settings for the 3D printed parts. For example, the motor attachments perform much better when they have 100% infill, and a teardrop shape must be used when printing vertical holes. To have success recreating Quick-Fold or improving upon the design, ensure that you perform many tests. Work through any calculations related to forces carefully to ensure that you purchase adequate electrical equipment. Perform these calculations with a large factor of safety if it is one of your first times designing something.

If you are working on recreating and improving the design, ensure you create many low fidelity prototypes. It is easy to learn from or validate design ideas by creating physical prototypes. We spent quite a bit of time trying to create a full-fledged conceptual design using CAD, however creating the physical parts helped us learn and move our prototype forward more quickly.

If we had a few more months to work on this project, and a larger budget, we would look into making the motor attachments and potentially the flaps out of metal as this is stronger and will withstand the stresses of the system better. As well, we would like to improve the enclosure to better fit the components and create spots for all of the items to rest. For example, adding spools to hold the excess wire and creating divots to place the battery pack and Arduino into. We would also add a clear acrylic cover underneath the t-shirt folder, above the electrical components to add another level of safety to the device.

One aspect the client had requested was that the button connect to the machine via an audio jack, so in future iterations this would be an essential function to add. As well, creating different folding sequences so that the folder may also accommodate larger sized shirts and sweaters would help Quick-Fold be marketable toward more businesses.

8 Bibliography

[1] "Ohuhu Tshirt Folding Board," Amazon, [Online]. Available: https://www.amazon.ca/Ohuhu-Tshirt-Folding-Board-Adjustable/dp/B09MCLNL9W/ref=sr_1_5?hvadid=229937455614&hvdev=c&hvlocphy=1002376&hvnetw=g&hvqmt=e&hvrand=3388953075449873263&hvtargid=kwd-299731564769&hydadcr=27178_10621444&keywords=shirt+folding+board&qid.

[2] "High Torque Low Speed Quiet DC Gear Motor," Alibaba.com, [Online]. Available: https://www.alibaba.com/product-detail/High-Torque-Low-Speed-Quiet-12V_1600732737022.html?spm=a2700.7735675.0.0.1864jTXJjTXJNY&s=p.

[3] "Motor Drive Shield Expansion Board Module," Amazon, [Online]. Available: https://www.amazon.ca/dp/B07TTRXXJ5/ref=sspa_dk_detail_2?psc=1&pd_rd_i=B07TTRXXJ5&pd_rd_w=zZPuR&content-id=amzn1.sym.88a70737-8341-4e83-b43f-2849bf84234d&pf_rd_p=88a70737-8341-4e83-b43f-2849bf84234d&pf_rd_r=1D8HDNWQRM995DH9E95Z&pd_rd_wg=0XNkA&pd_rd_r=087b.

[4] "Momentary Push Button," Canada Robotix, [Online]. Available: https://www.canadarobotix.com/products/1882?variant=14423784030257&currency=CAD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&com_cvv=d30042528f072ba8a22b19c81250437cd47a2f30330f0ed03551c4efdaf3409e.

[5] "On-Off Power Button," MakerStore, [Online]. Available: https://makerstore.ca/shop/ols/products/on-off-power-button-pushbutton-toggle-switch.

[6] "AF_DC Motor Class," Learn Adafruit, [Online]. Available: https://learn.adafruit.com/afmotor-library-reference/af-dcmotor.

[7] "CLion - A cross-platform IDE for C and C++," Jet Brains, [Online]. Available: https://www.jetbrains.com/clion/promo/?source=google&medium=cpc&campaign=11960744855&term=clion&content=489240779231&gclid=CjwKCAjw586hBhBrEiwAQYEnHdIa7X32dkUC7LCOw7mZDjU2sy9dtMIapWk5Al-a5ko03KKBHz32aBoCFgYQAvD_BwE.

APPENDICES

9 APPENDIX I: Design Files

Zip file package with all design documents can be found at:

https://makerepo.com/mrodr031/1486.quickfold-automated-tshirt-folder

Table 7. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Base for Enclosure.pdf	Zip file package – "Enclosure" Folder	April 2023
Enclosure walls.pdf	Zip file package – "Enclosure" Folder	April 2023
Support box to hold center of tshirt folder.pdf	Zip file package – "Enclosure" Folder	April 2023
LeftSideFlap.STL	Zip file package – "MechanicalSubsystem" Folder	April 2023
Motor Attachment.STL	Zip file package – "MechanicalSubsystem" Folder	April 2023
Motor_holder.STL	Zip file package – "MechanicalSubsystem" Folder	April 2023
RightSideFlap.STL	Zip file package – "MechanicalSubsystem" Folder	April 2023
Button cover.SLDPRT	Zip file package – "Accessible Button" Folder	April 2023
UM2_button cover.gcode	Zip file package – "Accessible Button" Folder	April 2023
Arduino Code.ino	Zip file package	April 2023