Automatic Cloth Folding Machine

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1. Introduction

1.1 Objective

For many people, the worst part of doing laundry is having to fold all the clothes once they come out of the dryer. This activity is not only tedious and time-consuming, but also requires some efforts to fold all the clothes in the same size. As a result, some people just dump their laundry into the draws without organizing them. This often leaves a mess in the closet and gives trouble for people when they are finding their clothes.

In order to cope with the problems stated above, we propose a low cost folding machine that could automatically fold the clothes when a piece of laundry is placed on the machine. This machine is easy to use and requires little human involvement, which is significantly useful for people who do not have time or not willing to organize their clothes. The machine is able to detect the clothes automatically and fold them in a neat way. For safety reasons, the folding procedure will only initiate after users leave their hands from the machine.

1.2 Background

Washers and dryers have become so commonplace that people do not think of them as a new concept. Since Hamilton Smith patented the rotary washing machine in 1858, our ways to deal with laundry have not changed for almost 160 years. [1] We get used to the process that put our dirty laundry into the washer and dryer, but it is the final step that folding the laundry troubles us the most. A recent Kickstarter campaign ThreadStax that helps people to fold, stack and dispense their clothes manually, raised a total of $ 181,058 out of a $50,000 goal, and this shows how troublesome for people to organize their clothes. [2]

As many can imagine, folding clothes is tedious for human, but it is even harder for machines. However, it is not impossible to achieve such a task through machines. Hotels, hospitals and many factories have machines that can fold large amount of towels, sheets, and other fabrics. These machines are typically huge in terms of size, and requires large amount of power to operate. [3] For household laundry, the only available machine in the market is called Foldimate, but it costs from $700 to $850 and has not started the pre-orders yet. [4] Our design is at much more affordable, while achieving the similar function in a smaller environment and lower power consumption.

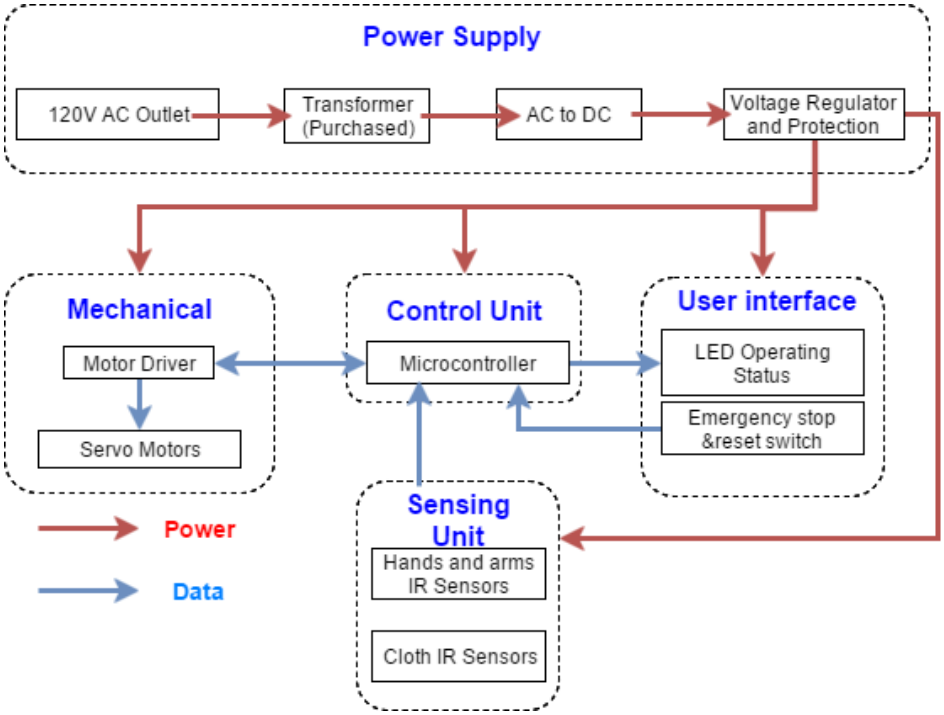
1.3 High-level Requirements List

- The user interface correctly indicates each operating state through LEDs.
- Motor controlled flipping must fold the clothes into a rectangle.
- For safety reasons, folding procedure only starts with no hands/fingers on board.

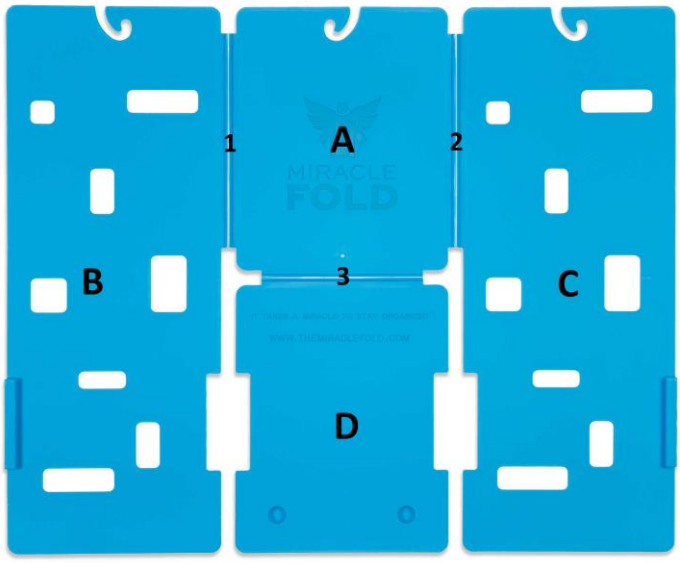
2. Design

The overall design requires five modules: power supply, control unit, sensing unit, user interface and mechanical components.

2.1 Block Diagram



2.2 Physical Design



We plan to install our control circuits, power circuits, and all wires below board A(since board A is the only board that stays still during folding process). Three servo motors at edge 1,2 and 3 to flip board B, C and D. Four IR sensors will be mounted on top of board A, B, C and D to detect presence of clothes. Additional two IR sensors will be mounted on the left edge of board B to detect motion of human arms and hands.

2.3 Functional Overview

2.3.1 Power Supply

This project is powered by 120 V AC outlet instead of battery so that we will not need to deal with battery safety and capacity issues. Since the rest of the components are powered by DC, we will design our own AC to DC converter, voltage regulator and protection circuits using knowledge from ECE 343. The DC voltage value is dependent on the microcontroller, IR sensors and servo motors. Voltage regulator and protection circuit is to provide stable power and prevent components from burning out. For safety reasons, we will use a pre-built transformer from the market to lower the 120V AC to 12V AC, and therefore we do not have to interact with any high voltages.

2.3.2 Control Unit

The core of the project is the control unit which consists of a programmable microcontroller. It handles data among all components and send commands accordingly for proper operation.

2.3.3 Sensing Unit

This unit consists of four IR sensors with detection range about 5 cm mounted on top of board A,B,C and D for cloth detection, 2 Passive IR sensors with detection range about 50 cm mounted on the left edge of board B for hands and arms motion detection.

2.3.4 User Interface

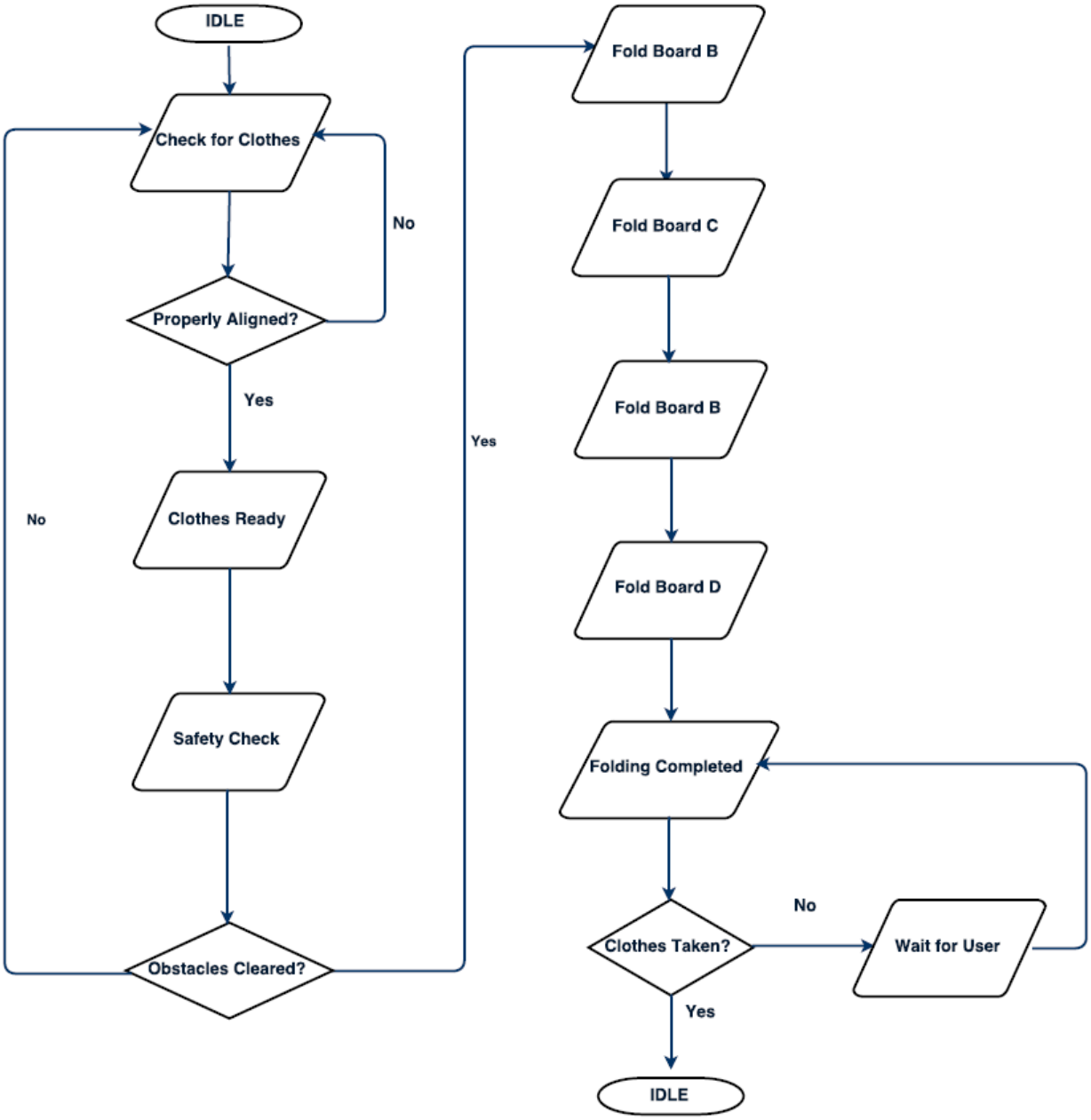
An emergency stop and reset switch is included in this unit for user to manually control the operation of the board in case of need. The LED status circuit will indicate the current mode of operation as shown in the table below:

State Number	Status	LED Output
1	IDLE	White
2	Clothes Ready	Yellow
3	Pass Safety Check	Green
4	Folding	Red
5	Folding Completed	Blue

Table 1: State Status

2.3.5 Operation Procedure and Flowchart

If the sensors circuits detect no presence of clothes on board, the machine is in idle state. As soon as the cloth IR sensors detect a piece of laundry on the board, and the hands and arms IR sensors detect no motion of the human body in the board area, the microcontroller sends out signals to motor drivers to initiate the folding process. Once boards B, C and D have completed their folding, our project will beep to remind the user to remove clothes from the board. Once sensors detect cloth has been removed, the project is ready for the next piece of clothes.



2.3.6 Mechanical

The mechanical components are three servo motors and their drivers. These servo motors can flip the board upon receiving a signal from microcontroller.

2.4 Block Requirements

2.4.1 Power Supply:

1. Able to produce following DC voltages to drive each unit:
    a. Servo motors: 7±0.5V
    b. Motor drivers: 5V±0.5V
    c. Microcontroller: 5±0.2V
    d. IR Sensors: 5±0.2V
2. Protection circuit should disconnect power when source current is greater than 1A.
3. AC to DC converter should provide a steady DC voltage within 2% of the desired voltage for motors, microcontroller, and sensors.

2.4.2 Control Unit:

The microcontroller should meet the following requirements:

1. Has 7 analog input pins to handle data from IR sensors and emergency switch.
2. Has PWM width of 1ms to control the movement of servo motors.
3. Able to read angle of rotation from servo motor within 95% of accuracy.

Requirements for IR sensors are:

1. Detection range should be greatly reduced to 5 cm for cloth detection and 50 cm for hands and arms detection.
2. Passive infrared(PIR) sensors should detect motion of any parts of human body that is larger than 10 cm^3.
3. Sensors should have a directivity of 180 degrees to cover all areas on the board.
4. Output signal should be binary.
5. Requires supply voltage less than 12V.
6. Requires current less than 1A.

2.4.3 Mechanical:

Requirements for servo motors are:

1. Able to turn both clockwise and counterclockwise faster than 0.30s/60 degrees.
2. Motor should produce a torque larger than 3kg×cm.
3. PWM controllable with pulse width of 1ms.
4. Degree of rotation should be within 5% of assigned value.
5. Required range of rotation: 180 degrees.
6. Requires supply voltage less than 12V.
7. Requires current less than 1A.

Requirements for motor drivers are:

1. Compatible with servo motors in terms of PWM signals.

2. Requires supply voltage less than 12V.
3. Requires current less than 1A.

2.4.4 User Interface:

Requirements for status LED:

1. Multiple LEDs should provide the color of white, yellow, green, red and blue.
2. Breakdown voltage larger than 12V.
3. Requires supply voltage less than 12V.

Requirements for Emergency Button:

1. Button should larger than 2 cm^2 for easy to push.
2. Debounced.
3. Placed in an obvious location on board.

2.5 Risk Analysis

One of the most challenging part of the design is the folding speed of the cloth folding machine. It is necessary for us to make sure that the folding speed is fast enough to fold the cloth properly and nicely. However, it is hard to make the folding speed too fast because of the power of the motor. Therefore, we have to design and test the folding speed that will indeed work well. Another major challenge is the accuracy of our IR sensors. Detection range need to be greatly reduced as stated earlier and additional design approach needed to ensure hands and arms IR sensors don't misinterpret cloth and board as human hands and arms. To address this issue, we propose to use PIR (passive IR) sensor to detect hands and arms as they are more suitable for motion detection rather than only presence detection. And the lighting environment and color of cloth may also affect the performance of our IR sensors. We need to extensively test our IR sensors make necessary adjustment to them and microcontroller to accommodate these variables.

3. Ethics and Safety

Since in our design, we will use a 120V AC power supply, it is likely that the circuit wire is shorted and the protoboard is burned. In order to protect the circuit, we will design a voltage regulator that has upper limit input voltage.[5] Furthermore, we will use a transformer to transform the 120V AC power supply to less than 12V, which will reduce the safety problem.

What's more, it is possible that the users don't have enough time to remove their hands after placing the cloth on the cloth folding machine. The folding machine may hit the user's hands, which leads to hand injury. In order to solve this problem, we will put an IR sensor on the left side of the board. The sensor will send IR light to the right side of the board. Whenever the hands are above the cloth, it will reflect IR light back to the sensor and the folding procedure won't start. Furthermore, we will also add some LED lights or sound beeps to warn the user before the folding procedure starts.

In our project, we will strictly obey the principle of IEEE Code of Ethics #1 and #9 :"to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment", "to avoid injuring others, their property, reputation, or employment by false or malicious action".[6] In our project, there are two safety problems: the power supply safety problem and user hands removing problem. To cope with these problem, we design the voltage regulator and IR sensor to avoid the potential endanger to the public as well as the injury to the user. According to the IEEE Code of Ethics #8 "to treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression"[6], we will treat each member equally and help each other without any discrimination on race and gender.

4. Citations

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