ECE 445

Spring 2024

Senior Design Project Proposal

Automated Multi-Mode Garment Folding System with Arduino Control

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Link to Github Notebook: Github Notebook

1. Introduction

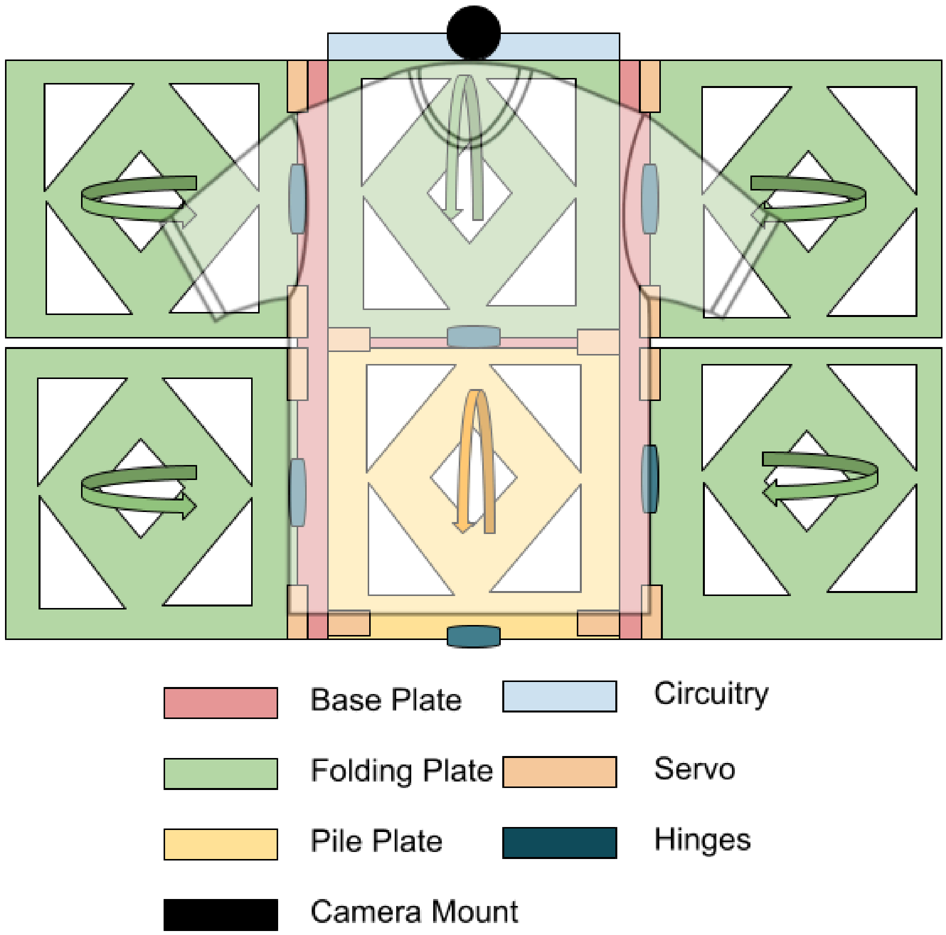
1.1 Problem

No one likes to fold laundry. It's dull, boring, and tedious. The only positive is that it gives you an excuse to listen to your favorite podcast that you may have had a backlog on. On top of that, folding laundry can prove to be a difficult task for the elderly and disabled. In commercial settings, employees of large retail clothing stores have reported getting carpal tunnel syndrome from the repetitive and manual task of folding clothes.

1.2 Solution

To solve this crisis, we want to create an automated multi-mode clothes folding system. This will allow the user to decrease the time and effort involved in folding laundry. The whole process takes place in three steps. A user will place one of three preset clothing items on the machine. An overhead camera is used to image the clothing item and send the data to a Raspberry Pi controller. The controller will run the image through a python program that will identify the item of clothing then send a series of instructions out to servos. The servos will operate mechanical folding panels that will properly fold the clothing item. A final panel will place the folded item into a pile.

1.3 Visual Aid



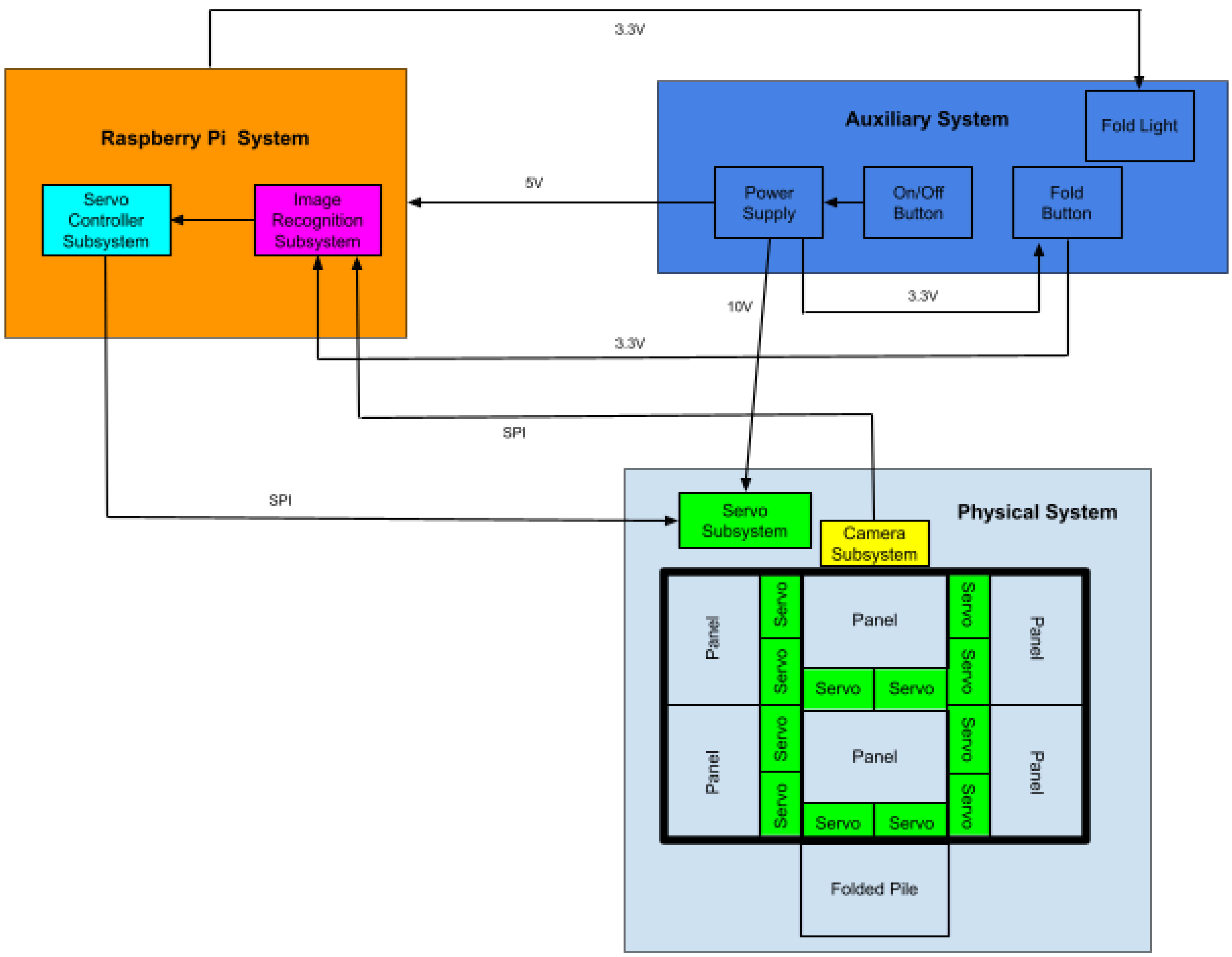
1.4 High-Level Requirements

- Image Recognition
  - The machine must be able to identify three different clothing items: t-shirt, pullover, trousers. To implement this, we will store a pre-trained ML algorithm that will accept an image and output the predicted clothing type.
- Correct Folding Instructions
  - Raspberry Pi code must be able to correctly know what is on the folding machine using image analysis software described above. Once the correct item is determined, one of the three folding processes is selected and carried out. These folding instructions will be determined beforehand following conventional folding techniques.
- Correct Folding Mechanic

    - Servos and Panels must be able to properly fold and pile the clothes neatly and in good time. The folding mechanics will be predetermined and follow conventional folding techniques as described above.

2. Design

2.1 Block Diagram



2.2 System Overview and Requirements

- RaspberryPi System
    - Servo-Controller Subsystem
        - The servo controller will contain three different programs, one for each type of clothing. Depending on the type of clothing identified by the image recognition subsystem, the servo controller will pick the corresponding program.
        - Each program will control sets of servos in a sequential manner, allowing the previous set of servos to return to their original position before activating the next set.

        - The Raspberry Pi system will be connected to the servo motors through a PCB chip.
    - Image Recognition Subsystem
        - The image recognition system will be written in python and called on system boot. We will train a [Convolutional Neural Network](#) model provided by Tensorflow on a [Fashion MNIST dataset](#) provided by TensorFlow's Keras.
        - The fashion dataset contains about 18,000 images for the 3 labels (t-shirts, pullovers, trousers) that we will be using. We should be able to achieve at least a 90% correct classification rate.
        - We will use Keras's save feature to save and store the model to our micro-sd card. This will save significant time and memory during the boot phase of our automatic-folder. The model will be loaded into memory on system boot and the prediction function will take an image as a parameter. The model should be able to output a correct classification within 1 second of getting called.
        - Upon receiving a high signal from the fold button, the RaspberryPi will save a frame of the streamed video. It will pass this frame to the prediction method of the CNN model. It will then pass the output of the prediction method to the servo controller subsystem.

- Auxiliary System
    - Power Supply
        - Must be able to supply stable voltage for multiple subsystems that will each require different levels.
        - The Camera will require 3.3V
        - The Raspberry Pi controller will require 5V
        - The Servo Motors will require 5V
        - Linear Voltage Regulators will be used to vary the voltage to the different subsystems.
        - 8V wall-outlet adapter supply will allow for stable power for each subsystem when working at maximum capacity
    - Fold Button that will start the entire folding process. Sends a high signal to Raspberry Pi
    - Folding Light that will inform the user when the machine is currently working and when it is ready for a new piece of clothing.

- Physical System (Includes PCB)
    - Servo Subsystem
        - The servos will be mounted using screws to a metal or wooden frame for structural support. The servos will receive power from the power supply and a SPI input from the RaspberryPi. This SPI input will tell the servos which position to rotate to, allowing the system to fold the item placed on top.
        - The servos will act in a certain order depending on the instructions that are chosen from the item on the folding table. The SPI input will be delivered when the servos need to act. This makes up our instruction order.

        - The Servos will rotate up to 120 degrees providing the necessary force and guidance duration to allow the clothes to be folded without sending them in strange directions or folding upon themselves.
        - Servos operate at 5 volts at about 20-25 mA when at rest and draw a maximum current at full load of 300-350 mA.
    - Camera Subsystem
        - The camera will be mounted on a rod pointing down at the mechanism. It will stream video to the RaspberryPi image recognition subsystem.
    - Panel Subsystem
        - Each panel will be mounted to 2 servos and will be constructed of a light-weight plastic-like material.
        - Each panel will have sections removed to allow airflow through. This prevents any major air disruptions which could cause mishaps in the folding process. This also reduces the amount of material needed to produce each panel.

- Edge Cases
    - Item not recognized
        - If an item is not recognized as one of the three in our folding categories, the folding light will turn red and blink three times.
    - No item on the folding table
        - If there is no item on the folding table, the folding light will turn red and blink once.

2.3 Tolerance Analysis

The greatest challenge to overcome will be regulating the voltage to each sub-system as they each have a different voltage requirement. To achieve this, our design uses three different linear voltage regulators to achieve stability in the different subsystems.

The main power supply unit will be a 8V AC adaptor that will plug into a standard 120V wall outlet. The adapter provides a maximum of 4A, which provides more than our maximum draw, while having a voltage ripple of less than 200mV. Linear voltage regulators will step down the voltage to 5V for the servos and the Raspberry Pi, and 3.3V for the camera system. The use of linear voltage regulators come with two issues, heat and dropout voltage.

Dropout voltage is the minimum voltage input to get a stated voltage output and is governed by this equation:

$$Vin - Vout > Dropout$$

The maximum voltage regulator dropout voltage is 2 volts giving us the following equations:

$$8V - 5V > 2V$$
$$3V > 2V$$

To avoid thermal issues, the maximum current going out of the regulators must be below a certain number, which is governed by this equation:

$$I_{out} = (T_j - T_a)/((V_{in} - V_{out})(\Theta_{jc} + \Theta_{ca}))$$

Setting Tj = 150 , Ta = 38 , Θjc = 10, and Θca = 90, the maximum current 373mA at 5V for the servos and 238mA at 3.3V for the camera.

Ethics and Safety

Due to the nature of our project, many of the ethical concerns listed in the IEEE and ACM Code of Ethics are upheld naturally (for example, the codes on intelligent systems don't apply because we are not implementing that capability.) In the IEEE code of ethics, there are two codes that I find to be extremely important as we progress. These two codes are I.1 and I.5. We want to hold the safety and welfare of the general public paramount while accepting criticism and updating our machine to fulfill the initial focus of helping the user of our machine. In order to fulfill this, we initially designed our project to help people with health conditions or impairments like arthritis, cerebral palsy, and other physically limiting conditions. As we go through the designing and construction phases, we will make sure to keep that in mind and not implement anything that competes with that focus. Finally, we should thoughtfully consider improvements and feedback that are offered to us from the recipients of our project.

In the ACM Code of Ethics, the most unique and relevant ethical concerns that are not previously mentioned in the IEEE's list are the Professional Leadership Principles. These will be paramount as a group to uphold since ultimately this is a learning opportunity. These codes of ethics pertain to allowing each member of the group to be able to contribute and best learn from this project. In order to ensure these are followed, a policy of open and considerate communication between group partners will be adopted. This will allow us to voice concerns while also considering one another's interests and overall experience throughout the project.

For the safety concerns, our project does not fulfill any of the special concerns listed on the website. We will not be using any batteries, large voltages, and no currents will be going through human subjects. Every member of the group has completed the Lab Safety Guidelines training and will strictly adhere to the rules and overall ethos of safety first. Our system will be designed in a way that no bodily harm could result from its regular use.

Citations and References

ACM. “”ACM Code of Ethics and Professional Conduct”.” (2018), [Online]. Available: https://www.acm.org/code-of-ethics (visited on 2/5/2024).

dfrobot. “”DSS-P05 Standard Servo”.” (2024), [Online]. Available: https://www.dfrobot.com/product-236.html (visited on 2/6/2024).

IEEE. “”IEEE Code of Ethics”.” (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 2/5/2024).

UIUC. “”ECE 445 SAFETY GUIDELINES”.” (2024), [Online]. Available: https://courses.engr.illinois.edu/ece445/guidelines/safety.asp (visited on 2/5/2024).