Smart Closet

ECE 445 Spring 2016

Design Review

Yiwei Li

Luchuan Zhang

TA: Luke Wendt

1 Introduction

1.1 Statement of Purpose

Our project's goal is to solve the problem that people meet when they try to pick up their clothing in a conventional closet. When the clothes are hanging inside the closet, nearby clothes may block the view of one specific clothing item, so users may have trouble picking up the desired clothes.

Also, when outside of the home, users may forget what clothes they have in their closet and may buy additional and unnecessary clothes in the retail store. This motivated the design of a smart closet system for private use. This closet can show a complete frontal view of each clothing item to users in the user interface and automatically drive the chosen clothes to a center location. There's a front end application that helps people remember their already owned clothes and also keeps track of the worn times of each clothing.

In more details, this closet will take photo for new incoming clothes after users put them in the center of rack. And it will move the chosen clothes by users (via smart phone or touch screen of Raspberry Pi) to the center rack location for them to easily pick up. Then it will send all information about owned clothes from Raspberry Pi to users' smartphones via Wi-Fi, and will have a complete LED system to instruct users.

Users can easily organize and check the status of all their owned clothes on their smartphones, and they may also indicate any clothes that need laundering or disposal. The smart closet system will light an LED on the chosen clothes to instruct users, for example, a red LED is for picking up and a green LED is for going to laundry. All the clothes that need to be picked up will be processed in the computer vision system and the motor will drive clothes to the center point of the rack. The project will largely reduce the difficulty of picking up desired clothes in a conventional closet and provide users a platform to easily organize their private closet.

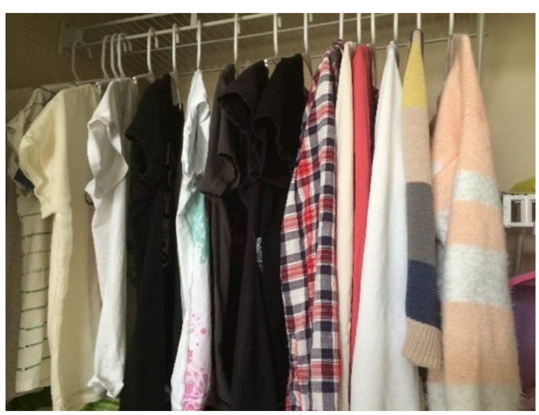


Figure 1 Partially seen clothes

1.2 Objectives

1.2.1 Goals & Benefits:

- Database for private closet
- Communication between hardware and software
- Help users organize and pick up clothes

1.2.2 Functions & Features:

- Automatically take photos for users' clothes
- Automatically drive chosen clothes to center point of the rack
- Record each clothes' worn times
- Having a touchscreen for Raspberry Pi as user interface
- Three IR distance sensors to collect physical data
- A conveyor belt system with a stepper motor controlled by Raspberry Pi
- LED system includes at least 10 LEDs controlled by Raspberry Pi
- An iOS smartphone app linked to Raspberry Pi

2 Design

2.1 Block Diagrams

2.1.1 Top Level Diagram

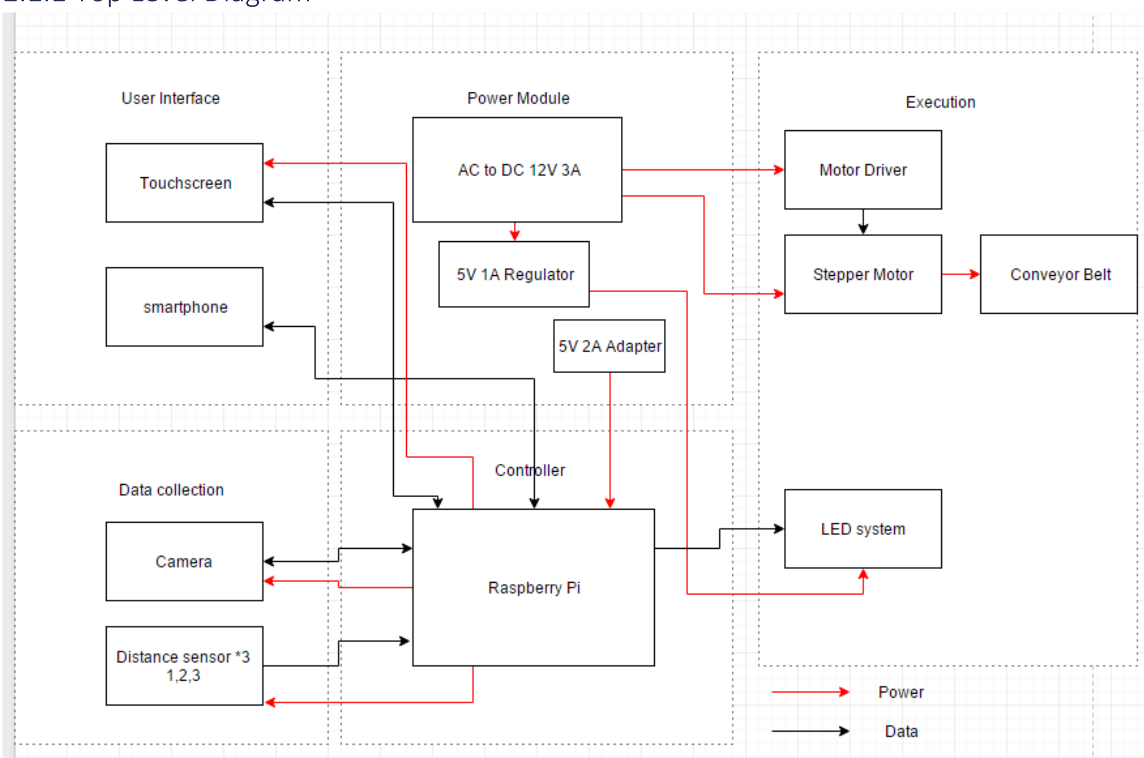


Figure 2 Block diagram

2.1.2 Design Diagram

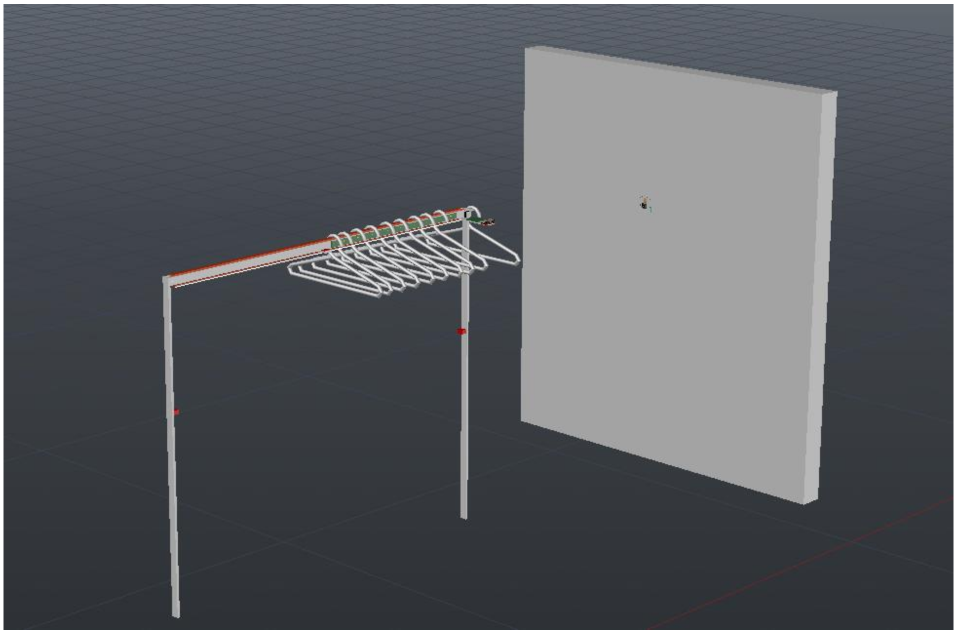


Figure 3 Overall view of our closet with the wall (which is 60cm away from closet)

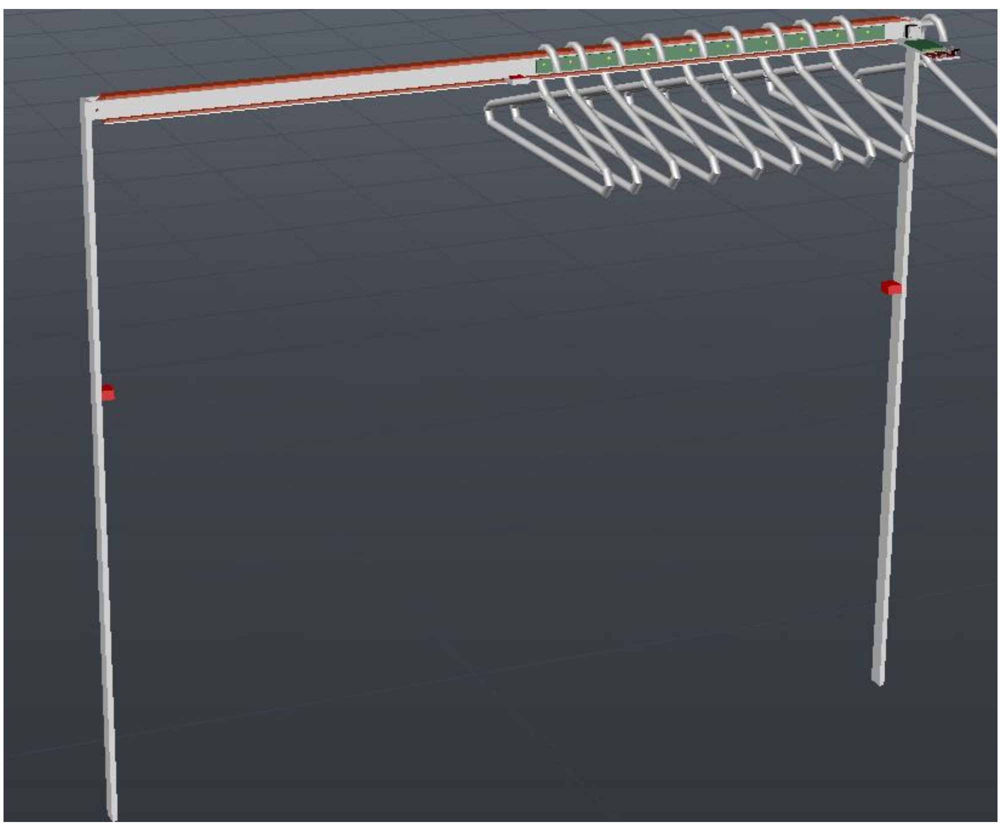


Figure 4 Overall closet view without the wall

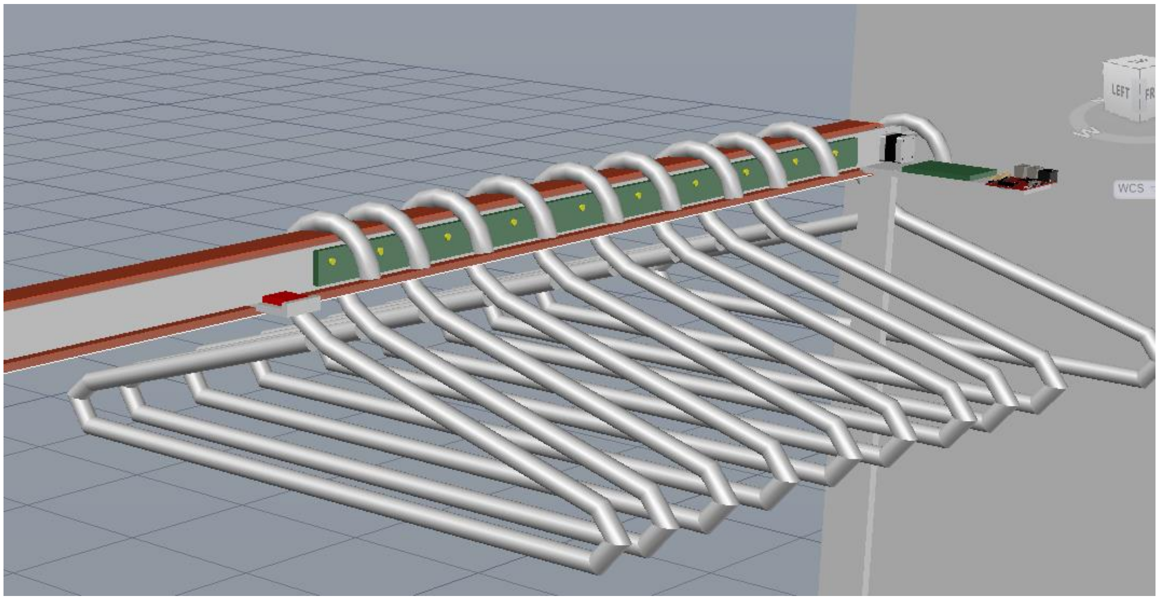


Figure 5 LED system attached on the belt

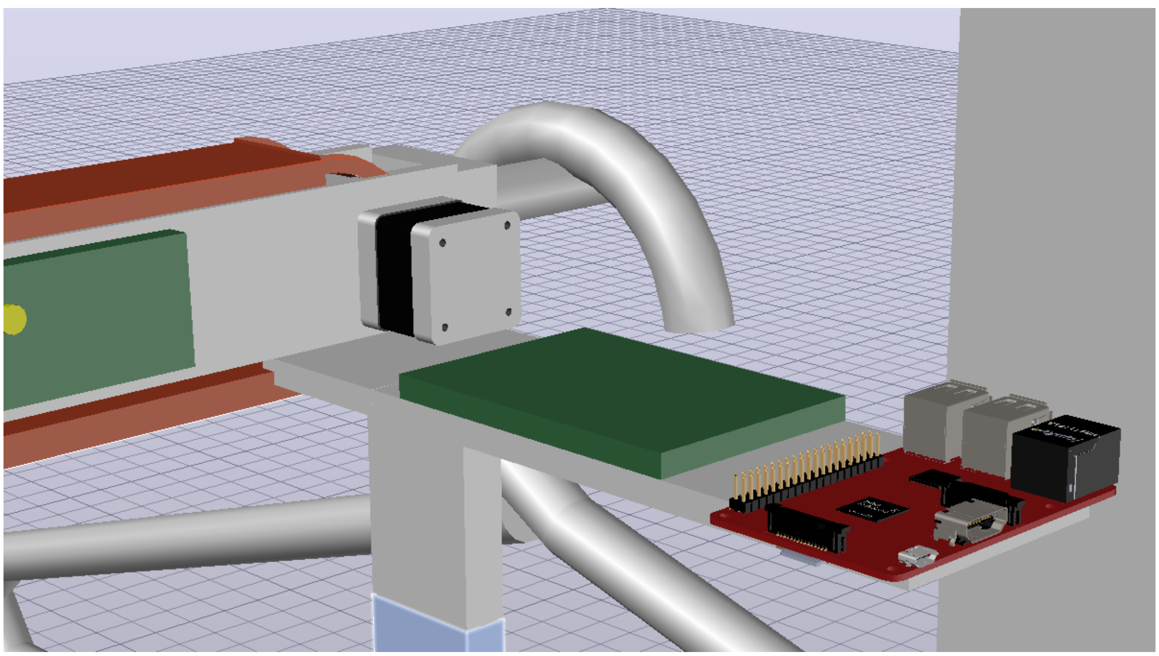


Figure 6 The motor platform along with the main PCB and Raspberry Pi

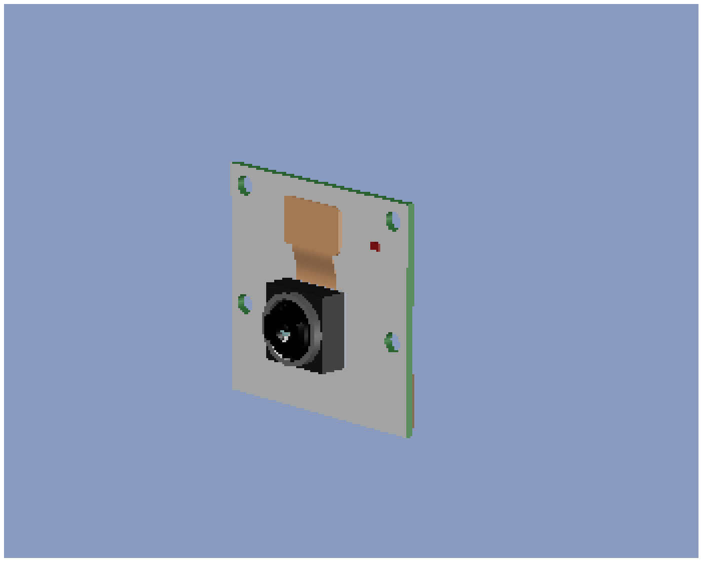


Figure 7 Raspberry Pi Camera board attached on wall which is 60cm away from the closet

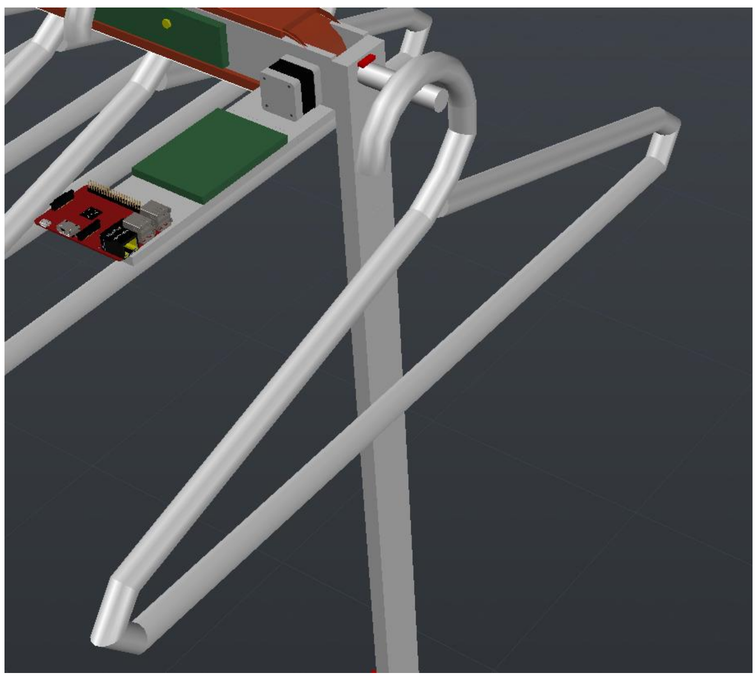


Figure 8 The slot for taking photo

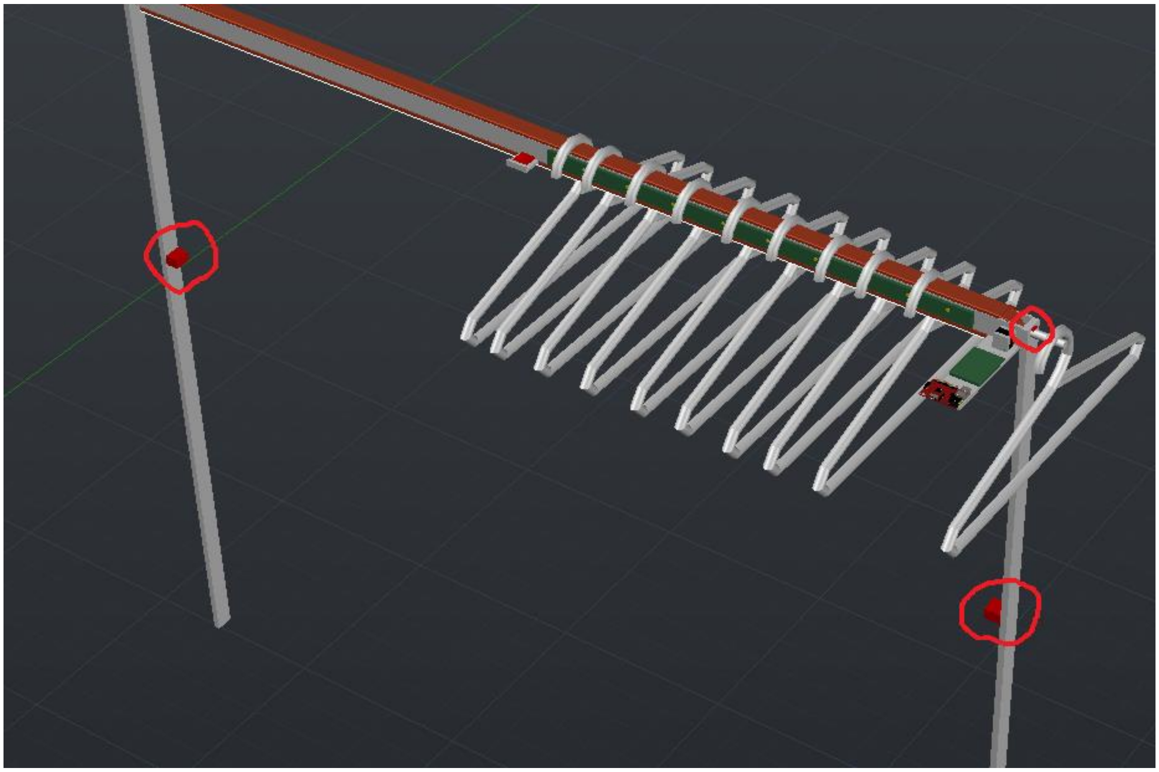


Figure 9 The location for all sensors (total is 3)

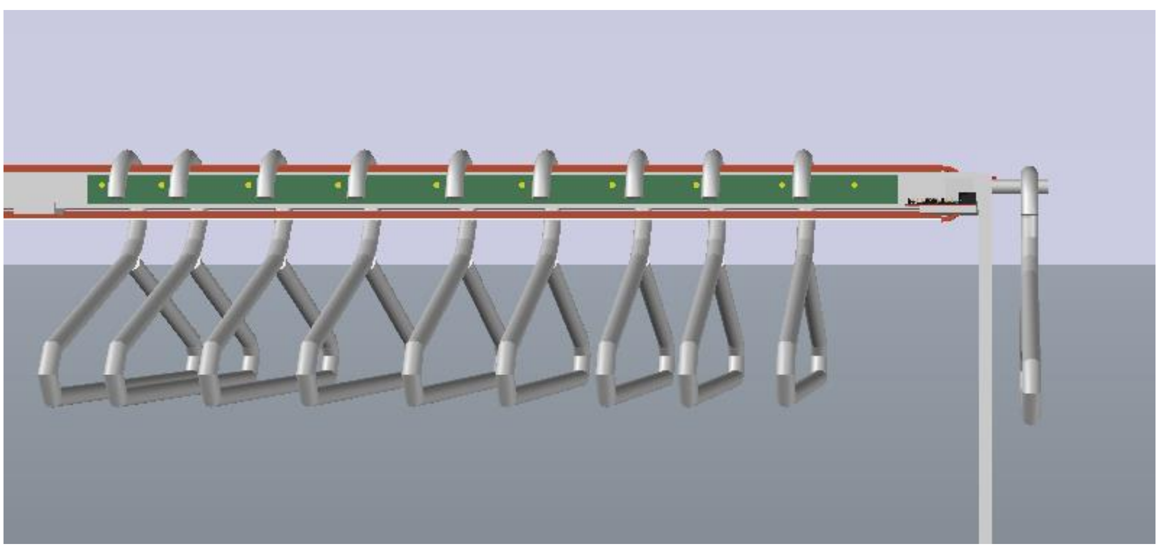


Figure 10 Frontal view for our closet design

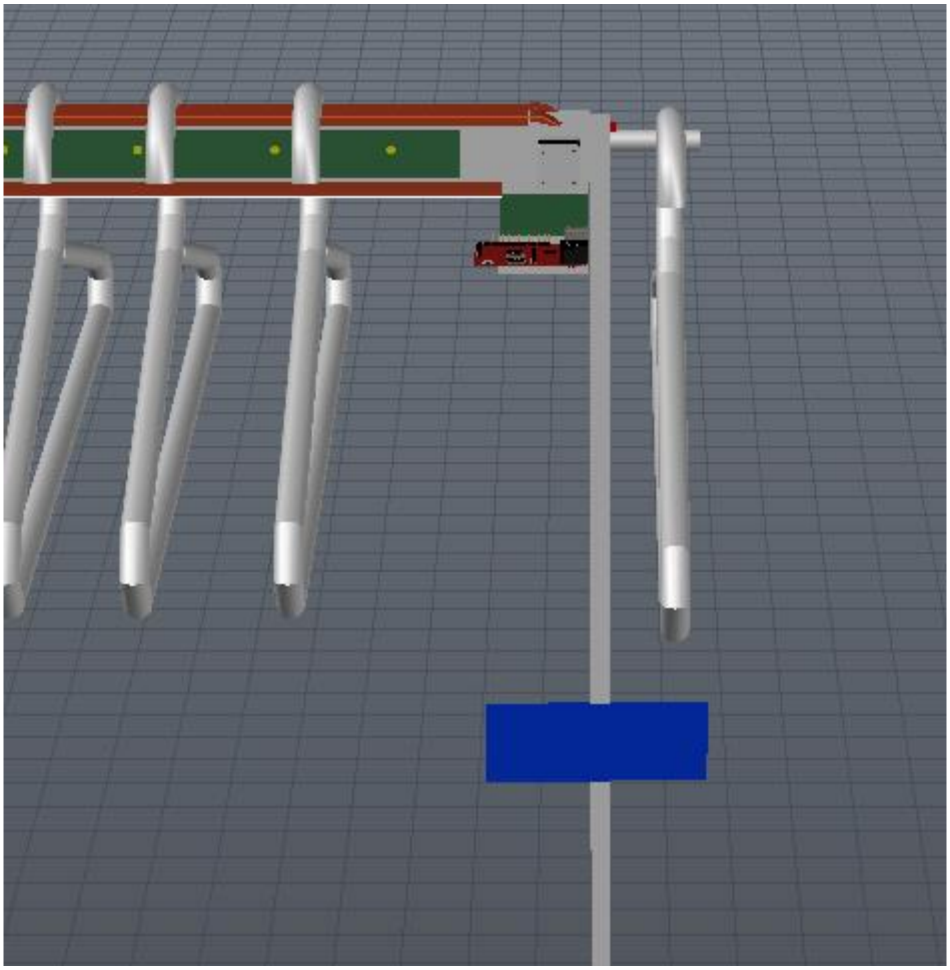


Figure 11 Our touchscreen location

2.2 Block Descriptions

2.2.1 Microcontroller (Raspberry Pi)

Input: 5V micro-USB power supply with 2 A, digital input from three distance sensors, data cable from camera

Output: Control signal to stepper motor driver/stepper motor, control signal to LED system with a level shifter, HDMI signal to touchscreen, power supply, and data cable to touchscreen, data cable to camera

Raspberry Pi is powered by a micro-USB cable with a 5 volts adapter with 2 Amp currents. It receives digital input from distance sensors through GPIO ports. It connects to the camera board through CSI bus, where the camera board is attached to Raspberry Pi by one of the two small sockets on the board upper surface. Pi also gives PWM output along with four other GPIO outputs to motor driver and drives the stepper motor, which can rotate clockwise and counterclockwise by programming. Pi links to a touchscreen through USB-micro cable and HDMI cable. The touchscreen can both display and act like a mouse. The control signal to LED system is from the PWM (PCM_clock) output of Raspberry Pi, that signal will go through a level shifter to shift from 3.3V to 5V, and then control the LED system with a rpi_ws281x library.

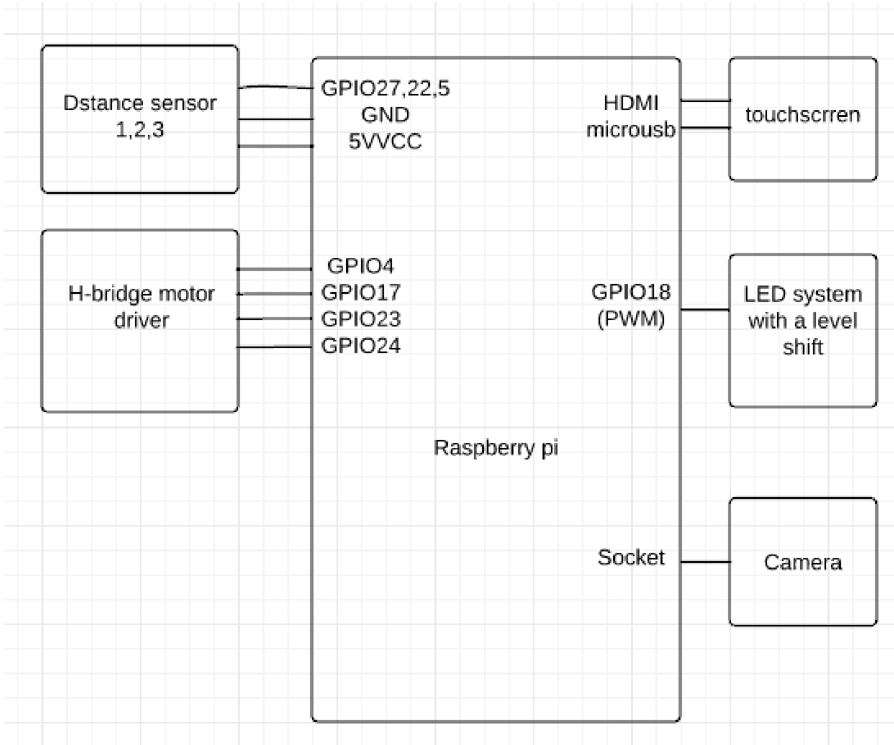


Figure 12 Design Block for Raspberry Pi

Pin Table for Raspberry Pi

Pin	Function	Connection
7	GPIO4	To IN1 of motor driver
11	GPIO17	To IN2 of motor driver
12	GPIO18,PCM_clock	LED control system
16	GPIO23	To IN3 of motor driver
18	GPIO24	To IN4 of motor driver
13	GPIO27	To output of Distance sensor1
15	GPIO22	To output of Distance sensor2
29	GPIO5	To output of Distance sensor3
6	ground	To ground supply
2	5V	To power supply of each chip
HDMI	HDMI	Touchscreen
Micro USB	Micro USB	Touchscreen
USB1	USB	FadeCandy
Socket	Socket	Camera Board

Table 1 for raspberry pi

2.2.2 Distance Sensors (Sharp GP2Y0D810Z0F with Pololu Carrier)

Input: 5 volts VIN and GND

Output: digital output VOUT links to Raspberry Pi GPIO pin

This is a digital output distance sensor. The output is normally high and when it detects objects in the range from 2cm to 10cm the output will be low. This sensor cannot measure how far the object is away from the sensor but is good at object detecting and counting. Because the project does not need to measure the exact distance between the object and the sensor so a fast distance sensor with a sample rate of almost 400 HZ. [1]

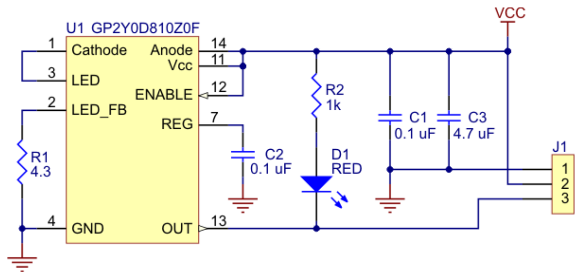


Figure 13 Circuit layout for GP2Y0D810Z0F [1]

2.2.3 Raspberry Pi HDMI 7’’ 800*480 Touchscreen

Input/Output: HDMI cable from Raspberry Pi, USB cable from Raspberry Pi

This touchscreen drains power from Raspberry Pi through the USB cable, which also roles as a data cable. It will need 600mA if the backlight is fully on. This touchscreen can display the screen of Raspberry Pi and input users' information of finger location to Pi. In our project, this touchscreen will be used as a second user interface besides the smartphone, and it will be mounted on the surface of the closet.

2.2.3 Raspberry Pi Camera Board

Input/Output: Flex cable for Raspberry Pi camera

This camera is linked to Raspberry Pi using one of two sockets on the board of Pi. No extra power supply needed. We ordered a 2-meter long flex cable for this camera so it can be attached far enough to get a good photo for the clothes. This camera will also help us do the computer vision part of our design. The camera will input the image to Raspberry Pi, and then Pi will do some basic image processing to detect the exact location for a specific red LED and then control the motion of stepper motor.

2.2.4 LED system (on PCB board)

Input: control signal(PWM) from raspberry pi

Output: 10 LEDs

Use the NeoPixel chip from Adafruit to build up a LED system with 10 LED chips. This LED chip can display different color to indicate different instructions to users. Each LED can be individually controlled by Raspberry Pi. This PCB will be a long rectangle strip that has dimension of 50cm*0.5cm.

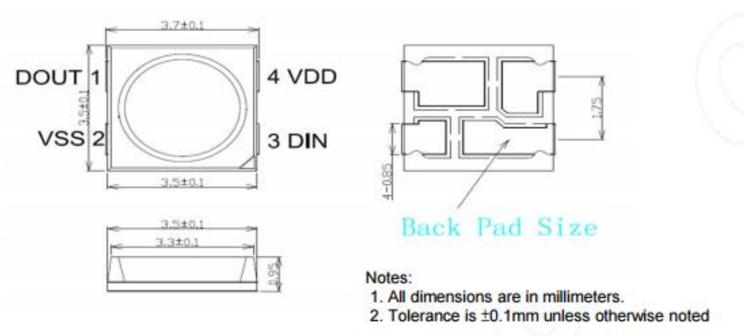


Figure 14 Datasheet for Neopixels ws281x [2]

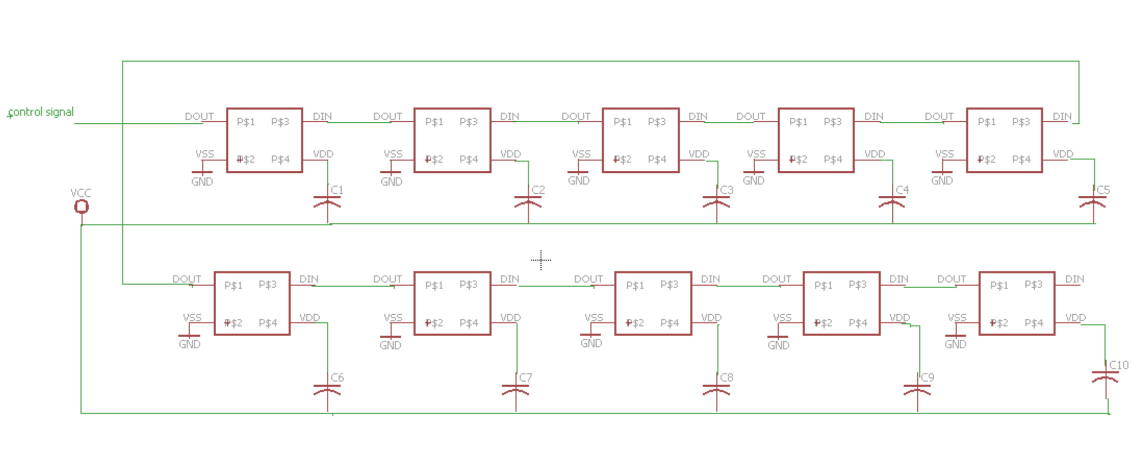


Figure 15 Schematic for LED strip

2.2.5Motor Driver and Motor (Nema 17 Stepper motor)

Input: Four control bits, power/ground supply from 12V 3A adapter

Output: Control signal to stepper motor (four wires, black, red, green, blue)

The stepper motor contains two coils, which are each driven by two H-bridge circuit. From the graph, we can see there are two PNP and two NPN included in each H-bridge. PNP and NPN will behave as a switch. Different combination of input signal will let motor go forward or backward. The rate current for the motor is 2 A, and resister for each coil is 5 ohms. Since two transistors are used in series, the voltage drop across the transistors are about 1.4V.

$$I_c = \frac{V_{cc} - 1.4}{5} = 2A$$

From this equation, we get Vcc=11.4V≈12V

Beta value for the transistors is around 1000. The rate current I_c is 2 A, $I_b = \frac{I_c}{\beta} = 2mA$, a current of 2mA that can be safely drawn from the Raspberry pi.

For PNP transistor, there need to add a resister in base side to limit the overall current through the *PNP*

$$R_b = \frac{Vcc - 0.7 - 3.3}{0.002} = 4000\ ohms$$

For NPN transistor,

$$R_b = \frac{3.3 - 0.7}{0.002} = 1300ohms$$

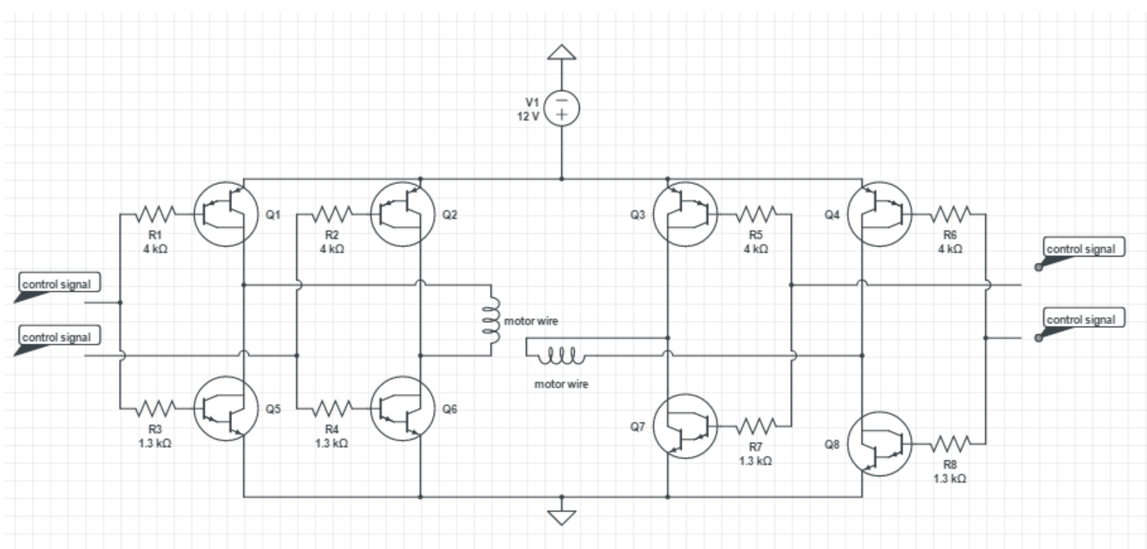


Figure 16 Schematic diagram for motor driver

2.2.5 Power Module

We have two parts in our power module. One part, is for Raspberry Pi, which contains a 5V 2A adapter. The GPIO pin from raspberry can output a 3.3V power to drive distance sensor (5mA). Another part is for motor and motor driver, which contains a 12 V 3A adapter. We also need a voltage regulator to convert 12V down to 5V in order to supply LED system (600mA). Figure (16) shows the voltage regulator for 12V dc to 5V dc, and the maximum current output is 1A.

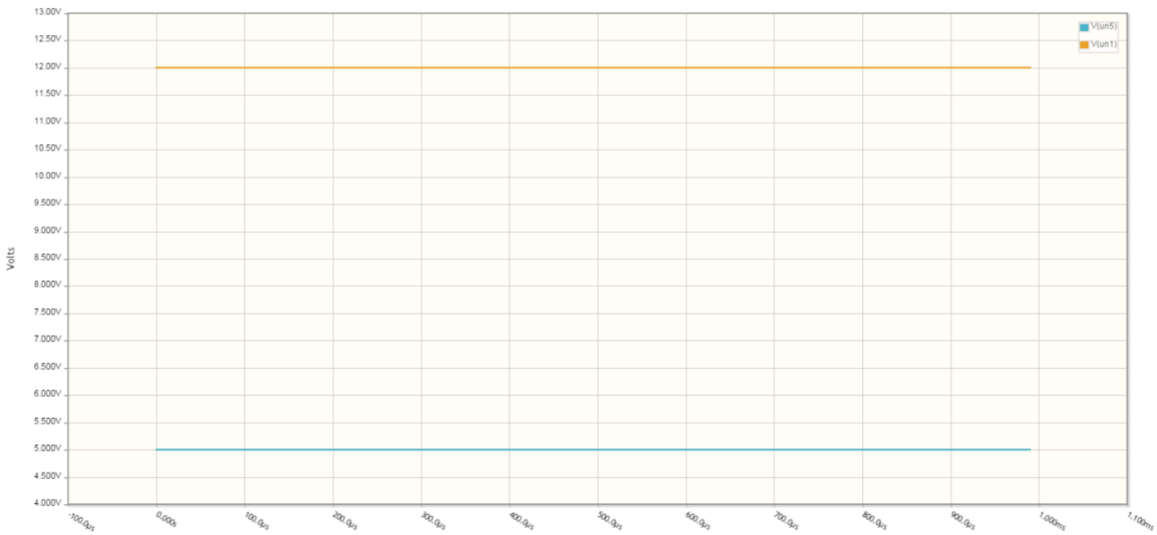


Figure 17 Simulation for voltage regulator

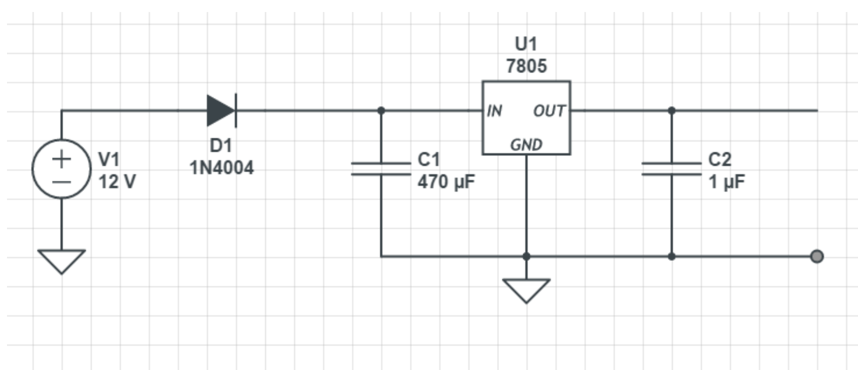


Figure 18 Schematic for voltage regulator

2.3 Schematics of Overall System

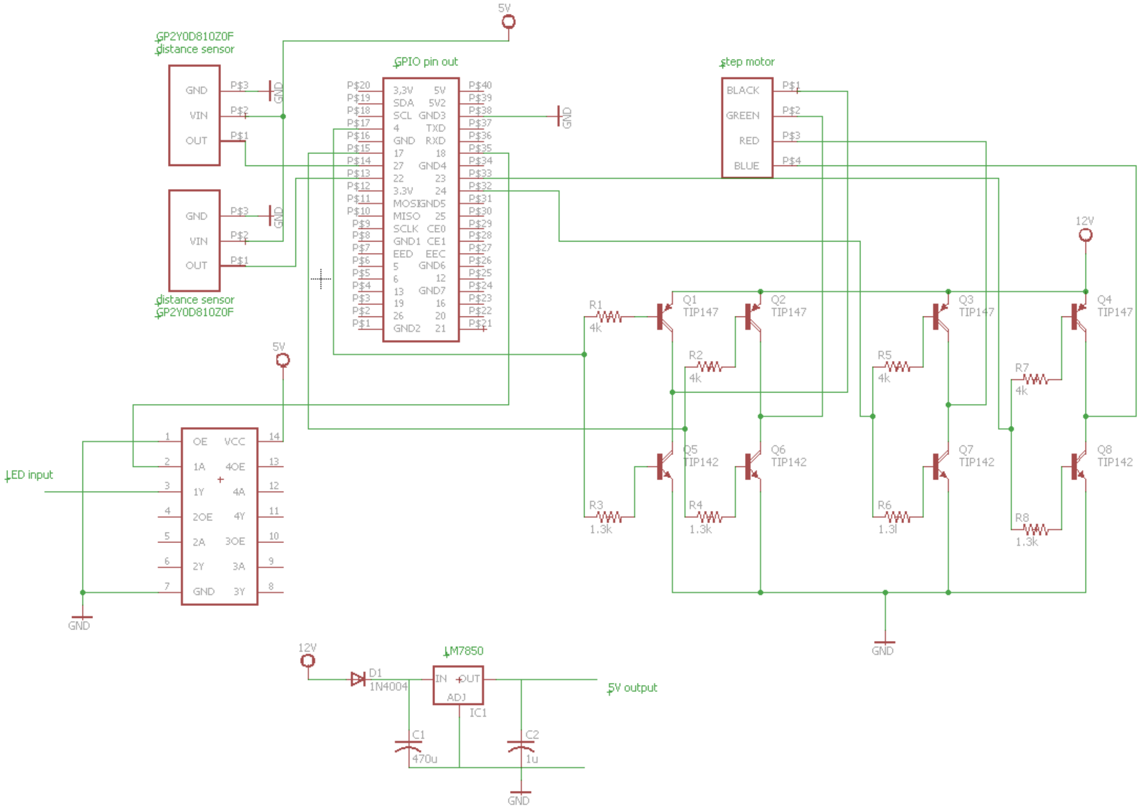


Figure 19 Schematic for system with motor driver and voltage regulator

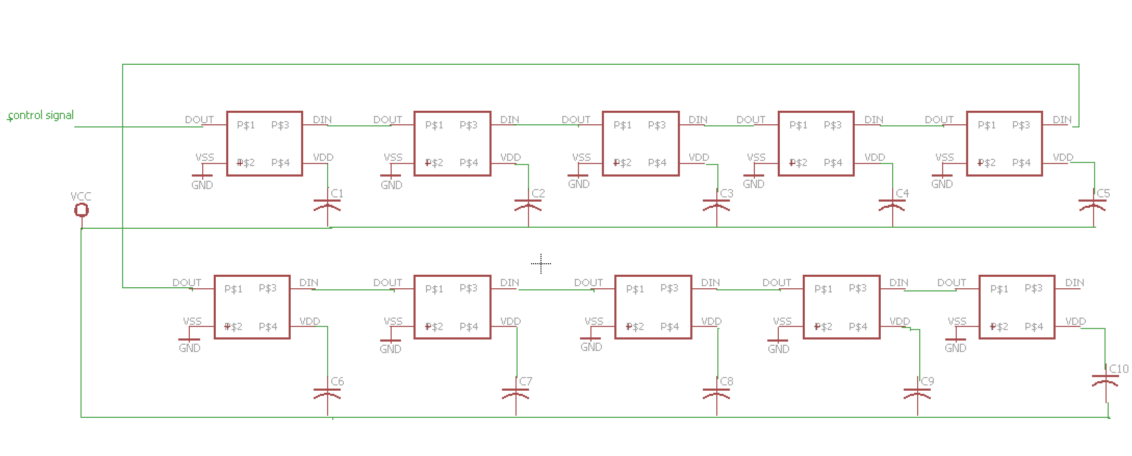


Figure 20 Schematic for LED strip

2.4 Overall Software Flowchart

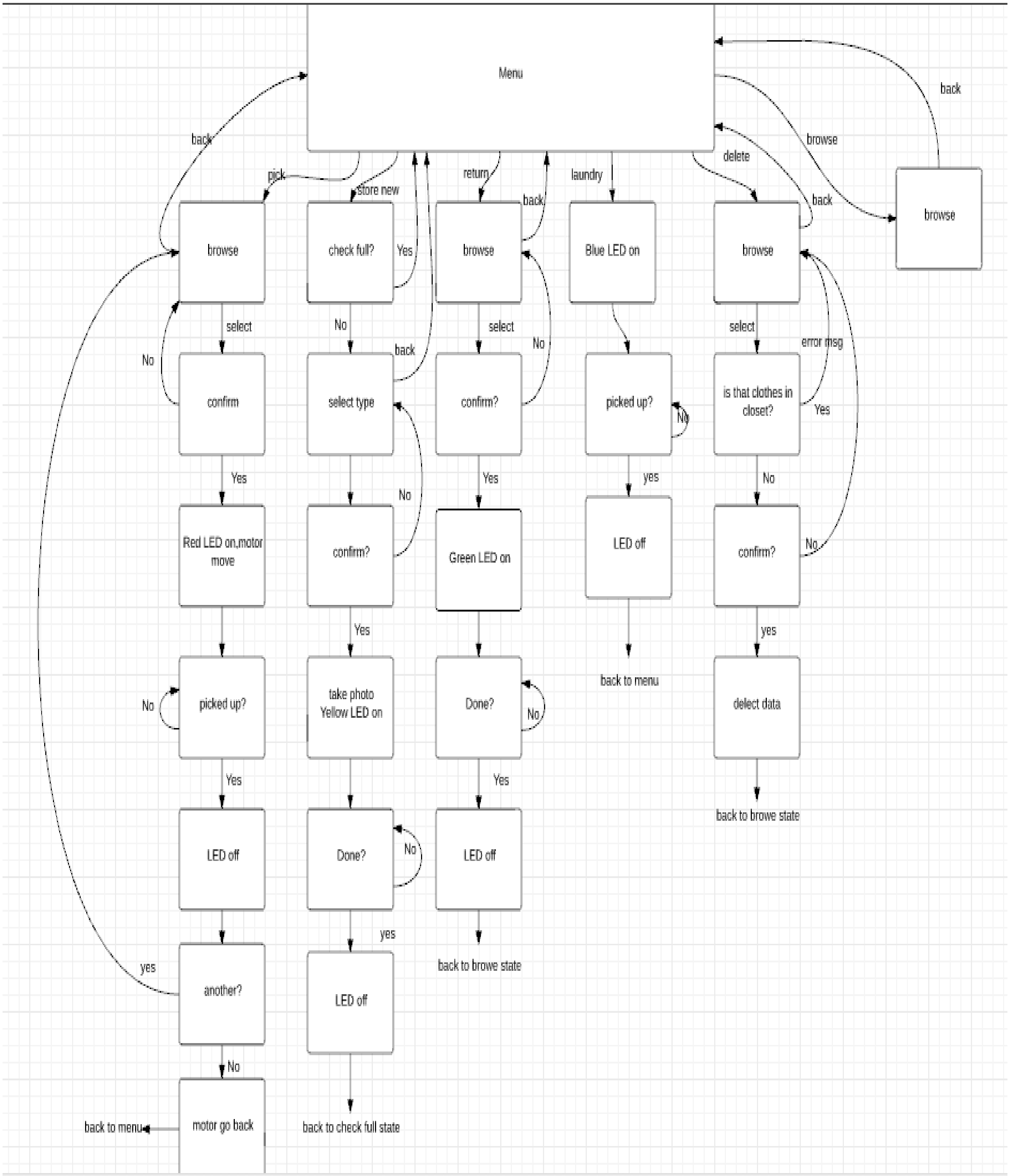


Figure 21 Software state machine

2.4.1 Software Descriptions

We decide to write our program in python inside raspberry pi. The program will be in a forever loop which always get back to the home page. The homepage contains 6 buttons; each button will lead to a different function of the program. The selecting page of each function will be a long page contains many rows, each row with two clothes and each clothes has one status description and one button for selecting.

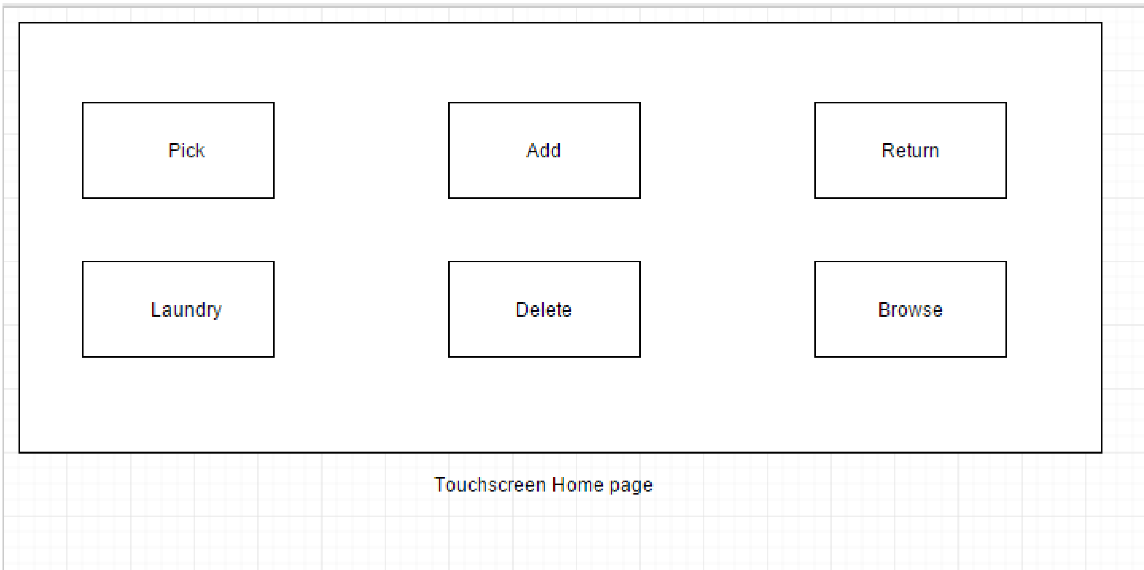


Figure 22 Home page design for touchscreen

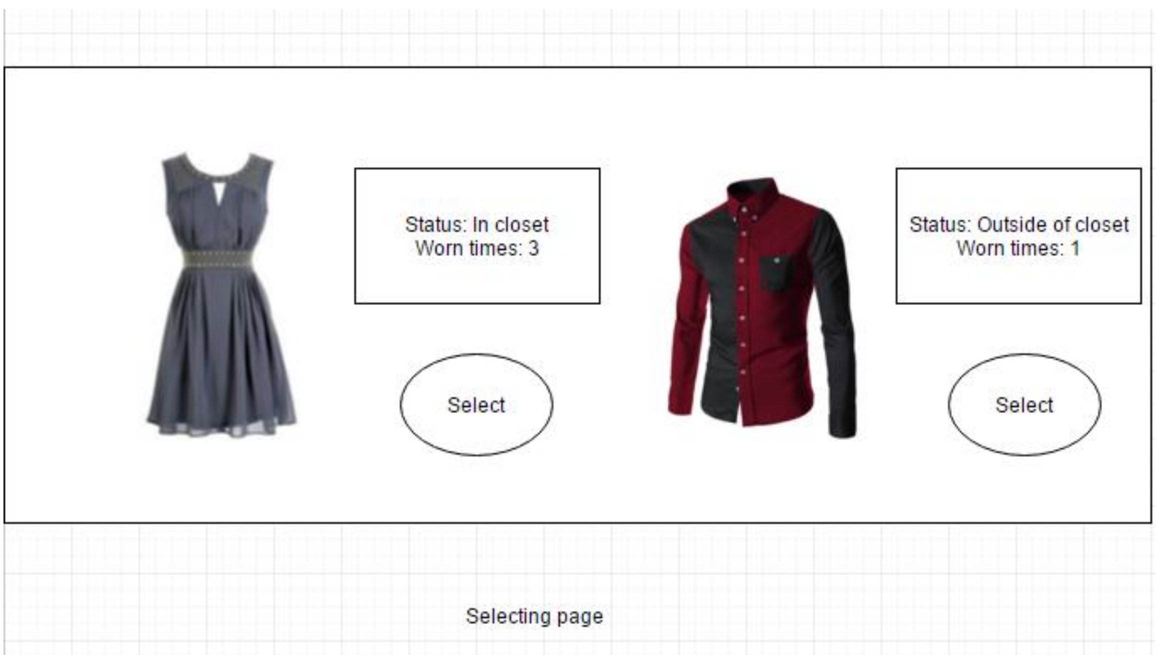


Figure 23 Selecting page design for touchscreen

For smartphone part, we are going to upload our database onto cloud by raspberry pi. Then using smartphone to access that data. So user can see all the data but cannot control the system directly on their phone.

2.5 Simulation and calculation

2.5.1 Power consumption

Power by 12V 3A Adapter

Load	Voltage	Current	Power consumption
LED(10)	5V	60mA/part	10*60=600mA
Motor and Motor driver	12V	2A	2A
Total			2.6A

Table 2

Power by 5V 2A Adapter

Load	Voltage	Current	Power consumption
Camera	5V	260mA	260mA [8]
Touchscreen	5V	600mA	600mA [7]
IR distance sensor	5V	5mA	3*5=15mA
Total			875mA

Table 3

As a result, we can see all our power consumption is lower than the maximum current that our power supply can provide.

2.5.2 Motor torque calculation

Step angle for our step motor is 1.8 degree.

We trying to build a 1-meter long conveyer belt, the diameter of the gear is 2 cm.

The total mass on the conveyer belt is around 5kg. The efficiency of the transmitting system is 90%.

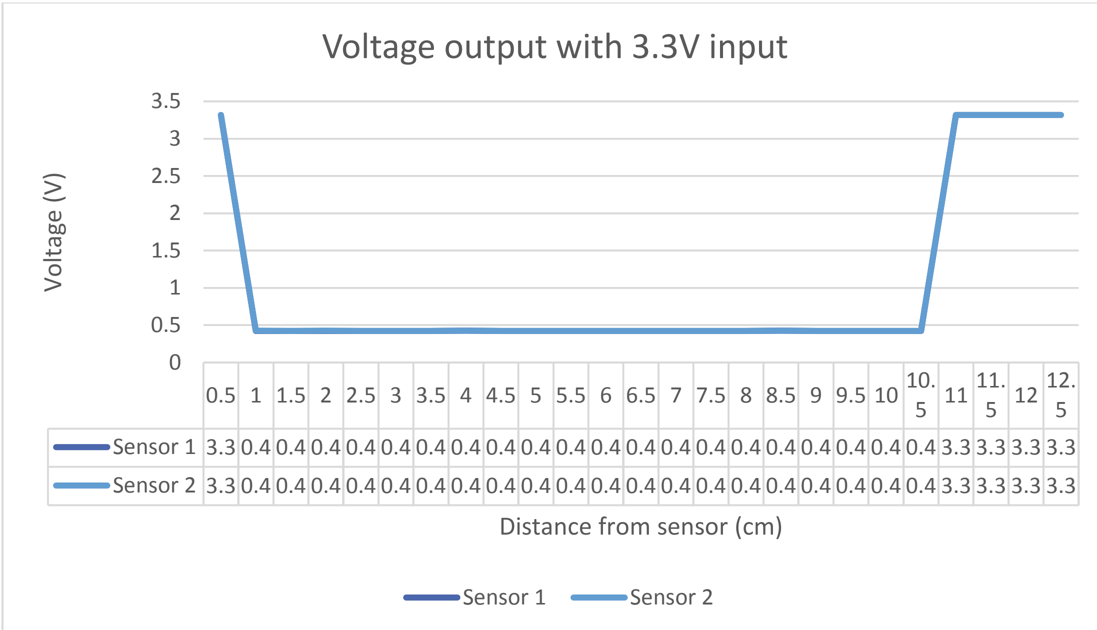
Torque=$\frac{D}{2} * mass * \frac{1}{\mu}[kgf * cm]$

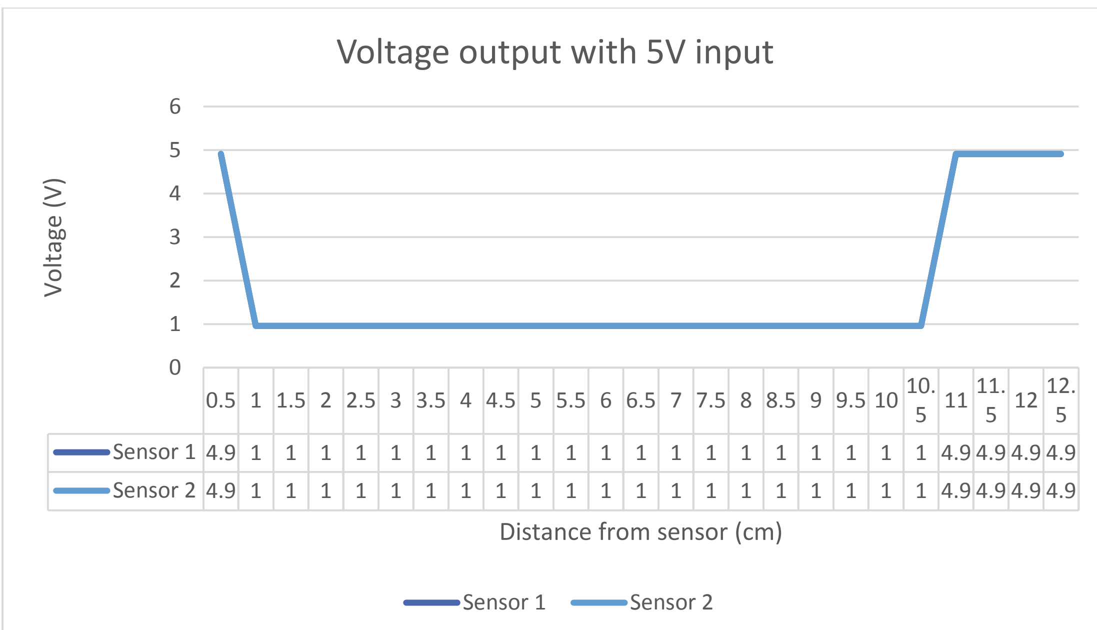
Torque=$\frac{2cm}{2} * 5kg * \frac{1}{0.9}$=5.55 kgf*cm =0.55 N.m

Our stepper motor has torque 0.59 N.m, so it is reasonable to choose our motor.

2.5.3 Distance Sensor Simulation

Our distance sensor has two inputs and one output. Inputs include Vin and GND, and output includes Vout. We test both our distance sensors under 5V input and 3.3V input to choose a better voltage input level.





Because voltage output of distance sensor under 5V is 0.956V which is too large to be considered as low in controller. So our project decides to power the distance sensor under 3.3V to get a low output at 0.4V.

2.5.4 Stepper motor steps calculation

The step angle for our motor is 1.8 degree. So the motor needs 200 steps to rotate a whole loop.

We will load 10 clothes on half of the rack, which has 50cm long. The distance between each clothes is $\frac{50cm}{11}$ =4.6 cm

The diameter of gear we will use is 1.8cm, so the perimeter is 2* π *0.9=5.6cm.

The positional accuracy of the motor is +- 5%, so one step will go $\frac{5.6}{200} * 95\% = 0.027cm$ to $\frac{5.6}{200} * 105\% = 0.03\text{cm}$.

position	Distance to center [cm]	step
1	46	1533
2	41.4	1380
3	36.8	1227
4	32.2	1074
5	27.6	921
6	23	768
7	18.4	615
8	13.8	462
9	9.2	309
10	4.6	156

Table 4 step calculation

3 Requirement and Verification

3.1 Requirement & Verification

<table>
<tr><td>Requirements</td><td>Verification</td></tr>
<tr><td colspan="2" align="center">Control System [10 Points]</td></tr>
<tr><td>Raspberry pi:
1) Module is supplied by 5V,2A.
2) GPIO pin2 can output 5V +-.2V
3) 30MB memory to store data for our database and at least 4 GB micro SD card for Pi (system use)
4) System process delay should less than 1 sec</td><td>1)
(a)Take a 5V 2A adapter
(b) Connect the adapter to Pi using a USB-MicroUSB cable
(c) See if the power indicator light is on. (located near GPIO PIN)
2)
(a)First complete 1) step above
(b)Attach voltmeter to Pin 2
(c)Attach voltmeter GND to GND (PIN 6)
(d)Read voltmeter, ensure it's in range 5V +- 0.2V
3)
(a)Look up the datasheet for micro SD card
(b)Ensure it is at least 4 GB
(c)Also, make sure the pi config is set to expand the system SD card
4)
(a)Power the Raspberry Pi
(b)Program Pi to run the motor
(c) Attach oscilloscope in1 to distance sensor output and GND
(d) Attach oscilloscope in2 to black and green wire of motor
(e) put an object in front of distance sensor
(f)measure the time delay between two falling edge in oscilloscope</td></tr>
<tr><td colspan="2" align="center">User Interface [5 Points]</td></tr>
<tr><td>Touchscreen
1) Display the image from Pi and detect finger movement</td><td>1)
(a) Set Pi's config.txt to required(written on the touchscreen tutorial)
(b) Connect USB cable and HDMI cable to Pi
(c)Ensure there is image on touchscreen and react to finger movement</td></tr>
<tr><td>Smartphone
1) Access database on webpage</td><td>1)
(a) Open up a webpage at a specific url
(b) Check all the information there is up to date(compare with local touchscreen)</td></tr>
</table>

Execute Unit [20 Points]	
Motor 1) Can rotate forward and backward (no speed requirement) 2) Drive 10 clothes on conveyer belt, clothes weight 0.2kg +- 0.1kg each and dimension is (55cm +-5cm) * (40cm +- 5cm)	1) (a)Power Raspberry Pi 5 V 2 A (b)Make sure raspberry pi has installed Linux system on it (Raspbian) (c)Correctly connect the raspberry pi to motor driver as specified in previous pin table (d)Run the code for stepper motor (e)See if motor can rotate forward and backward 2) (a) Put 10 clothes on the belt (b) Run the motor as specified by step 1) (c) Ensure motor have enough torque to drive 10 clothes
Motor Driver 1)check switch function for PNP and NPN 2) there is 1.8A to 2A going through motor coils	1) (a)connect a PNP and a NPN in series (b)add a 5 V power supply between this series circuit (c)input high signal(3.3V) to NPN and low signal(GND) to PNP (d) Attach voltmeter between this series circuit (e) Read voltmeter, ensure it is 5V (f) Repeat the steps above but input low signal to NPN and high signal to PNP (g) Read voltmeter and ensure it is less than 0.4V. 2) (a) Connect with Pi and motor using specified pin table (b))input high signal(3.3V) to NPN, and low signal (0,4V) to PNP, let one coil connect between source and ground (c)input high signal(3.3V) to NPN and low signal(0.4V) to PNP (d) Attach currentmeter between this series circuit (e) Read currentmeter, ensure it is 1.8 to 2A

LED System 1)Check if each LED can be controlled individually by Raspberry Pi 2)Each LED can display red, green, yellow, and blue	1) (a)Connect Vcc and GND to NeoPixels PCB (b)Connect GPIO18 to level shifter as shown in the overall schematic diagram (c)Run the testing program on Pi (d)Check each LED can be controlled and lit 2) (a)Complete 1) step (b)Add programs to use four colors on each LED (c)Check each color is correct for every LED on PCB
Data Collection [10 Points]	
Camera 1) Import picture and video data to Raspberry Pi	1) (a)Connect camera to Pi through socket on board (b)Remotely control Pi through computer, and check the photo/video input
Distance sensor 1) Output 0.0-0.6V for object in range from 0 to 10 cm 2) Output 3.3+-0.2V when no object in front of the sensor or object is 11 cm away from sensor	1) (a)Attach voltmeter to Vout of sensor (b)Put clothes in front of the sensor and change the distance from 0 cm to 10 cm (c)Always ensure the reading from voltmeter is in range 0-0.6V 2) (a)Attach voltmeter to Vout of sensor (b)Put clothes in front of the sensor and change the distance from 11 cm to 100 cm (c)Always ensure the reading from voltmeter is in range 3.3V (d)Put nothing in front of the sensor (e)Always ensure the reading from voltmeter is in range 3.3V

Power Unit [5 Points]	
DC 5V Adapter 1) Power from 110-240 AC and output a 5 +- 0.2V DC	1) (a)Connect the adapter one end to 110-240 AC (b)Plug the other end to a DC Jack which mounted on a breadboard (c)Attach the Voltmeter to the DC Jack output (d)Ensure readings in voltmeter is 5V +- 0.2V
DC 12V Adapter 1) Power from 110-240 AC and output a 12 +- 0.2V DC Voltage regulator 2)12V input and output 5V +- 0.2V DC	2) (a)Repeat steps in above cell (a) to (c) (b) Ensure readings in voltmeter is 12V +- 0.2V 3) (a)Wired the regulator as specified in schematic (b)Attach the Voltmeter to the output of regulator and GND (c) Ensure readings in voltmeter is 5V +- 0.2V

3.2 Tolerance Analysis

The critical part of the design is the distance sensor module. If the digital signal cannot immediately pass to the microcontroller, the microcontroller cannot stop the motor from running, which will cause the belt be worn out eventually.
So we will discuss here how slow we can tolerate about the signal delay of our distance sensors.

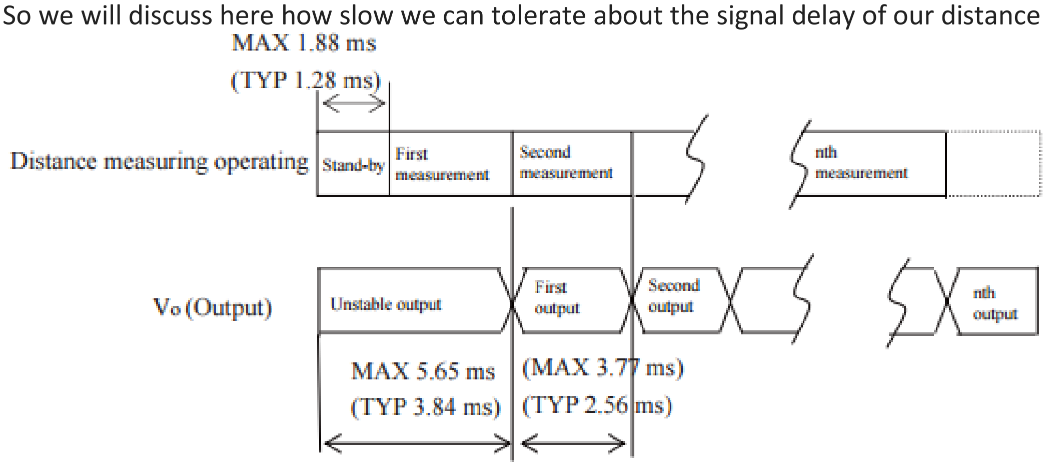


Figure 34 The time delay for the output from distance sensor [3]

The distance sensor will output low when the object is between 20 and 100mm. We design to let clothes stop at 70-80mm ahead of the closet side. By our test on the motor, when loading 6 pieces of clothes, the speed of the conveyor belt is 10mm/sec. Then the distance that conveyor belt will travel after sending the signal is 10*0.00384 = 0.0384mm to [50*(0.00384+0.00256)] = 0.064mm.
Also, there will be inertia causing clothes move a little bit forward. The clothes has 10mm/sec initial speed. The belt is made of rubber so the friction coefficient is 1.16.

$$F = ma$$
$$a = \mu * m * g = -11.368\, m/s^2$$
$$V_t = V_0 - a * t$$
$$t = 8.8 * 10^{-4}\, s$$
$$S = V_0 * t - 0.5 * a * t^2$$
$$S = 0.01 * 8.8 * 10^{-4} - 0.5 * 11.368 * (8.8 * 10^{-4})^2$$
$$S = 4.4 * 10^{-3}\, mm$$

So this distance caused by inertia is negligible.
Thus, the distance caused by signal delay plus the distance caused by inertia is 0.06444mm, which is also negligible (only if we choose this fast distance sensor).

3.3 Safety

The smart closet has low power consumption overall. So there are few power things need to care about. Our project includes mechanical part like gear and belt, this becomes a safety issue.

- Do not apply voltage more than 24 V for motor
- Do not apply current more than 2 A for motor
- Make sure ground body first in order to connect cable
- Do not adjust belt when motor is running
- Make sure power supply is not connected inversely
- Make sure not let clothes get close to electric device

All members of the team should complete the lab safety training before engaging with any lab work.

3.4 Ethical issue

1. To accept responsibility for 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;
2. To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;
3. To be honest and realistic in stating claims or estimates based on available data;
4. To reject bribery in all its forms;
5. To improve the understanding of technology; its appropriate application, and potential consequences;
6. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;
7. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

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;
9. To avoid injuring others, their property, reputation, or employment by false or malicious action;
10. To assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

4 Cost and Schedule

4.1 Cost analysis

4.1.1 Labor

Name	Hourly rate	Total hours	Total= hourly Rate *2.5 *total hours
Luchuan zhang	$30	250	$18750
Yiwei li	$30	250	$18750
		500	$37500

Table 5

4.1.2 Parts

Item	Quantity	Cost
Distance sensor(infrared Proximity by sharp)	3	$20.85
Raspberry pi	1	$39.95
LED strip pack	1	$24.95
Raspberry pi Miniature WIFI	1	$11.95
Raspberry pi camera Board	1	$29.95
RioRand Stepper motor	1	$24.95
Flex cable for camera (2m)	1	$5.95
Raspberry pi cobbler breakout	1	$14.99
Touchscreen	1	$89.95
HDMI cable	1	$4.95
USB cable	2	$5.9
Raspberry pi case	1	10.99
DC barrel jack	1	0.95
Grand Total		$286.23

Table 6

4.1.3 Totals

	Labor	Parts	Total
Cost	$37500	286.23	$37786.23

Table 7

4.2 Schedule

Week	Task	Delegation
2/8/2016	Prepare project proposal Research Raspberry pi	Luchuan zhang Yiwei li
2/15/2016	Research camera and wifi module	Yiwei li
	Purchase Raspberry pi and other module	Luchuan zhang
	Prepare mock design review	Yiwei li Luchuan zhang
2/22/2016	Draw all schematics and block diagram	Luchuan zhang
	Write design review (introduction and block description and R&V table)	Yiwei li
	Contact the machine shop to build our clothes rack	Yiwei li Luchuan zhang
2/29/2016	Research camera part for Raspberry pi	Yiwei li
	Research distance sensor	Luchuan zhang
	mechanical part debugging	
3/7/2016	Write code for computer vision and test it	Yiwei li
	Order PCB	Luchuan zhang
3/14/2016	Simulate the condition that motor driving the clothes on the rack	Luchuan zhang
	Debug code part for camera	Yiwei Li
3/21/2016	Install LED system	Luchuan zhang
	Run and test code for controlling LED system	Yiwei li
3/28/2016	Write code for database and application on Raspberry Pi	Yiwei li
	Test part of R&V table	Luchuan zhang
4/4/2016	Modify R&V table final attempt	Luchuan zhang Yiwei li
	Testing/debugging system	Luchuan zhang Yiwei li
4/11/2016	Testing/debugging system	Luchuan Zhang Yiwei Li
	Mock demo preparation	Luchuan zhang Yiwei li
4/18/2016	Final Paper	Luchuan Zhang Yiwei Li
4/25/2016	Final Demo	Luchuan Zhang Yiwei Li
	Prepare final report	Luchuan zhang Yiwei li
5/2/2016	Final Presentation	Luchuan Zhang Yiwei Li

Table 8

5 Reference

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