Smart Closet

ECE 445 Spring 2016

Design Review

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1 Introduction

1.1 Statement of Purpose

Our project's goal is to solve the problem that people met when they trying to pick up their clothes in their private closet. When the clothes are hanging inside the closet, nearby clothes may block the view of one specific clothing item, so users may having 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. So we come up with this solution of building a smart system for people's private closet. This closet will take photo for incoming clothes after users put them in a specific location, and will move the chosen clothes by users (via smart phone or touch screen of Raspberry Pi) to a fixed location for them to easily pick up using technique of computer vision, and 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.

So users can easily organize and check the status and worn times of all their owned clothes on their smartphones, and label any clothes they want to wear for tomorrow, or any clothes they want to go for laundry or throw away. Then the smart closet system will lit LED on the chosen clothes to instruct users, for example, red LED is for picking up and green LED is for going 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. Hence, our 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.

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
- Two 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
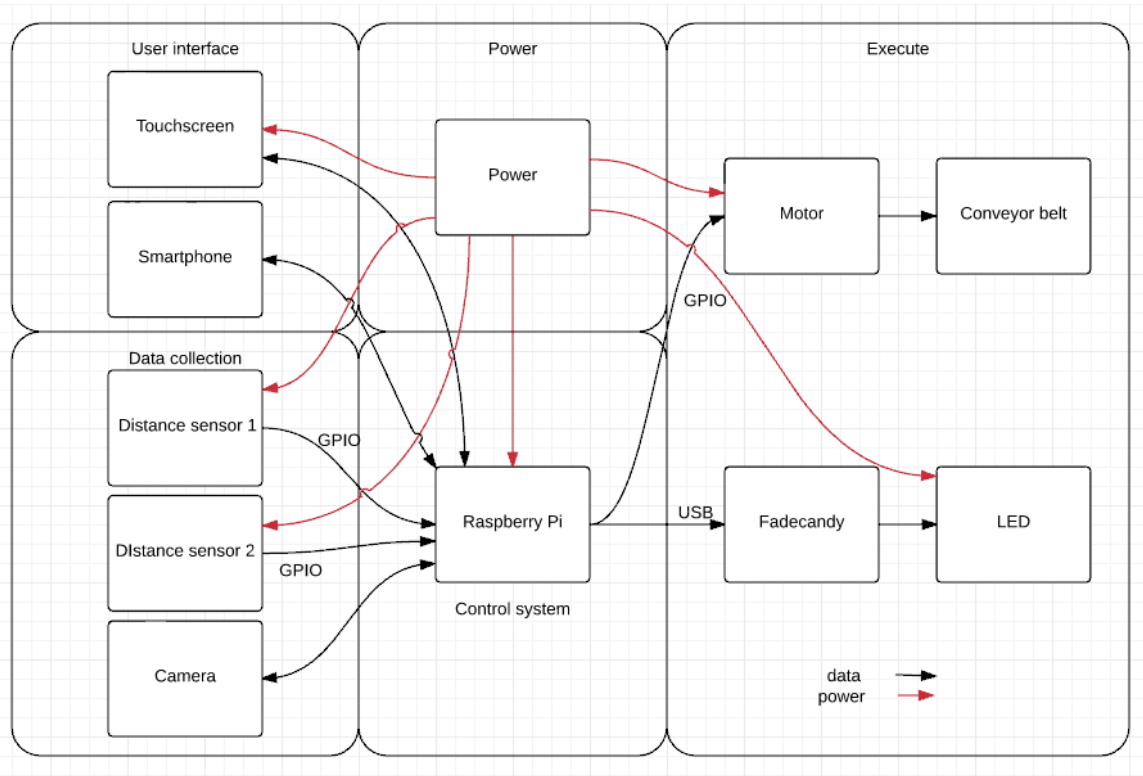
2.1.2 Design Diagram

2.2 Block Descriptions

2.2.1   Microcontroller (Raspberry Pi)

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

Output: Control signal to stepper motor driver/stepper motor, control signal to LED system via FadeCandy (Dithering USB-controlled driver), HDMI signal to touchscreen, power supply, and data cable to touchscreen, data cable to camera

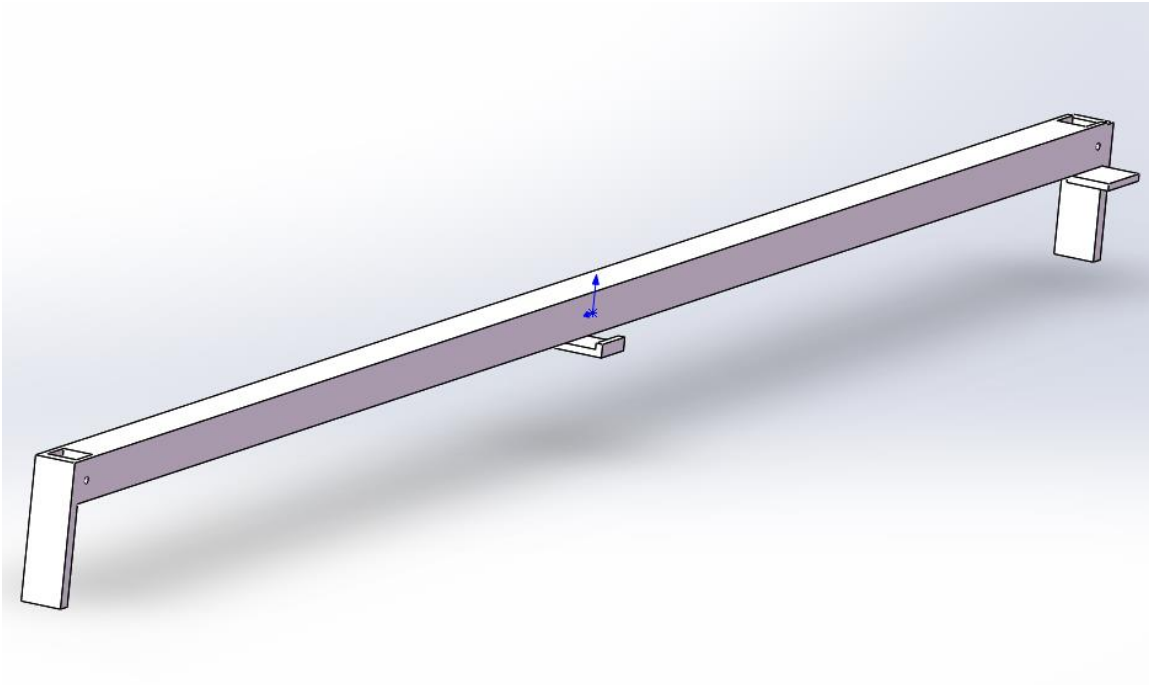Raspberry Pi is powered by a micro-USB cable with a 5 volts adapter with 2 Amp currents. It receives digital input from distance sensors through GPIO ports. It connects to the camera board through CSI bus, where the camera board is attached to Raspberry Pi by one of the two small sockets on the board 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 FadeCandy driver is to control the LED system, in our project is a "NeoPixel LED Strip" provided by Adafruit, and it is linked with Raspberry Pi through a USB port.
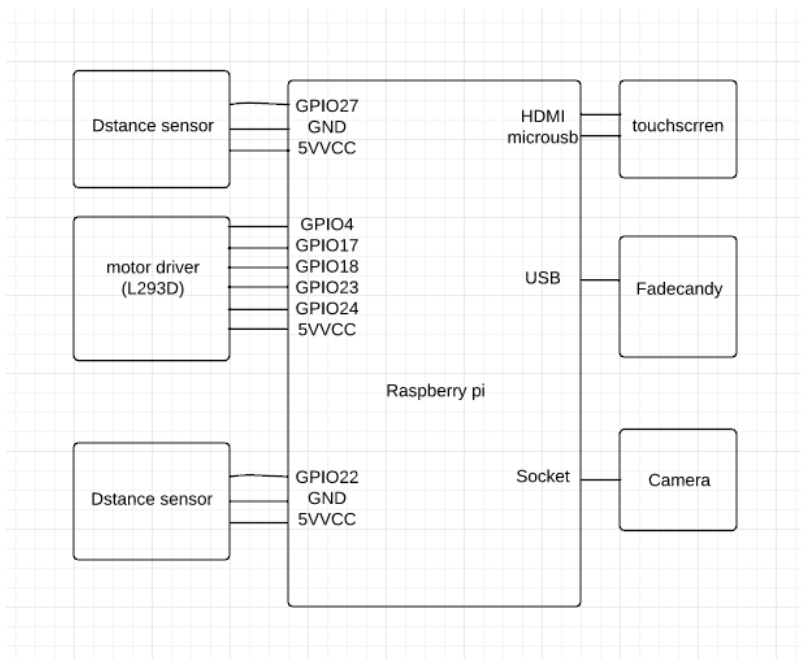
Figure 1 Design Block for Raspberry Pi

Pin Table for Raspberry Pi

Pin	Function	Connection
7	GPIO4	To IN1 of L293D
11	GPIO17	To IN2 of L293D
12	GPIO18,PCM_clock	To EN of L293D
16	GPIO23	To IN3 of L293D
18	GPIO24	To IN4 of L293D
29	GPIO5	To output of Distance sensor1
31	GPIO6	To output of Distance sensor2
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

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 our project

does not need to measure the exact distance between the object and the sensor so we choose this fast distance sensor with a sample rate of almost 400 HZ. [1]

Figure 2 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
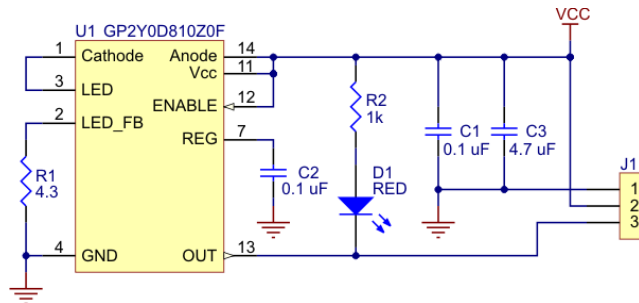
This touchscreen drains power from Raspberry Pi through the USB cable, which also roles as a data cable. It will need 600mA if the backlight is fully on. This touchscreen can display the screen of Raspberry Pi and input users' information of finger location to Pi. In our project, this touchscreen will 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   FadeCandy (Dithering USB-Controlled Driver for NeoPixels)

Input: USB cable from Raspberry Pi

Output: Data cable and ground cable to LED system

This is a controller for the LED system which contains about 10 LEDs. We use this controller so that we can use just one data cable to control all 10 LEDs instead of wiring 20 wires to all LEDs and adding complexity to our wiring design. This FadeCandy controller has its own server software to program and control the LED up to 512 pixels, and we can use many languages like python and C++. [2]

https://learn.adafruit.com/led-art-with-fadecandy/wiring-your-leds
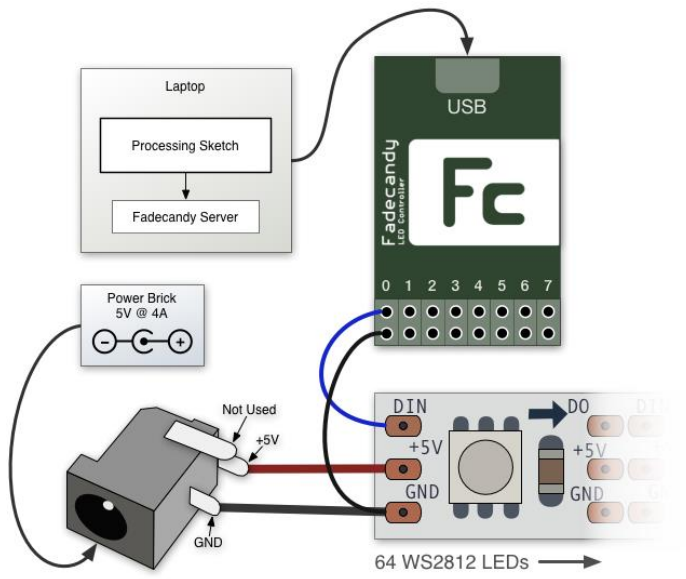
Figure 3 Design Diagram for FadeCandy [2]

2.2.5 Motor Driver (L293D) / Motor (Nema 17 Stepper motor)

Input: Control bits, PCM_clock signal and power/ground supply from raspberry pi

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

This motor driver is controlled by Raspberry Pi and then control the stepper motor. We can, therefore, program the Raspberry Pi to send an exact number of pulse signals to the stepper motor and control the rotating direction of the stepper motor (clockwise or counterclockwise).

Pin Table for Motor Driver

Pin	Function	Connection
1	Enable	To GPIO18 of raspberry pi
2	IN1	To GPIO4 of raspberry pi
3	OUT1	To motor black wire
6	OUT2	To motor green wire
7	IN2	To GPIO17 of raspberry pi
8	Vmotor	To power supply from pi
9	Enable2	To GPIO18 of raspberry pi
10	IN3	To GPIO23 of raspberry pi
11	OUT3	To motor blue wire
13	0V	To ground supply
14	OUT4	To motor red wire
15	IN4	To GPIO24 of raspberry pi
16	V	To power supply from pi

2.2.6 Power Module

Our Project has two power module, one power for LED system and one power Raspberry Pi. The power module for LED system is a 5V 2A power adapter attached to a DC jack. The power module for Raspberry Pi is a 5V 2A power adapter through USB-micro USB cable.

2.3 Schematics of Overall System

GP2Y0D810Z0F
distance sensor

GND	P$3
VIN	P$2
OUT	P$1

GND

distance sensor
GP2Y0D810Z0F

GND	P$3
VIN	P$2
OUT	P$1

GND

GPIO pin out

P$20	3,3V	5V	P$40
P$19	SDA	5V2	P$39
P$18	SCL	GND3	P$38
P$17	4	TXD	P$37
P$16	GND	RXD	P$36
P$15	17	18	P$35
P$14	27	GND4	P$34
P$13	22	23	P$33
P$12	3.3V	24	P$32
P$11	MOSI	GND5	P$31
P$10	MISO	25	P$30
P$9	SCLK	CE0	P$29
P$8	GND1	CE1	P$28
P$7	EED	EEC	P$27
P$6	5	GND6	P$26
P$5	6	12	P$25
P$4	13	GND7	P$24
P$3	19	16	P$23
P$2	26	20	P$22
P$1	GND2	21	P$21

GND

step motor

BLACK	P$1
GREEN	P$2
RED	P$3
BLUE	P$4

motor driver
293D

P$8	EN1	VCC	P$16
P$7	1A	4A	P$15
P$6	1Y	4Y	P$14
P$5	GND1	GND3	P$13
P$4	GND2	GND4	P$12
P$3	2Y	3Y	P$11
P$2	2A	3A	P$10
P$1	VCCM	EN2	P$9

GND

9

2.4 Overall Software Flowchart
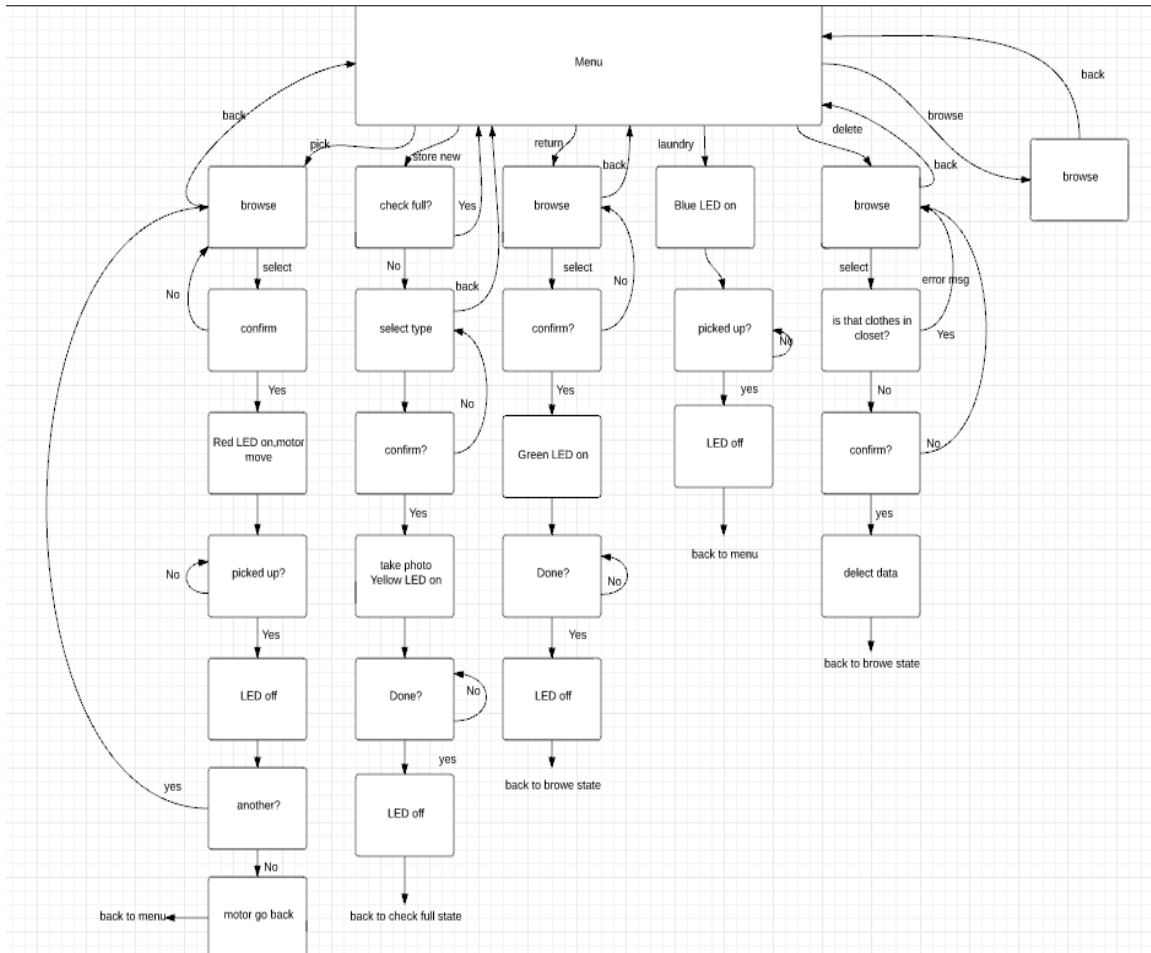
2.5 Simulation and calculation

2.5.1 Power consumption

Power by DC voltage regulator

Load	Voltage	Current	Power consumption
LED(10)	5V	60mA/part	15*60=900mA
Total			900mA

Power by microUSB in raspberry pi

Load	Voltage	Current	Power consumption
Camera	5V	260mA	260mA [8]
Touchscreen	5V	600mA	600mA [7]
Step Motor	5V	833mA	833mA
IR distance sensor	5V	5mA	2*5=10mA
Total			1.703A

The stepper motor will have 2 A if provided 12V power supply. So, if the relation between voltage and current is linear, then stepper motor will have 0.83A if provided 5V power supply.

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.

The frequency of the signal is 2000HZ. [6]

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.

3 Requirement and Verification

3.1 Requirement & Verification

Requirements	Verification
Control System [10 Points]	

Raspberry pi:
1) Module is supplied by 5V,2A.
2) GPIO pin2 can output 5V +-.2V
3) 30MB+-5MB 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
	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 if GPIO 27 is low.
	  (c)Measure the time start from GND the GPIO 27(initially high) to when

	motor is rotating, ensure it is less than 1 second
User Interface [5 Points]	

Touchscreen
1) Display the image from Pi and detect finger movement
	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

Execute Unit [20 Points]	

Motor
1) Can rotate forward and backward
2) Drive 10 clothes on conveyer belt
	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) If correctly powered should output 5V +-0.2V in Pin 14 and 6
	1)
	   (a)Connect with Pi using specified pin table
	   (b)Attach voltmeter to Pin 14 and check readings, ensure it is in range
	   (c)Repeat step(b) for pin 6, ensure readings is in range also

LED System
1)Check if each LED can be controlled individually by FadeCandy
2)Each LED can display red, green, yellow, and blue
	1)
	   (a)Connect Vcc and GND to NeoPixels Strip
	   (b)Connect Vin and GND from NeoPixels Strip to FadeCandy
	   (c)Connect FadeCandy to Pi through USB
	   (d)Program FadeCandy to control each LED
	   (e)Check each LED can be controlled and lit
	2)
	   (a)Complete 1) step
	   (b)Program add four colors to each LED

	(c)Check each color is correct for every LED on strip
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 4.4-5.0V 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 4.4-5.0V (d)Put nothing in front of the sensor (e)Always ensure the reading from voltmeter is in range 4.4-5.0V
Power Unit [5 Points]	
DC 5V Adapter 1) Power from 110-240 AC and output a 5 +-0.2V DC with 2 +-0.1 Amps	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 (e)Attach Multimeter to the DC jack output and read the current (f)Ensure readings in current are 2A +-0.1A

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.
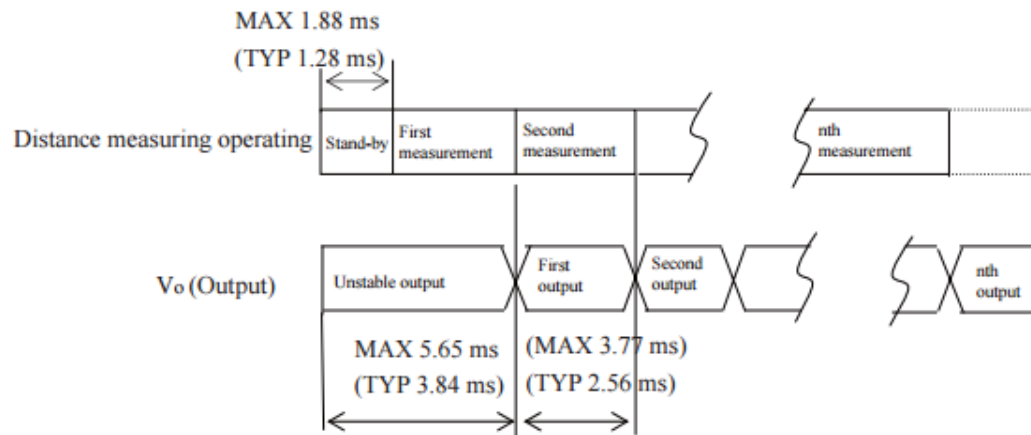
MAX 1.88 ms
(TYP 1.28 ms)

Figure 4 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 = (umg)/m = -11.368m/s^2

Vt = V0-a*t; t = 8.8*10^(-4)s;

S = V0*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^-3mm

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

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

4.1.2 Parts

Item	Quantity	Cost
Distance sensor(infrared Proximity by sharp)	2	$13.9
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
Motor driver	1	$2.95
HDMI cable	1	$4.95

USB cable	2	$5.9
Raspberry pi case	1	10.99
DC barrel jack	1	0.95
3-pin JST SM plug	1	1.5
Fadecandy USB driver	1	24.95
Grand Total		$308.73

4.1.3 Totals

	Labor	Parts	Total
Paid Engineering	$56250	$308.73	$56558.73
Volunteer Engineering	$0	$308.73	$308.73

4.2 Schedule

Week	Task	Delegation
2/8/2016	Prepare project proposal	Luchuan zhang
	Research Raspberry pi	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 computer vision	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

5 Reference

[1] Sharp GP2Y0D810Z0F with Pololu Carrier

https://www.adafruit.com/products/1927

[2] FadeCandy

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[3] Datasheet SHARP GP2Y0D810Z0F (2006, December). Retrieved from

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[5] Datasheet L293D Quadruple Half-H Drivers (2004). Retrieved from

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[6] Datasheet for Motor (Nema 17 Stepper motor). Retrieved from

http://ecx.images-amazon.com/images/I/81RsrEX4IAL.pdf

[7] Touchscreen for Raspberry Pi

https://www.adafruit.com/products/2407

[8] Camera for Raspberry Pi

http://elinux.org/Rpi_Camera_Module