ShowMi Technology Inc.

March 10th, 2016

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

RE: ENSC 440W Design Specification for *MagicMirror*

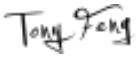
Dear Dr. Rawicz,

The document attached from *ShowMi Technology Inc.* describes the design specification for the *MagicMirror*. In fact we are very passionate about introducing the MagicMirror that speeds up shopping time and enhances shopping experience by being able to search the inventory information and self –checkout through the gesture controls.

The purpose of this design specification is to provide information and specifications for designing the *MagicMirror*. This design specification contains software, hardware and mechanical modules, in order to meet their desired design specification. At the same time, this document will also discuss about the test plan that the system will go through to ensure its correct operation. The test plan section will be divided into unit tests, integration tests and system tests.

ShowMi is a partnership of five engineering science students: ChangShuo(Tony) Feng, Xukai(Aaron) Zhong, Ziye(Nick) Zhu, Hongji(Terrence) Dai and Yanjie(Jenny) Zhan. If you have any questions or concerns about our proposal, please feel free to contact me by phone at 778-385-2407 or by e-mail at csfeng@sfu.ca.

Sincerely,



CEO – Tony Feng

ShowMi Technology Inc.

Design Specification for the

MagicMirror

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Abstract

Going shopping is always girls' beloved activity. During the holiday season, like Black Friday, Christmas and Boxing Day, big sales on the clothing stores are very attractive to women. However, people usually feel a little depressed after they finish their try-on and see a very long line in front of the cash desks.

Although the development of technology is rapidly, the existing self-checking out system is only designed for supermarkets and furniture stores. The *MagicMirror* from *ShowMi Technology Inc.* seeks to provide clothing stores with a space-saving, modern and brand new self-checkout fitting room mirror. The purpose of *MagicMirror* is to make a full use of time when customers go shopping in clothing stores. If they are tired of waiting in the long line, this product design provides an option for customers to use fitting rooms to check-out their items.

This document will discuss the design specification for the prototype of the *MagicMirror* system, which consists of three main modules:

- Software – PHP web application user interface design; QR code generation and RealSense camera application
- Hardware – Minicomputer binding with barcode scanner and RealSense camera; Arduinos as central controller controls distance sensor, 19 inch display screen, and Bluetooth module.
- Mechanical – Wooden frame design at back of the mirror; wiring

This document will also conclude with a test plan for the prototype, and it will take place independently for the modules to catch anomalies at early stage and ensure a reliable foundation of the system. Testing of the integrated system will then be carried out to ensure compliance and functionality requirements are met.

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Glossary

QR Code	Quick Response Code
PHP	A server-side scripting language designed for web development but also used as a general-purpose programming language.
RealSense Camera	A platform for implementing gesture-based human-computer interaction techniques.
UI	User interface
PWM	“Pulse-width modulation” A modulation technique used to encode a message into a pulsing signal.
SRAM	Static random-access memory
Digital I/O Pins	The pins on the Arduino can be configured as either inputs or outputs.
Analog Input Pins	A description of the analog input pins on an Arduino chip
EEPROM	“Electrically Erasable Programmable Read-Only Memory” and is a type of non-volatile memory
ATmega328P	ATmega328 is a single chip micro-controller created by Atmel and belongs to the megaAVR series.
g	Gram
Hz	Hertz
MHz	Megahertz

cm	Centimeters
mm	Millimeter
mA	Milliamps
V	Volt
us	Microsecond
ms	Millisecond
TTL	“Transistor–transistor logic”. A type of digital circuit built from bipolar junction transistor and resistors.
GPIO	General Purpose Input/output
PC	Personal Computer
AC	Alternating Current
DC	Direct Current
Arduino UNO	A microcontroller board
MySQL	An open-source relational database management system
VGA	Video Graphic Array
LED	Light-emitting diode
CSA	Canadian Standards Association

1. Introduction

The *MagicMirror* has two major functions. Firstly, when the customers scan the cloth labels, *MagicMirror* could help the customers check its detail information, like size, color, and the amount in stock, so it will help the customers to choose their most favorite items and add to the shopping cart; Secondly, it allows people to use their phones to scan the barcode that generated from the *MagicMirror* to pay for the items.

For this design specification, *MagicMirror* can be divided into three parts. The first part is software, it is dealing with the PHP web program and UI design, as well as the data transfer between the web application and QR code scanner and RealSense camera. The second part is hardware design, it includes two main portions: one is centered with minicomputer connected with barcode scanner and RealSense camera; the other portion is surrounded with Arduino controlling distance sensor and monitor. The last part is mechanical design, it involves main body design and the wooden frame at the back of the mirror, and the electronical wiring design inside the wooden box. These three main portions will each have its own section in this document with detailed description on its design logic, function and implementation.

1.1 Scope

This document outlines the detailed design specifications each parts of the *MagicMirror*. This document explains how the prototype design meets the functionality of the system including the software program, hardware assembly, mechanical design and the general system set up. It includes the design logic, design methods, and pros and cons of the design. This design specifications document focuses on proof-of-concept model and prototype but may still involves final product model.

1.2 Intended Audience

This design specification is intended for use by all members of *MagicMirror*. Our group will refer to this document as overall design goals through development. This

documentation will also be used to justify any design decision as well as serve as a temple for future modification. If there are any issues encountered during the testing and quality assurance stage before finalizing the product.

2. System Overview

2.1 High Level System Diagram/General Function

The following figure outlines the high-level block diagrams of the *MagicMirror* and the interactions happening between different stages:

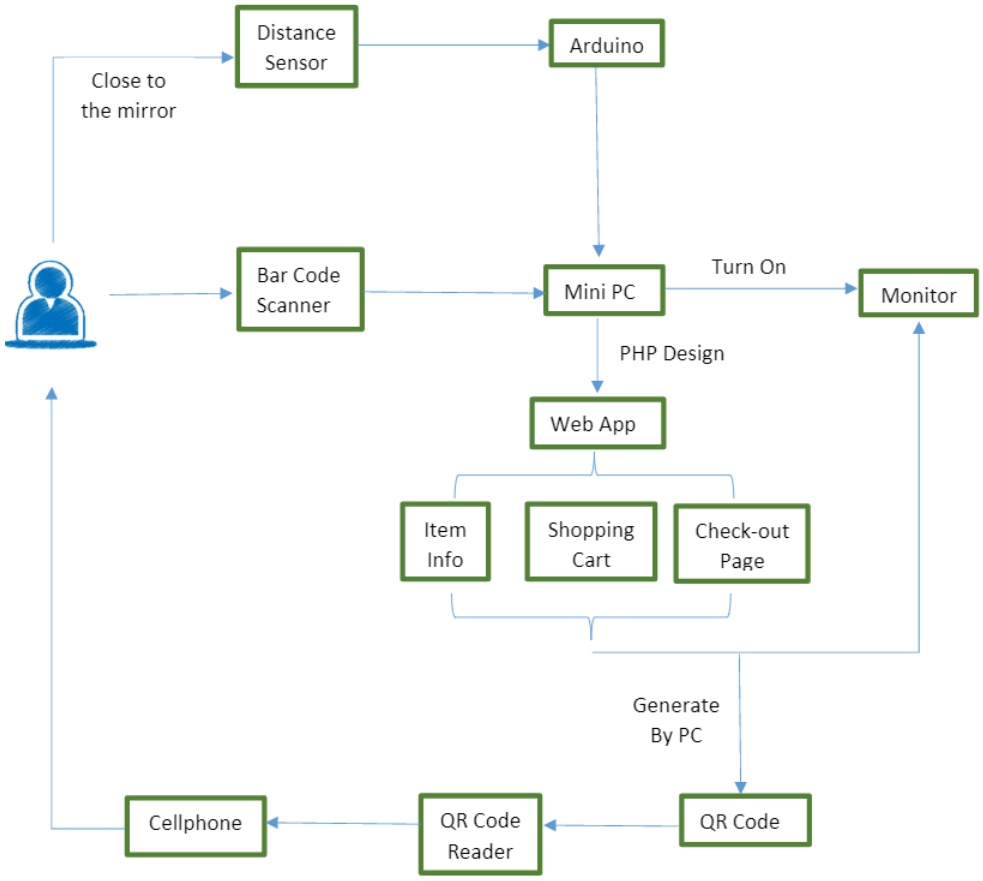

Figure 1 System Diagram

MagicMirror is a product that combines mirror, inventory searching and self-checkout system together for the purpose of reducing waiting time and creating convenience. In

terms of functionalities of *MagicMirror*, it is very compatible for clothing store. Also, *MagicMirror* is a perfect combination between technology and traditional business.

2.2 General Demonstration of the Product

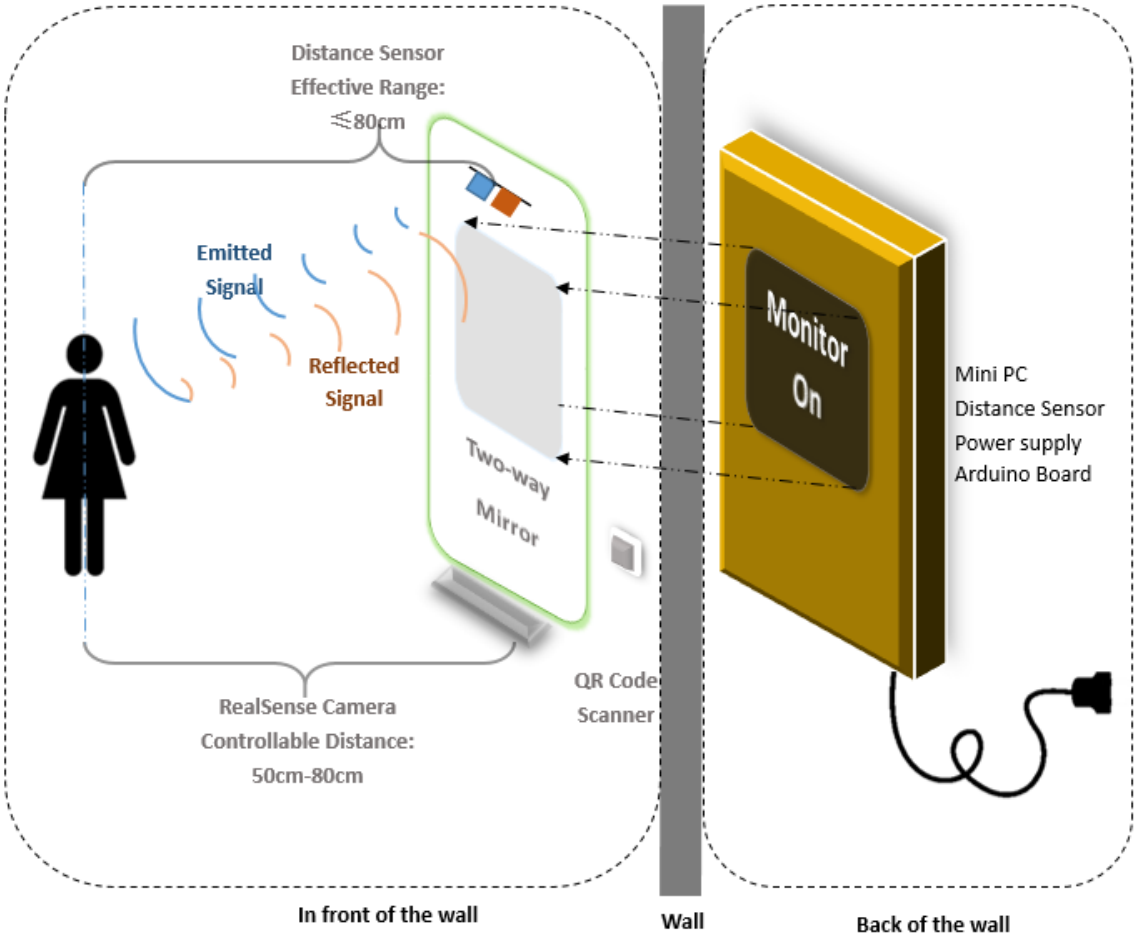

Figure 2 General Picture of the System

In general, *ShowMi Technology Inc.* divided this product into three main parts shown in the figure above, which contains a two way mirror, a screen and the "box". The basic idea is to use the unique property of a two way mirror: the dimmer side could always see through the mirror whilst the brighter side can only see the reflected image. On one hand, if customers stand 80cm within of *MagicMirror*, the distance sensor that sends out

continuous signals will be able to detect the presence of an object. Then the distance sensor will send out a high frequency pin to the back stage, which will be contained by the "box". Inside the "box", all hardware components will be placed and connected together including: an ultrasonic distance sensor, a QR code scanner, a mini PC, an Arduino Board and a voltage transformer. On the other hand, when our system is off, it will act like a normal mirror;

2.3 System Description

Generally speaking, the first step for activating our display, customers will need to be detected by the distance sensor. Once there is an object within 80cm to the sensor, the Arduino will send out a signal to system board of *MagicMirror* to activate front screen. Secondly, the software part is UI design and system build in our mini PC hide in our "box", we are using PHP programming language to make the website functional and interactive, check-out function will make customer's shopping more convenient and time saving, item information check will connect to database, so the information will update frequently, fast and precisely. Thirdly, we are using LEAP Motion RealSense Camera for sensing hand gestures as our mouse to move around the target, select command or quit. Lastly, in our "Box" design, we will have a room place our 15 inches screen, mini PC and voltage transformer. Wires in the box will be well organized, otherwise it may lead to signal noises, short circuit or other problem that will discussed in the coming details.

The prototype of *MagicMirror* is powered by 110V voltage. Since we have other small component for example Kinect and Arduino board only required 5V operating voltage, we will have a voltage transformer placed in our design. The function of the transformers is to change electric power from one voltage to another.

The low level design of the *MagicMirror* will be discussed details about hardware system,

software system and mechanical system in the following of the document.

3. Hardware System

3.1 Arduino UNO

ShowMi Technology Inc. decided to use Arduino UNO as microcontroller. It is used to communicate with Distance Sensor and is in charge of turning ON/OFF the monitor. UNO represents the basic type of Arduino. In this project, we considered that UNO is sufficient to operate the desired functions. Arduino UNO has 14 digital I/O pins, 6 analog input pins, a 16MHz quartz crystal, a USB port, a power jack, an ICSP header and a reset button.

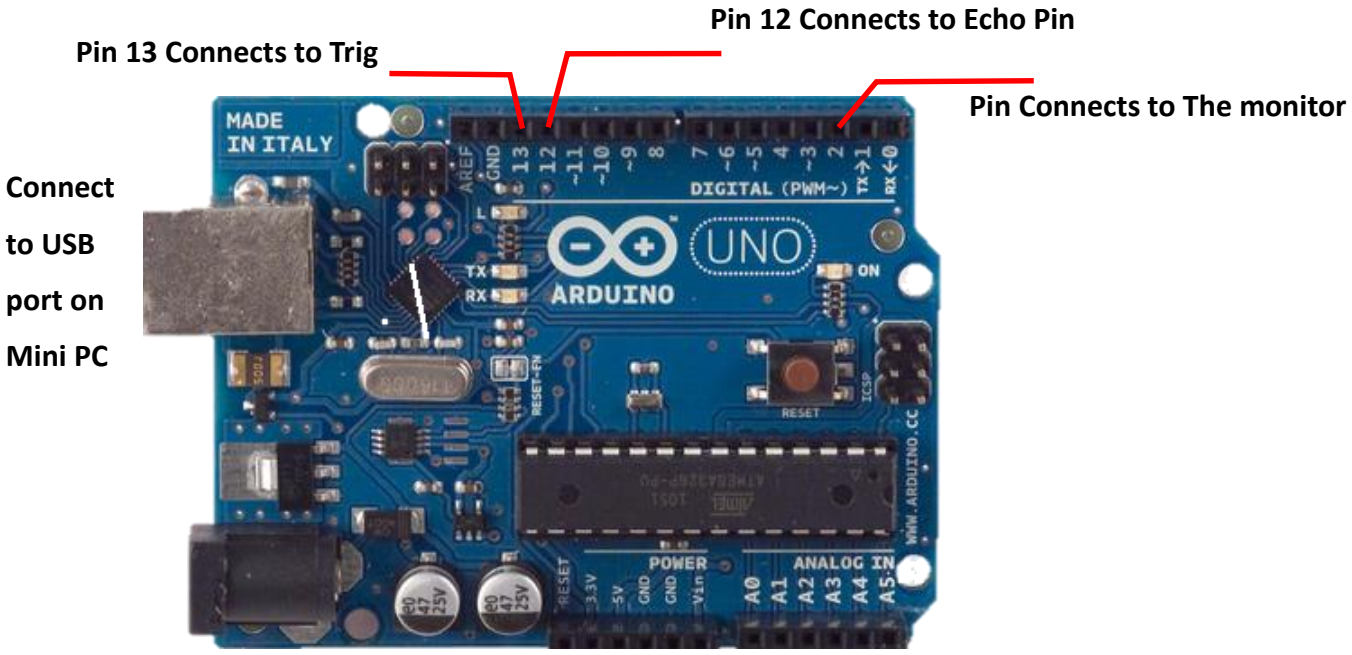

Figure 3 Arduino UNO Pins Diagram [1]

The requirements are based on [MD-3.4.1-3.4.6] in function specification. These requirements are related to control the distance sensor and the monitor.

The following table provides detailed datasheet for Arduino UNO, and the limits are

strictly followed during our system development

Table 1 Arduino UNO Specifications [2]

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7 ~ 12V
Input Voltage (limit)	6 ~ 20V
Digital I/O Pins	14
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P)
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

3.2 Ultrasonic Ranging Module HC-SR04

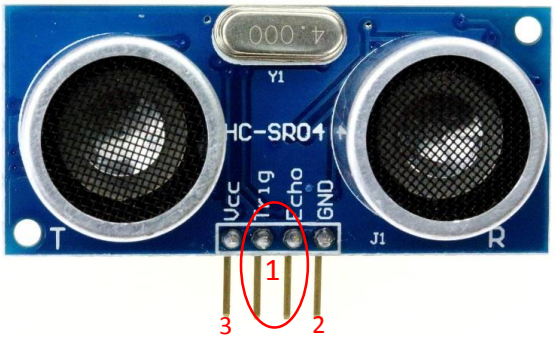

Figure 4 Ultrasonic Distance Sensor [3]

Pin 1: Connect to the Digital ports (12, 13) separately on the Arduino Board;

Pin 2: Connect to the GND pin on the Arduino Board;

Pin 3: Connect to the 5V Power input Pin on the Arduino Board;

Distance Sensor is used to detect the distance between customer and the mirror. Once the

distance is less than 80cm, the monitor will be turned on. Otherwise, the monitor is off. The Detailed Data Sheet is shown on the following table.

Table 2 HC-SR04 Specifications [4]

Working Voltage	DC 5V
Working Current	15mA
Working Frequency	40Hz
Max Range	4m
Min Range	2cm
Measuring Angle	15 degree
Trigger Input Signal	10us TTL plus
Echo Output Signal	Input TTL lever signal

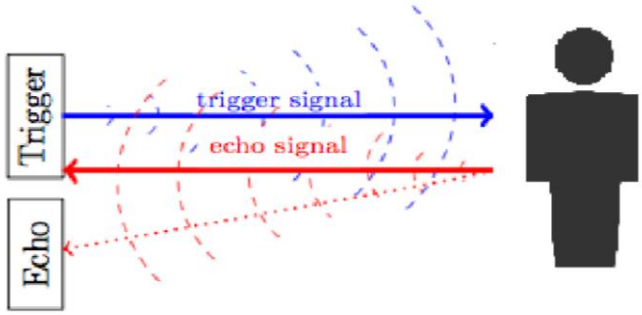

Figure 5 Working Principle [5]

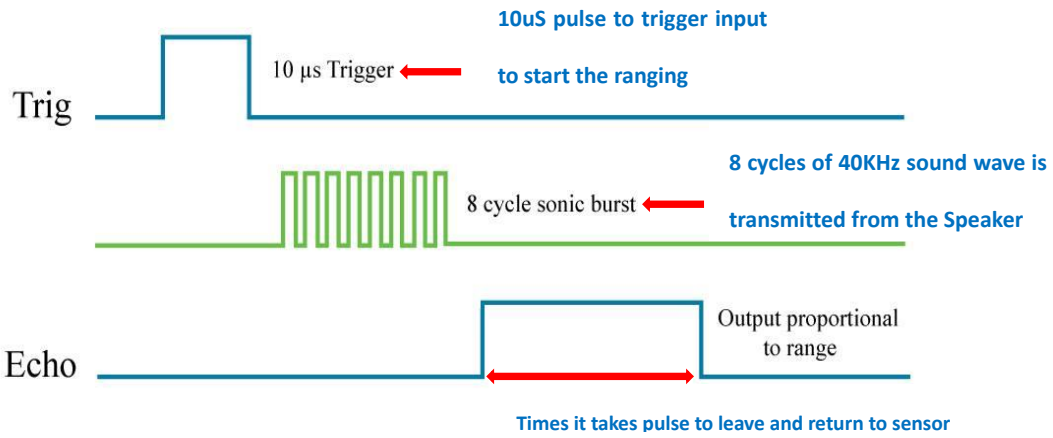

Figure 6 Trigger Waveform [6]

The distance sensor will calculate the difference in the time between Trigger and Echo.

The algorithm of calculating the distance is shown below:

Speed of Sound:

V=344m/s=0.0344cm/us [7]

Distance:

X=t*0.0344/2

3.3 Mini PC

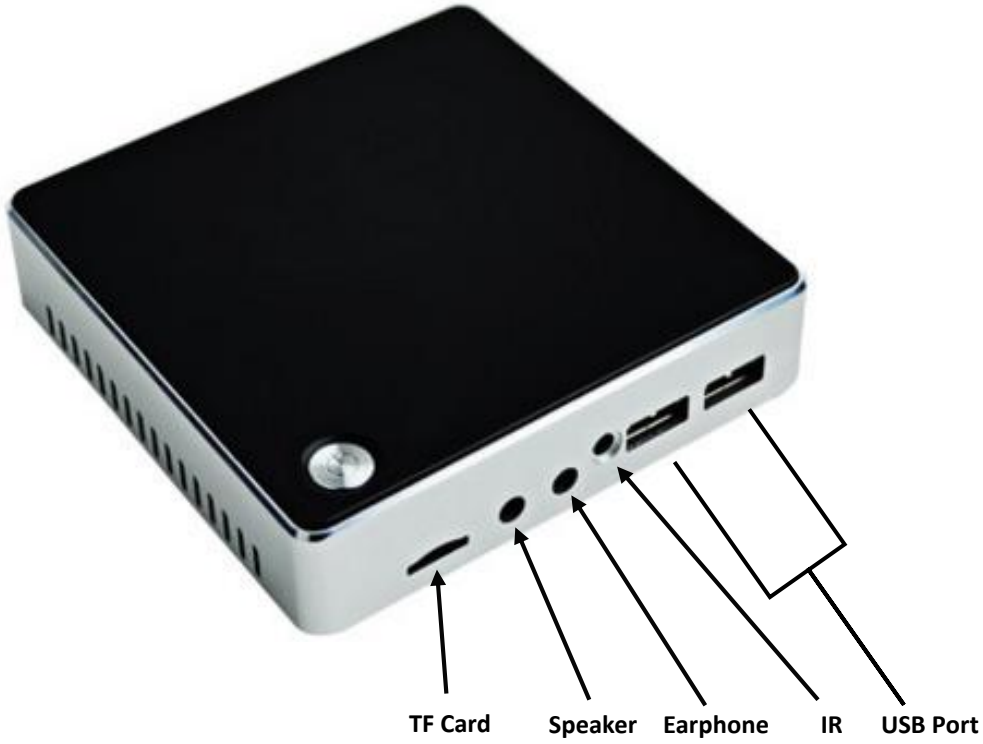

Figure 7 Mini PC [8]

Our concerns on using mini-computer are based on the reasons listed below:

- **Low energy cost: 60% less energy cost than normal computer.**
- **Quiet working environment**
- **Portable and Easy maintenance**

3.4 QR code Scanner (MJ-400)

Figure 8 QR Barcode Scanner [9]

Our concerns on this specific brand of Barcode scanner are based on the reasons listed below:

- **Multi-functional Scanner: Bar code and QR Code**
- **Manual and automatic combined**
- **Support Angle adjusting**
- **360-degree detecting**
- **Relatively low cost**

Table 3 QR Barcode Scanner Specifications [10]

Working Voltage	5V
Working Current	450mA
Operating Temperature	0 ˚C ~ 50 ˚C
Storing Temperature	-30˚C ~ 60˚C
Reading Distance	10mm

Brightness Resistance	Strong
Average Reading Speed	150ms

3.5 Circuit Integration

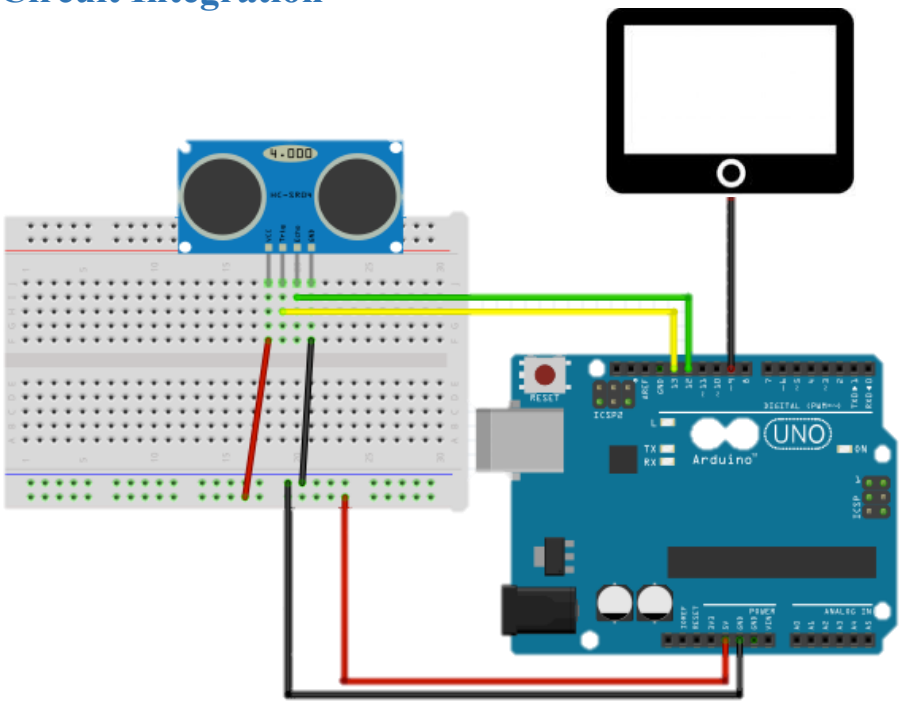

Figure 9 Circuit Integration of Monitor Controlling

The monitor will be turned on whenever an object is detected by distance within 80cm, which is an average distance that customer is comfortable to control the self-checkout system.

4. Software System

The software part of the *MagicMirror* includes a web application which allows the customers to check the item information by scanning the QR Code and the RealSense camera application.

4.1 Web Application

4.1.1 User Interface of Welcome Page

When the users get close to the mirror, a welcome page is going to show up which is shown below in Figure 10.

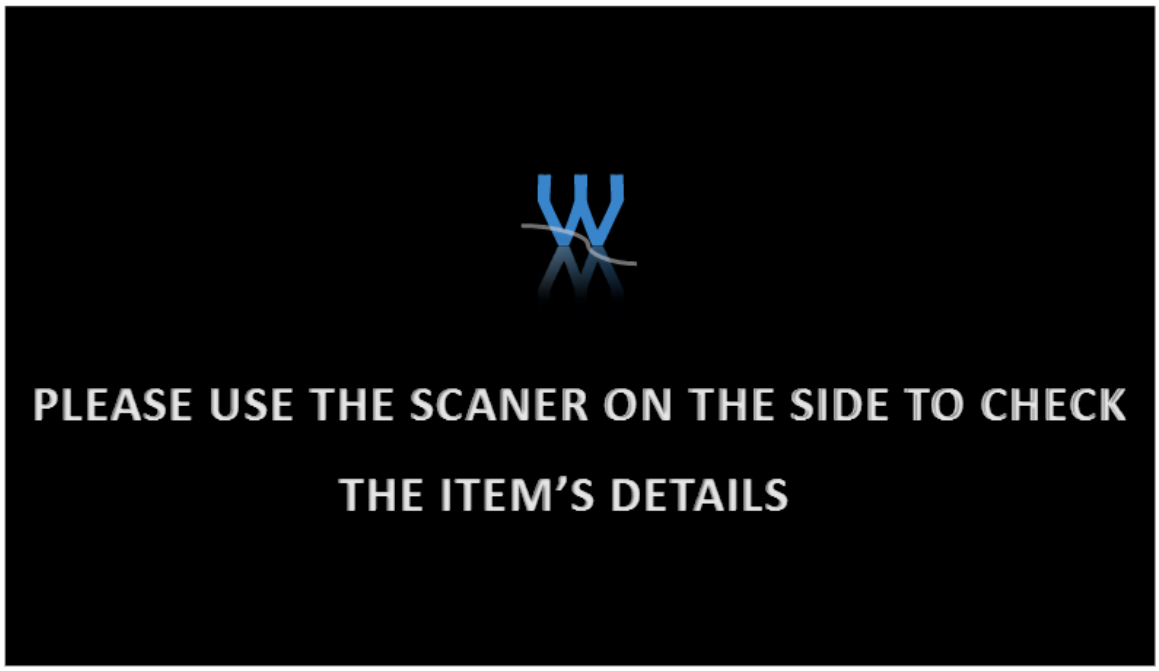

Figure 10 User Interface of the Welcome Page

4.1.2 User Interface of Information Displayed

A website application of the self-checkout system will be published to the public server so that customers are able to check out the items via the mirror.

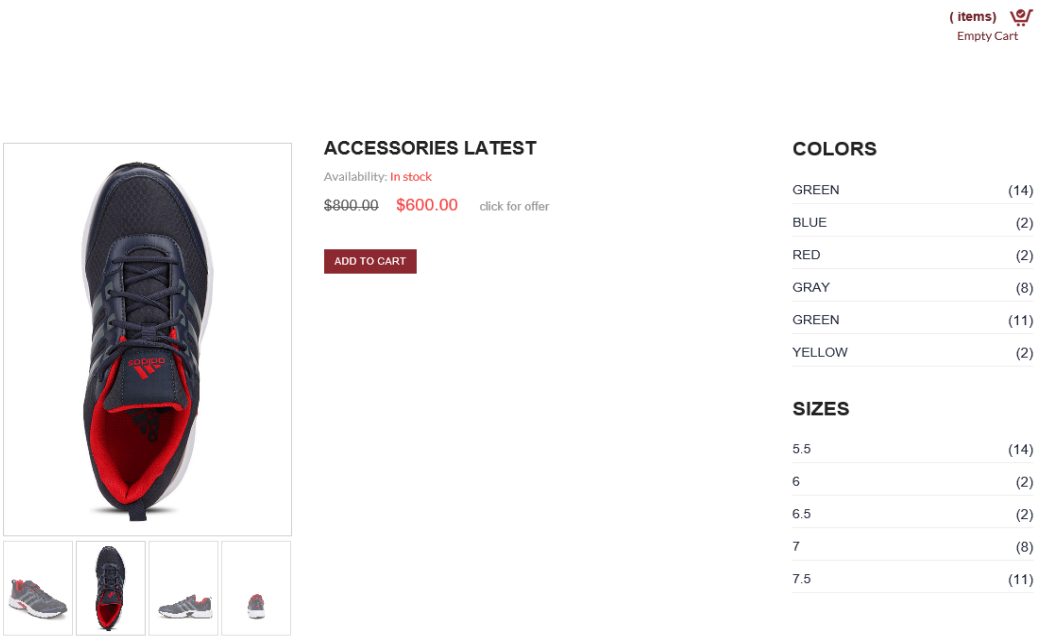

Figure 10 User Interface of the Information Displayed System

The figure above shows the user interface of the information displayed system of the web application based on the requirement [MC - 5.1.3 - II], [MC - 5.1.4 - II], [MC - 5.1.6 - II] and [MC - 5.1.7 - II]. By clicking the small pictures below the item photo, users are able to look at the item from different angle. Also, the states of the item, such as if it is on sales or not, will be displayed on the screen. In terms of the table on the right side of the screen, customers can check the states of storage of the alternative size or color for the selected item.

Further, if the users decide to purchase their selected item, by clicking the "Add to Cart" button will take them to the self-checkout page with all the items that they selected.

Table 4 Button Performance

Button	Function
Add to Cart	Selected item and move to checkout page
Color	Check the picture of the selected color
Empty the Cart	Remove all the items from shopping cart

4.1.3 User Interface of self-checkout

The figure below shows the interface of the check-out system according to the requirement [MC - 5.1.8 - I]. There is a "delete" button to remove item from the shopping cart.

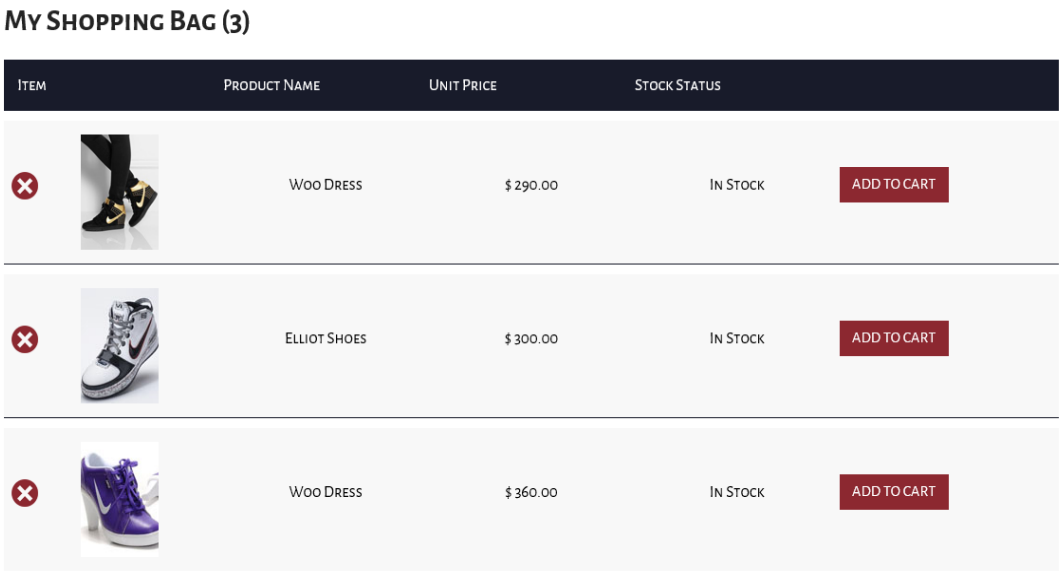

Figure 11 User Interface of the Check-out Section

If the users decide to purchase the items placed in the shopping cart, by clicking "checkout" button, the system will generate a QR code for the customers so that they can pay for the items by scanning the QR code using their cell phone based on the requirement [MC - 5.1.9 - I]. An example of the payment QR code is shown in the Figure below.

Figure 12 Payment QR Code [11]

4.2 RealSense Controller Application

4.2.1 The RealSense Controller Choice

In terms of how to control the web application, at first we came out with the idea to make a touchscreen. However, since we are making a mirror monitor, touching might make the mirror dirty which might affect the quality of the mirror. Thus, we decided to make a hand gesture so that users can control the self-checkout system by the hand signals. The RealSense controller we are going to use is called Leap Motion. Leap Motion is designed to capture the movement of the users' hand by tracking the location of the fingers when the users put their hand on the Y coordinate of the gesture as presented in the figure below [12].

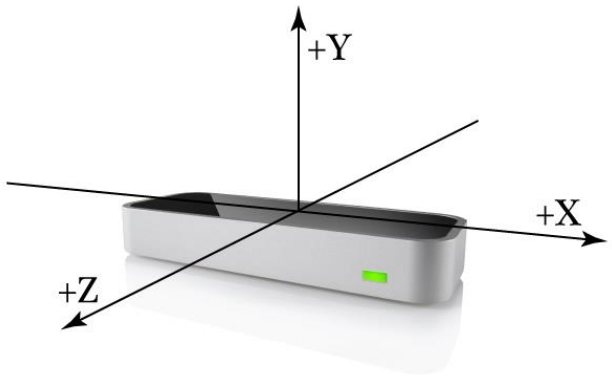

Figure 13 Tracking Coordinate of the Leap Motion [13]

4.2.1 The Hand Signal Tracking

The finger tracking is implemented by an application in the Leap Motion SDK called Mudra mouse. By running this application, users can move and select the trigger, which meets the requirement of [MC - 5.2.1 - II], [MC - 5.2.2 - II], [MC - 5.2.3 - III] and [MC – 5.2.4 - III] in the website application by moving the forefinger and pointing the finger forward respectively. The finger tracking demonstration for this application is shown in the figure below.

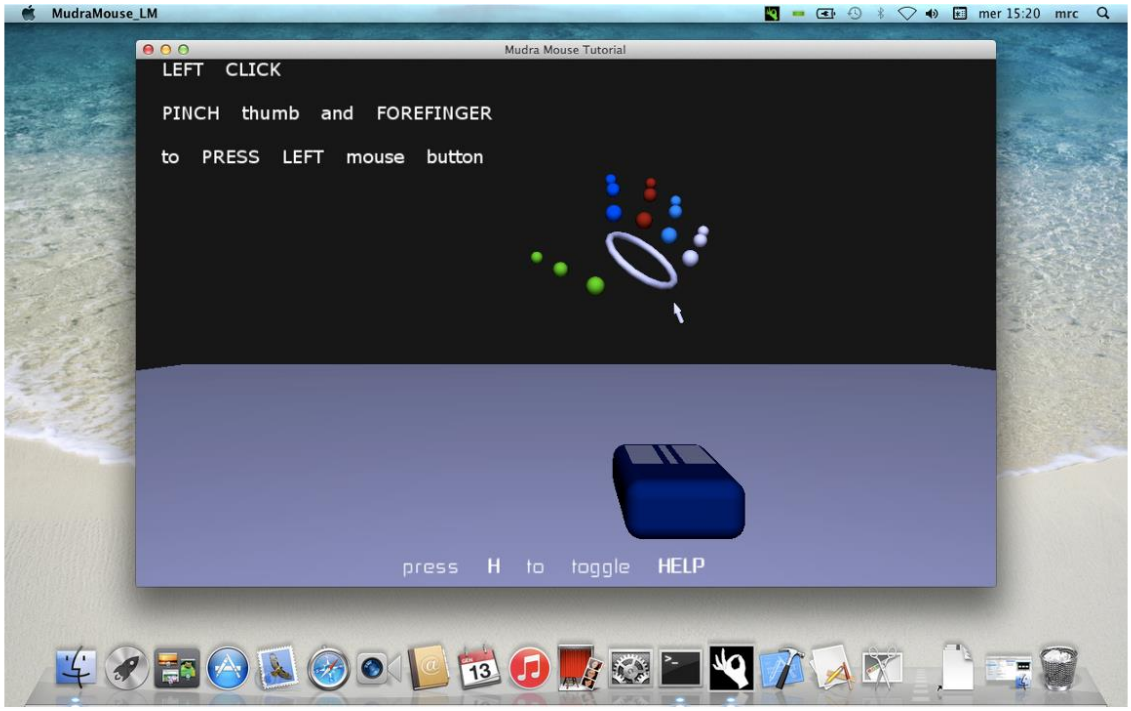

Figure 14 Kinect Tracking Demonstration [14]

However, since the tracking is not perfectly accurate, right now the selecting function is not working perfectly, *ShowMi Technology Inc.* decided to change the algorithm so that the selecting can be implemented by pinching thumb and forefinger.

4.3 Website and Storage Information Integration

In order for the users are able to check the information of the item they select through the web application, the data from the database of the store needs to be retrieved. The PHP + MySQL is the back-end structure we are going to use. We have our information stored in MySQL, and connected with the front page using the PHP as the scripting language.

5. Mechanical System

This section will focus on the design of mechanical system of *MagicMirror*, which includes mechanical components, transmission system, and design in mounting, integration and wiring of the system. These components will be discussed by *ShowMi Technology Inc.* in the following pages.

5.1 Wiring/System Assembly

First of all, the general wiring and design of the system is shown in the figure below which demonstrates the components and the approximate positions of the hardware components, and all of these designs are strictly designed to base on the standards provided in the System Requirements of the functional specification of the product. To be more specific, the following sub-sections are described within the System Requirements section: 2.2 general requirement, 2.3 User Interface/Software Requirements, 2.4 physical requirement and 2.5 Standards.

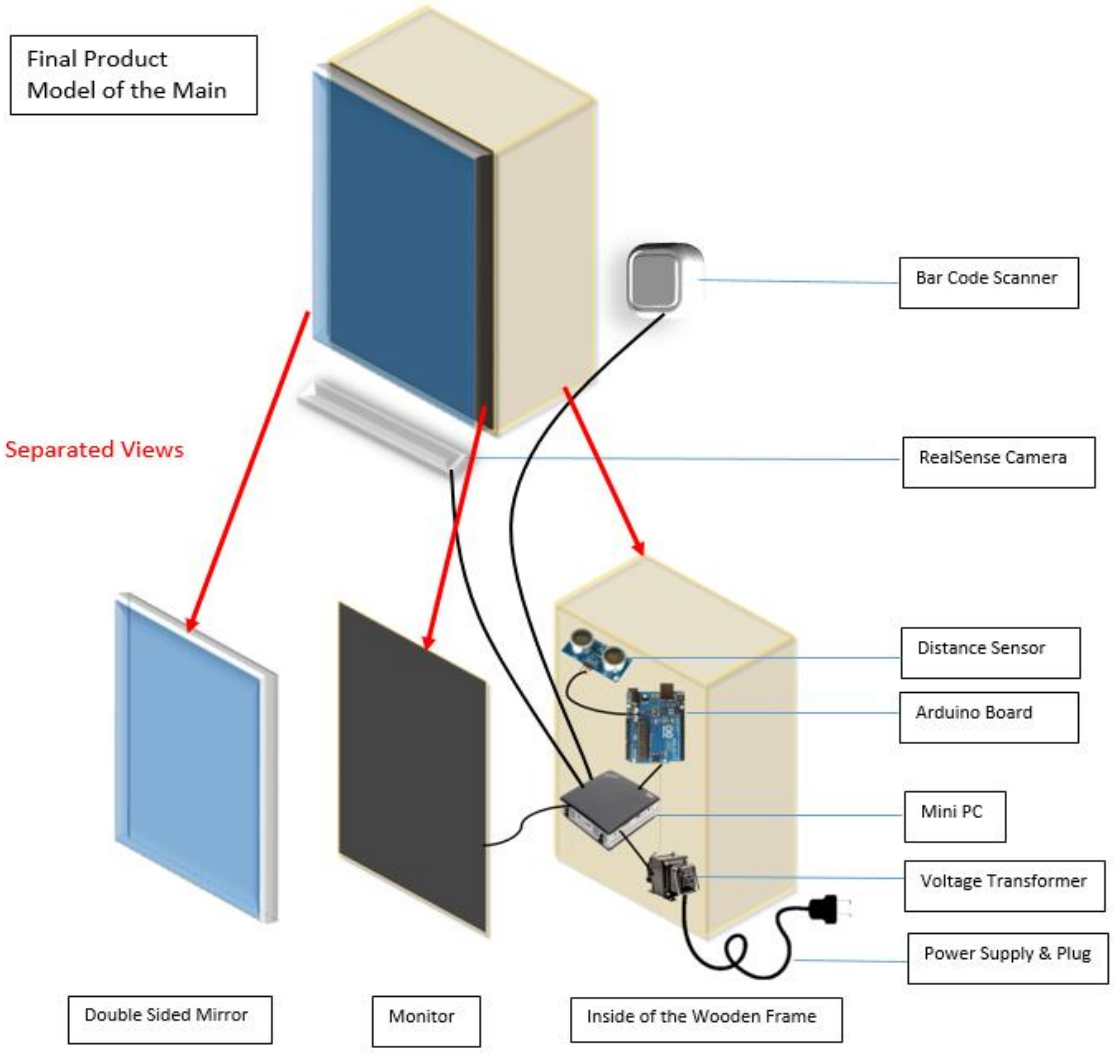

Figure 15 Mechanical Design of the System

5.2 Two Way Mirror

To go into the details of the mechanical components, the most important component of the *MagicMirror* would be the two-way mirror itself. When we choose the size and properties of the mirror, ShowMi Technology Inc. strictly follows the requirements as listed in the functional specification [MD - 3.1.1 – II] to [MD - 3.1.3 – II]. These requirements fully describe the conditions of the mirror: 1. its dimensions of the mirror to be 500mm by 450mm; 2. the fully coverage of the components behind the mirror is ensured since the monitor itself is only 19 inches which is about 400mm by 330mm; 3. the lighting condition for the mirror to work is ensured since the back of the mirror will be covered by wooden planks;

5.3 Frames

Accompanying the mirror itself, frames are also an essential part of the system to ensure the stability of the system and the good-looking appearance the *MagicMirror* is supposed to have when presented in front of customers. The position and stability of the mirror which includes maintaining the mirror itself will be made easier by placing the mirror inside a wooden frame which has an easy to access spot on the side. The design shown below is based on requirements [MD - 3.1.4 – II] and [MD - 3.1.5 – II] from the functional specification. (NOTE: Figure 17 in the Appendix shows the isometric view of the frames and the approximate prototype dimensions)

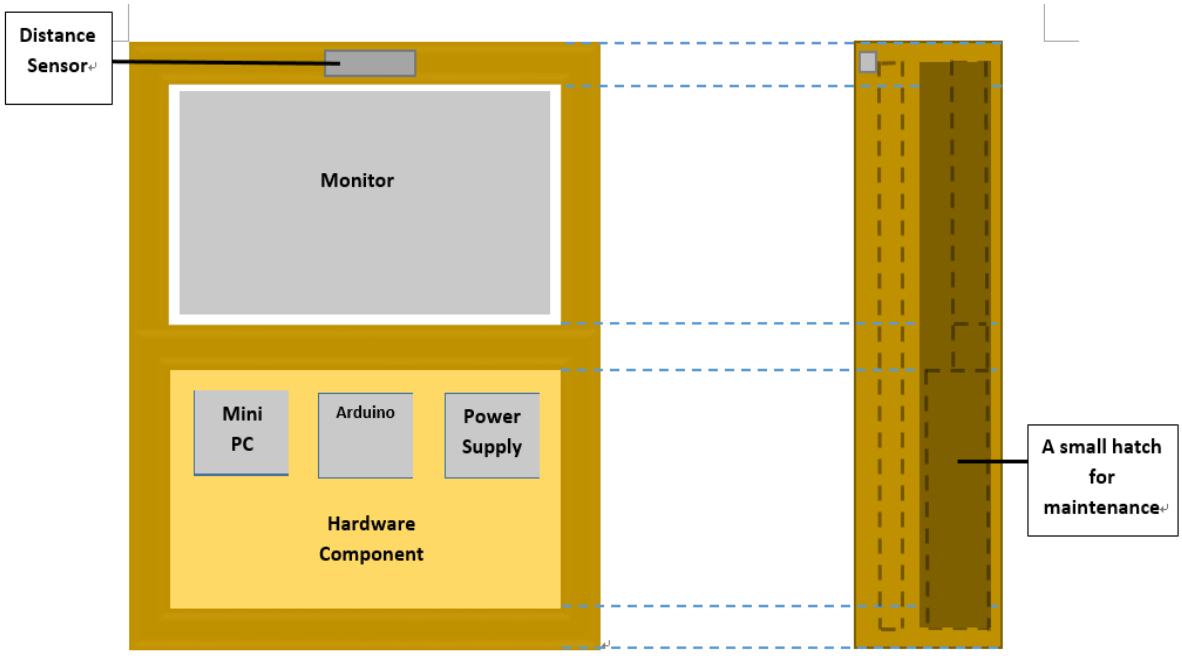

Figure 16 Back View and Side View of the Frame

6. Unit Test

At *ShowMi Technology Inc.*, the *MagicMirror* will undergo a significant amount of testing procedures before it is put into use and finalized for product production to ensure it meets all the functional specifications suggested by the requirements. More specifically speaking, each part of the system will be tested separately first to ensure the meeting of the requirements. Then, the parts will be combined into the product where stress tests for temperatures, sustainability and power consumption tests will be performed to make sure the product meets the international standards.

6.1 Monitor Test

Monitor is the central displaying unit of our system. The monitor will be tested using standard 110V power outlet and the adapters that come along with the monitor to see if monitor works correctly. After testing power function of the monitor, a VGA cable will be used to connect with a desktop to make sure that the monitor can receive signal and that

the VGA port on the monitor functions properly.

6.2 Distance Sensor Test

Distance Sensor acts as the switch for our system, hence will be tested. Currently distance sensor is connected on a breadboard with Arduino acting as the control. Since the sensor we are using is an ultrasonic sensor which can sometimes cause high uncertainties after a small movement. So we will try to test the distance sensor using a small LED and give it a total trial of 10 times and measure how many times the LED would light up if objects are placed in front of the sensor and whether there is disruption of connection or not.

6.3 LEAP Motion RealSense Camera Test

The RealSense camera is the operational control for the system, customers will need it to complete the interactions with the system. Hence it is important for proper testing done on the camera. First of all, the power of the sensor will be tested to make sure that there is no overheating which may cause potential risks. Secondly, the x and y axes movement of the sensor are tested to make sure the sensitivity is suitable for users and that the result is consistent. Lastly, the pinch gesture which stands for left click in the system will be tested to make sure that the acquisition of the signal is on point and correct.

6.4 UI/Webpage Application Test

The UI/Webpage Application is a central part of our design as it displays all the information needed and provides interaction with customers. The UI/Webpage Application will be tested on our developing computer first to ensure that all the proper functions word with no front-end bugs. Since the information of the product will be connected with our database, so we will simulate functions such as scanning barcode, checking item information, adding items to cart, generating barcode and updating item information after checkout is done. These processes will be repeated no less than 5 times to ensure system stability and the correct update of the information.

6.5 2D-Barcode/QR Code Scanner Test

Scanner is what we use as the initiation of the Webpage/Application. It will be tested by scanning certain generated QR code and see if it actually displays the correct and accurate information as generated. Once this step is made sure, we will test the power stability of the scanner to make sure that the scanner will be on all the time once the power is on and that there is no sudden disruption of services or risks created such as overheating of the device.

6.6 Mini-Desktop Power Test

Mini-Desktop is the central processing unit of our product, hence it is very crucial to the success of the product. We will test the mini-desktop by making sure that the system can run almost error-free when we are operating it like other normal desktops. Also, we will make sure that it can endure the 110V standard voltage supply for a long period of time without any breaking down of services. Lastly, we will test on the temperature performance of the mini-desktop to see whether it can cool down itself.

7. System Test

7.1 System Power Test

First the integration of the system will be performed whilst power is off, that is to say all the parts integrated will be integrated together including the distance sensor, the mini-desktop, the mirror, the wooden frames, the monitor, the scanner, the webpage application and the RealSense camera. After integration, the whole system will be connected to the power adaptor and all the components should be able to obtain power through the central power adapter.

7.2 System Integration Test

After system power test is completed, the system will be tested as a whole no less than 10 times to ensure the stability of the system. These tests include first placing an object in front of the sensor to make sure that the monitor turns on. Once the monitor is turned on,

we should be able to interact with the system using gestures through RealSense camera and corresponding mouse commands should be able to be accomplished and all the functions including scanning the barcode, checking storage information, adding items to cart and self-checkout. Lastly, once the operation is done and the object leaves the range of the distance sensor, the system should revert back to its original start after 5 seconds and make itself available for further instructions.

References

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Appendix

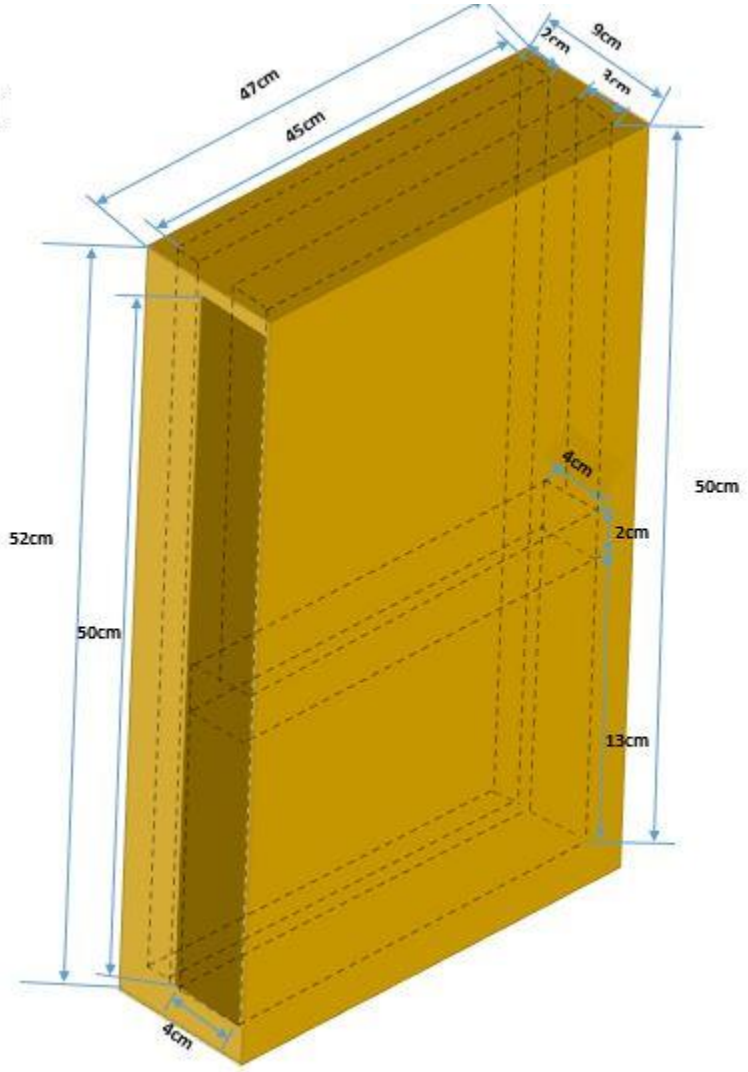

Figure 17 Isometric View of Frame