February 15, 2016

Andrew Rawics
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440W – Functional Specification for a Smart Room Control System

Dear Dr. Rawics,

The attached document is the functional specification for *MOTOUSCONTROL*'s *Smart Room Control System.* Our objective is to design, implement, and construct this product to enhance people's control of their own space by using expressive and meaningful hand gestures and smartphones.

The functional specification outlines the functionality of the overall system as well as the functionality of its three main subsystems; the central processing unit, the hand-gesture recognition subsystem, and the feedback subsystem. Additionally, the document includes a description of the high-level functional requirements for the system. *MOTUSCONTROL* will use this document as a guide for development and testing activities.

MOTUSCONTROL consists of five experienced and motivated fourth-year engineering students: Moha Alharbi, Saad Alkhalifah, Ryadh Almuaili, Adrian Fettes, and Yuhui Jin. Should you have any questions or concerns regarding our functional specifications or product, please feel free to contact me by phone at (604) 500-5416 or by email at salkhali@sfu.ca.

Sincerely,

Saad Alkhalifah
Chief Executive Officer
MOTUSCONTROL

Enclosure: *Functional Specification for Smart Room Control System*

Functional Specifications for Smart Room Control System

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Executive Summary

With the evolution of technology and the continuous enhancement of people's standard of living, interactions between human and electrical devices have become quick and easy. However, elders and individuals with disabilities may find it tough to communicate with machines without external aid. Although there has been great development of different technologies with regards to smart home control systems, elders and disabled people still have many troubles in managing their space. Alternatively, hiring home care professionals to provide an environment, which is conductive to keeping the client safe and independent, could put a financial and emotional squeeze on physically impaired individuals and their families. In addition, physically impaired people may feel frustrated and stripped of their independence and privacy [1]. MOTUSCONTROL is eager to fill this void and provide this necessary supervised care to disabled people in an affordable manner, regardless of their impairment.

MOTUSCONTROL is creating the Smart Room Control System to give disabled people the ability to control their own space by using expressive and meaningful hand gestures, which get converted to signals that are sent to a computing system. The system is programmed to operate lighting, temperature control, security, appliances, and many other features specifically chosen to ensure that our final product be a valuable utility for the physically impaired individuals.

This functional specification document outlines all the functional requirements for the overall system as well as each of the individual components. Each module used in the system must achieve a set of functional requirements that represents a proof of concept, on-going development, and final production. In addition to functional requirements, further dictate a set of standards and guidelines that puts users at ease in terms of safety, reliability, and electrical concerns.

The completion for the design and implementation of the product will be accomplished with an estimated date of April 16, 2016.

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Glossary

User's Palm Size: A hand with palm size between 7-9 cm, close to the average

size of 8 cm [2]

SMS: Short Message Service

CSA: Canadian Standards Association

CDA: Canadian Dollar

IEEE: Institute of Electrical and Electronics Engineers

V: Volts

iOS: iPhone Operating System

AC: Alternating Current

DC: Direct Current

Wi-Fi: Wireless Fidelity

GSM: Global System for Mobile Communications

RAM: Random Access Memory

CPU: Central Processing Unit

Hz: Hertz

mm: Millimeter

cm: Centimeter

°C: Degree Celsius

1. Introduction

The *Smart Room Control System* aims to give disabled people the ability to complete simple, everyday actions with no more difficulty than anyone else. The system's users will wear our wearable motion-control sensor that will allow them to interact with devices on their space using simple hand gestures. The wearable sensor will send a predefined signal that corresponds to an electrical device ,intended to be controlled, to our intelligent computing system. The system is programmed to operate lighting, temperature control, security, appliances, and many other functions to improve the user's quality of life. Additionally, Our smartphone application will give both the system's user or the user's caretaker the ability to to monitor information such as temperature, alarms, and air conditioning. The requirements for the Smart Room Control System, as proposed by the *MOTUSCONTROLL* team, are described in this functional specification.

1.1 Scope

The functional requirements for *MOTUSCONTROL*'s proposed Smart Room Control System are described in this functional specification document. The specifications listed in this document will describe the functionalities of both subsystems and the main unit system. This document describes the proof-of-concept and production versions for the design and development of *Smart Room Control System,* and it will serve as a reference to ensure that stated requirements are satisfied during development stages of *Smart Room Control System*. Minor modifications may be required during development or testing.

1.2 Intended Audience

The functional specification document will be be used by all members of *MOTUSCONTROL* throughout the product development. It will also serves as a reference towards the design and implementation process. The project manager will use this document as a measure of compliance to ensure that development is progressing as planned. Additionally, the test engineers will use this specification to evaluate functionalities of the final product.

1.3 Conventions

The functional requirement specification will be shown throughout the document by the following:

[Rn-p]

where R stands for requirement, n represents the functional requirement number, and p is the priority of the functional requirement as one of the following three development stages:

i - High Priority: The requirement applies to the proof-of-concepts system, and must be completed for the prototype
ii - Medium Priority: The requirement applies to the the prototype system
iii - Low Priority: The requirement applies to the final production system

2. System Requirements

The general overall requirements for the *Smart Room Control System* are presented in this section. This section includes requirements with respect to performance requirement, safety standards, and reliability.

2.1 System Overview

An overview diagram of *MOTUSCONTROL*'s *Smart Room Control System* is shown in Figure 1.
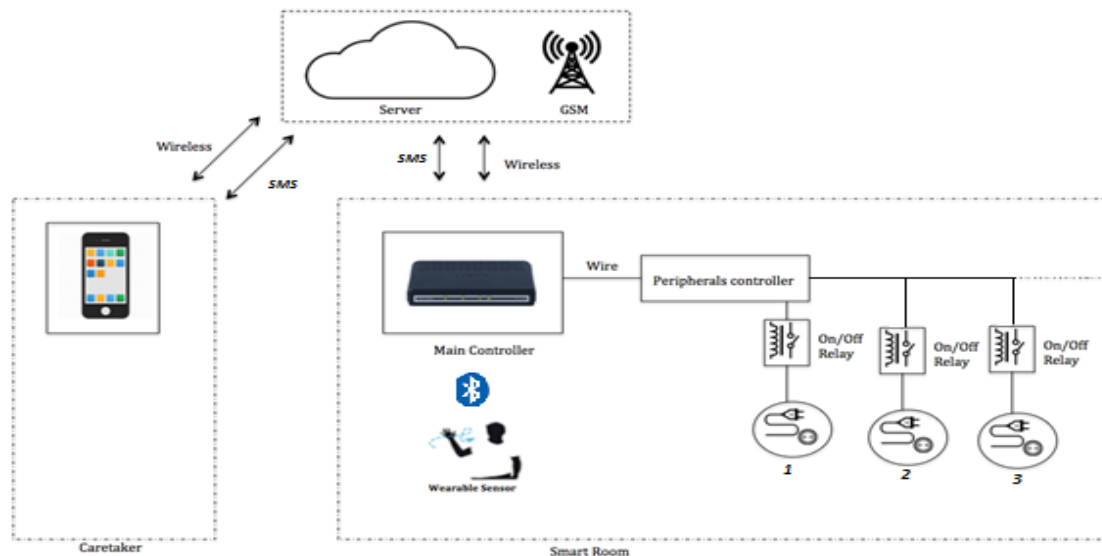

Figure 1: High-Level Model of Smart Room Control System [3][4]

As shown above, the system consists of three main components: wearable sensor, main controller, and peripherals controller. The wearable sensor will allow the system's user to control peripherals inside the smart room. The signals generated by the sensor will be sent from the user to the main controller. The main controller is programmed to take different actions based on the signal it receives from the sensor. Depending on the signal, it will communicate with and change the state of a different peripheral. Some peripherals also have the ability to send feedback to the main controller.

The main controller saves the current status of the peripherals and passes it to the server. The server will then communicate with our smartphone application via internet connection to reflect the changes made. Moreover, the user's caretaker can use the application to monitor the room remotely to ensure the safety of the person inside our smart room. Besides notification via internet, the caretaker also has the option to receive SMS alerts from the system in possibly dangerous cases, such as extreme cold or smoke detection via smoke alarm.

2.2 General Requirements

[R1-iii]	The product shall provide training prior to use.
[R2-iii]	The product shall be easy to set up with minimal knowledge.
[R3-iii]	The sensors used in the product shall be invisible to the client.
[R4-iii]	The product shall cost no more than CAD $600 [5].
[R5-i]	The system shall not interfere with devices that are not integrated with our system.
[R6-i]	The system's performance shall not be affected by nearby devices that are not integrated with our system.

2.3 Electrical Requirements

[R7-iii]	The product shall contain a power switch to be turned on/off.
[R8-i]	Power shall be sufficient to power all components.
[R9-i]	The product shall meet the electrical standards shown in section 9.
[R10-i]	The product's electrical component shall be grounded properly for safety.
[R11-i]	The product shall not produce any current when it is turned off.
[R12-ii]	The product shall be operated with a power supply of 120/110V, 60Hz AC.
[R13-iii]	The product shall have fuses on all the components to provide overcurrent protection.

2.4 Environmental Requirements

[R14-i]　　The product shall operate at typical room temperature (15°C ~21°C) [2].

[R15-i]　　The product shall not be affected by other wireless signals.

[R16-i]　　The product shall be used in indoor environment.

[R17-iii]　The product shall operate under typical humidity.

[R18-iii]　The product shall not be affected by nearby wireless communications such as WiFi or cell phones.

[R19-i]　　The product shall not produce significant noise, heat, or smell (within human sense range).

[R20-iii]　The product shall be resistant to small amounts of water or other liquids.

[R21-iii]　The product shall not be damaged by light collisions.

[R22-iii]　The product shall not be damaged if dropped from a height below 2 meters.

3. Main Controller Requirements

The main controller consists of a microcontroller integrated with a GSM shield to enable sending SMS from the device. This unit is the heart of our Smart Room Control System, and it is responsible for bridging the connections between all the components of our system. The main controller will receive a command from the wearable sensor, which identifies the hand gesture movement. The command will then be passed to the peripheral's controller to control the device associated with the command sent by the user. The main controller will update our server regarding the status of the peripherals so that our smartphone application gets updated. Figure 2 shows the components utilized in our main controller system.
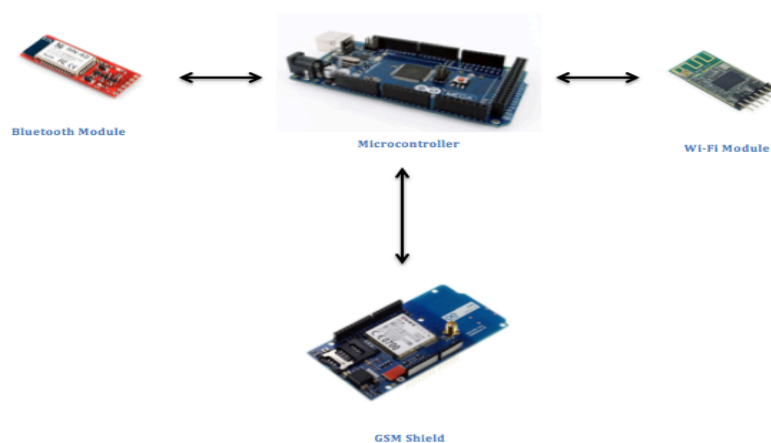

Figure 2: Main Controller System Overview [6]

3.1 General Requirements

[R23-i]   The microcontroller shall receive motion data from the wearable sensor.

[R24-i]   The microcontroller shall communicate with the peripheral's controller based on the received data from the wearable sensor.

[R25-iii]   The microcontroller shall be able to establish a network communication with the server.

[R26-iii]   The microcontroller shall update data to the server.

[R27-iii]   The microcontroller shall store the current status of the appliance being controlled and monitored at all times.

[R28-iii]   The microcontroller shall be in sleep mode when it is not used.

[R29-ii]   The microcontroller shall have a fast response time.

 [R30-i]   The microcontroller shall send SMS to the caretaker of the system user in case of emergency when the internet is not working.

3.2 Electrical Requirements

[R31-ii]   The microcontroller shall be provided with regulated DC power supply.

[R32-i]   The microcontroller shall have low power consumption.

[R33-i]   The main controller requires an external power supply that ranges from 7 to 12 volts. Using a higher voltage than the specified range may lead to overheating and damage the voltage regulated of the main controller. Using lower voltage will make the controller in an unstable condition.

3.3 Physical Requirements

[R34-iii]   The main controller must be secured by an enclosed box and placed on the wall with the main room switches.

[R35-iii]   The microcontroller's case shall not be electrically conductive.

[R36-iii]   The box must contain ventilation holes to allow air flow and heat dissipation.

4. Wearable Sensor Requirements

The wearable, motion-control sensor is the main way in which the user interfaces with and controls the various peripherals connected to our smart room control system. Using the sensor attachment, the user should be able to control each of the peripherals that we attach to the system using a variety of simple hand motions.

As this is the most user-facing piece of the control system, it must be more visually polished and ergonomic in the final product then any of the other components.

4.1 General Requirement

[R37-i]   The sensor shall be able to be worn on the user's hand or wrist.
[R38-iii]   The sensor shall be comfortable and as unobtrusive as possible to the user.
[R39-i]   The sensor shall be able to send motion data back to the main controller.
[R40-ii]   The sensor shall have an on/off switch or button.
[R41-ii]   The sensor shall provide feedback to the user via an on light when it is on and functioning correctly.

4.2 Electrical Requirements

[R42-iii]   The sensor shall be powered by a rechargeable battery containing enough power for at least one week of regular use.
[R43-iii]   The rechargeable battery shall be recharged using a power adapter compatible with the typical North American wall supply of 110/120V at 60Hz.
[R44-iii]   The electrical components shall be hidden from the user and the environment by the case.
[R45-iii]   The battery shall be accessible for maintenance.
[R46-ii]   The sensor shall have a power saving mode where it either is turned off or put to sleep.

4.3 Physical Requirements

[R47-iii]   The width and length of the sensor shall not exceed the user's palm size, a maximum of 7 cm x 7 cm.
[R48-iii]   The height of the sensor shall not exceed 3 cm.
[R49-ii]   The sensor shall be able to fasten securely on the user's hand or wrist and only deliberately be removed.

4.4 Usability Requirements

[R50-iii]   The sensor shall be less than 100 grams, in order to minimize strain on the user.
[R51-iii]   The motions required to activate the sensor shall be simple to use and remember.

[R52-ii]   The sensor shall be easy to put on and remove, even for the disabled.

[R53-iii]   The sensor shall be comfortable to wear when sitting, standing, or lying down.

5. Peripherals Controller Requirements

This part of our *Smart Room Control System* contains the peripherals that need to be controlled by the user. The peripherals controller will receive signals from the main controller to control the device intended by the user. Also, it will send feedback signals indicating the status of the devices. Some components require a proper connection to the main controller via wires. Most requirements needed for this part are listed in the system overview section. Other general requirements of the peripherals controller are shown in the following subsections.

5.1 General Requirements

[R54-i]   Peripheral's controller shall be capable of receiving a signal from the main controller to turn on/off the device.

[R55-iii]   Peripheral's controller shall be capable of sending the status of the peripherals to the main controller over wires.

[R56-ii]   Peripheral's controller shall be connected with smoke sensor, motion sensor and lights over wires.

5.2 Electrical Requirements

[R57-iii]   The power cord shall be less than 1.7 mm in diameter to fit the into the main controller package [8].

[R58-i]   The motion sensor shall accept an input voltage range from 5 to 12 [9].

[R59-ii]   The smoke sensor shall accept an input voltage of 5V[10].

6. Software Requirements

The software package of the *Smart Room Control System* includes either an Android or IOS controlling app as well as a server that communicates between the application and the control system. The application software package allows the users to control their home using their mobile devices, and to monitor data such as temperature. Moreover, in the case of dangerous or extreme incidents such as smoke in the house, the user will also receive alerts from this application, as well as have the possibility of receiving an SMS.
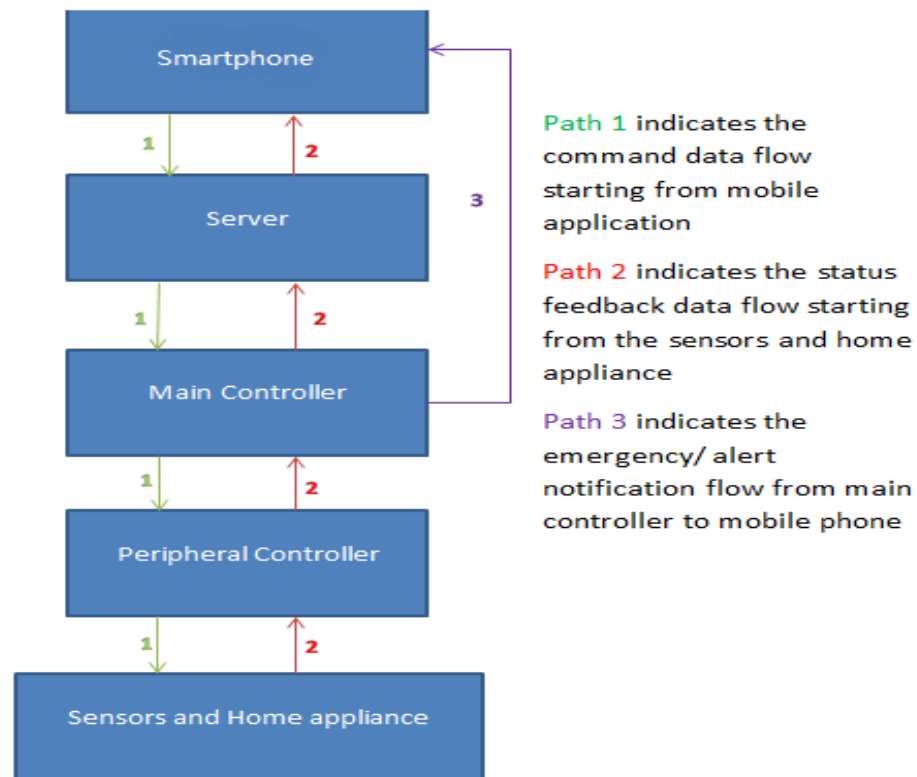
Path 1 indicates the command data flow starting from mobile application

Path 2 indicates the status feedback data flow starting from the sensors and home appliance

Path 3 indicates the emergency/alert notification flow from main controller to mobile phone

Figure 3: Schematic Diagram of Data Transmitting

6.1 General Requirements

[R60-i]   The server shall be set up on a computer with 500GB hard drive, 3GB RAM and Intel Core i5 CPU.

[R61-i]   The server shall operate 24/7.

[R62-i]   The controlling application shall be easy to use without training.

[R63-i]   The application shall be compatible with android 5.0.

[R64-iii]   The application shall be compatible with different versions of android operating systems and iOS.

[R65-iii]   The application shall downloadable and installable via Google Play Store.

6.2 Functional Requirements

[R66-i]   The server shall be able to transmit data to mobile application from the main controller.

[R67-i]   The server shall be able to transmit data from mobile application to the main controller.

[R68-ii]   The server shall be able to store data.
[R69-i]   The mobile application shall allow user authentication.
[R70-i]   The application shall allow the user to add and remove devices from the control network.
[R71-i]   The application shall be able to provide the operating status of each connected home appliance.
[R72-i]   The application shall notify the user when it receives relevant data from the server.
[R73-ii]   The application shall download stored data from server.

6.3 Usability Requirements

[R74-i]   The server shall be able to send and receive correct data.
[R75-ii]   The server shall be able to operating for one year.
[R76-i]   The application shall have no critical bugs that can lead to system crashes.
[R77-ii]   The application shall not contain bugs that can affect usability.
[R78-ii]   The server shall be able to respond to requests made by mobile applications in 30 seconds.
[R79-ii]   The server shall be able to store the previous setting made by the mobile application.
[R80-iii]   The application shall prompt user to install upgrades if applicable.
[R81-i]   The application shall give an error message when failures occur.
[R82-ii]   The application shall provide a user manual at the first time of use.

7. Electrical Relays Requirements

A relay is implemented to control a high power circuit connected to the peripheral controller. Most requirements needed for this part are listed in the system overview section. Other general requirements of the relay are shown in the following subsection.

7.1 General Requirements

[R83-ii]   The relay shall be connected to the peripheral controller.

8. User Documentation

The user documentation section outlines the functional requirements for the user manual that will accompany the *Smart Room Control System* and will assist users in the proper operation of the system. Requirements of the user documentation are shown below.

[R84-iii]   The user manual shall contain detailed setup instruction for non-technical users

[R85-iii]   The user manual shall include warranty information.

[R86-iii]   A detailed technical document shall be created for technicians and vendors

[R87-iii]   The user manual shall be written in English, French and other languages for international markets.

[R88-iii]   The user manual shall contain proper warnings and safety information.

[R89-iii]   The user manual shall provide a phone number for technical support.

9. Standards

As stated by Canada Consumer Product Act Safety Act, manufacturers shall manufacture or sell consumer products that are danger to human health or safety. Therefore, *MOTUSCONTROL* aims to meet the regulations for safety and electrical impact. The engineering standards that must be met by *Smart Room Control System* are the shown below.

[R90-iii]   The product shall meet CSA-C22.2 No. 60335-1:11 standards [11].

[R91-iii]   The product shall meet ISO 50001 standards [12].

[R92-iii]   The product shall meet Bluetooth Low Energy standards [13].

[R93-iii]   The product shall meet IEEE Standards for Sensor Performance Parameter Definitions [14].

[R94-iii]   The product shall meet the IEEE 802.11 wireless transmitting standards [15][16].

[R95-iiii]   The product shall meet the GSM frequencies standards using in Canada [17].

[R96-iii]   The relay shall meet IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus (C37.90-2005) [18].

10. Safety Requirements

In order to avoid potential injuries to customers caused by *Smart Room Control System*, *MOTUSCONTROL* comes up with a list of safety requirements that could minimize the possibility of harmful accidents. All system's components of the final prototype should meet the requirements listed below. Moreover, all software should meet specific safety requirements to protect customer's privacy.

[R97-ii]   The product's cables shall not be exposed to the client.

[R98-ii]   The product's power connection shall be enclosed.

[R99-ii]   The product shall not generate any shock hazards to the user.

[R100-ii]   The product shall cause no harm to the user in case of system failure.

[R101-ii]   The product shall be protected from water.

[R102-iii]   The microcontrollers shall be enclosed using ASB material that is strong and durable with low heat conductance [19].

[R103-iii]   The exterior of the wearable sensor shall be smooth so as not to damage the user's skin.

[R104-iii]   The casing should insulate any electrical portions of the wearable sensor.

[R105-ii]   The wearable sensor shall not generate significant amounts of heat.

[R106-i]   The wearable sensor shall not interfere with other close by electronic equipment.

[R107-iii]   The wearable sensor shall be fastened securely enough to stay attached to the user during day to day activities.

[R108-ii]   The motions required to activate the wearable sensor shall be within a normal range of motion.

[R109-iii]   Peripherals controller shall contain a voltage regulator to control the internal current and provide thermal shutdown control [20].

[R110-ii]   The connection between the peripheral and the circuit shall follow safety protocol and standards shown in section 9.

[R111-ii]   Wires must be flame, moisture and sunlight resistant. Also should fall under the Canadian Electrical Code [21].

[R112-ii]   The server shall only allow users with correct credentials to send and download data through the mobile application.

[R113-ii]   The mobile application shall allow the user to reset their password if necessary.

11. Sustainability Requirements

Sustainability is an increasingly important topic, which applies to all consumer electronics. The Smart Room Control system shall comply with BC's regulations surrounding consumer electronics recycling [22], in order to legally sell the product in BC. In addition to this, our final product will follow Cradle-to-Cradle design as much as possible, ensuring that as many of the materials and processes used are sustainable and as waste free as possible.

It is difficult to design an electronic product entirely with Cradle-to-Cradle design, but the *Smart Room Control System* shall implement as many of its ideas as possible.

All the materials used in our system fall under the "technical nutrient" category, as any organic materials, or "biological nutrients" are not suitable for the long life cycle we envision of our product. This means that the recycling of our product will not be as simple as allowing the materials to return to the ground. However, we can still follow the Cradle-to-Cradle design by avoiding use of non-recyclable materials in our systems, and particularly ensuring that the various parts of our system are separable in order to be properly recycled.

Some requirements for our cases for Cradle-to-Cradle design: The cases of each part of the systems shall be constructed out of completely recyclable plastics, for example Polypropylene plastics, which are hard and long lasting, but also recyclable. Furthermore, these cases shall be able to separate completely from the inner electronics to allow for sorting without introducing more impurities in the recycling process. This separation can be achieved by simply attaching the circuits through removable screws to the case, rather than using glue or another substance.

Achieving Cradle-to-Cradle design for the circuits and electronics is much more difficult. The composition and variety of the components in electronics makes them inherently much harder to fully recycle. However, there are multiple companies, which offer standards and information to simplify this. In particular, the R2(Responsible Recycling) Standard offers many requirements for electronics to be fully recyclable, including the use of heavy metals and mercury in parts, as well as requiring batteries to be removable from the circuits [23]. By conforming to these standards, we can ensure that the life cycle of the electronic components in our Smart Room Control System has as little as possible impact on the environment.

Finally, one more important thing to consider for our product is the waste products which it may produce over its life cycle. Considering this, we have decided to power our product using one rechargeable battery for the motion sensor, as well as simple wall outlets for the other portions. This eliminates the possible waste produced by using disposable batteries. Furthermore, we shall offer replacements for various parts of the system, so that if one part is broken the whole does not have to be

replaced. This will also significantly reduce the waste products produced. Although it is difficult for an electronic product to be waste free, we will work towards creating as sustainable a product as our design processes allow.

12. Conclusion

MOTUSCONTROL aims to provide solutions to people with disabilities who face difficulties when it comes to controlling a device that is out of their reach. The solution that *Smart Room Control System* provides is to provide control of the devices and peripherals surrounding the system's user by using simple hand gestures. Our system will not only improve the quality of life for the disabled, but also their safety. No longer will they need to stretch to reach a thermostat or light switch, or worry about hearing their fire alarm. The ability to send information via wireless and cellular to a caretaker ensures that in the case that something goes wrong, our system ensures a quick response.

This document has presented the *MOTUSCONTROLL* system functions and the priorities under our constraints. This document serves as a guide to the development and implementation stages. Priority levels i and ii will be included as requirements for the prototype currently being developed. In brief, these are the main controller, peripherals controller, wearable sensor, and smartphone application for feedback information. The main focuses are the main controller, peripherals controller, wearable sensor controlled by the system's user. This prioritization will allow the team to develop the essential hardware framework without spending excessive time developing the application and the server. We are confident in our ability to deliver a safe product to the user of the *Smart Room Control System*. These guidelines will enable us to build a prototype by April 2016.

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