February 20, 2017

Dr. Steve Whitmore
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Re: ENSC 405W Requirements Specifications for a Voice Controlled Lighting System

Dear Dr. Whitmore,

The attached document, “LightWave System Proposal”, outlines the requirements specifications of our project for the course ENSC 405W/ENSC 440. The document summarizes the overall guidelines needed to achieve our goal of designing a voice controlled home lighting system. The system aims to be responsive to voice commands and have features such as a natural wake-up alarm using the home lights.

The specifications and requirements outlined in this document are of strict importance for the design phase of the project. Requirements were dependent on each component’s desired behavior and performance. These requirements will facilitate the decision making on part ordering and circuitry design of the product. The requirements specifications are divided into hardware and software and present sustainability measures to be implemented during development stages.

Light Matters consists of five talented and hard-working Engineering students: Alicia Pavan, Kevin He, Yifan Chen, Haining Yu, and Yuchen Ding. Please feel free to contact us if you have any questions or concerns about our proposal via e-mail at avpavan@sfu.ca.

Sincerely,

Alicia Pavan
CEO
Light Matters

Enclosure: *Requirements Specifications for a Voice Controlled Lighting System*

LIGHTWAVE SYSTEM

REQUIREMENTS SPECIFICATIONS FOR A VOICE CONTROLLED LIGHTING SYSTEM

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Issue Date

February 20, 2017
Revision: 1.1

Executive Summary

From the moment we wake up to the time we hit the pillow at night, we are surrounded by technology. Over the years, the word “smart” has had different meanings, especially when it comes to old times. Today, many devices are made to be smart, i.e. smart watches can keep track of one’s heart rate, walking steps and hours of sleep while smart pajamas can read bedtime stories. All these inventions have one thing in common, and it is that they aim to make everyone’s life more interactive and easy with the use of technology. The Light Matters Team goal is to design a smart lighting system to make the target user's’ life more convenient and enjoyable at home. With the LightWave system, people will have the ability to control any light inside their homes with an easy voice command.

LightWave system follows a server-client architecture that the system is categorized into two parts: switch unit and central unit. Switch units are installed in every room of a building where as the central unit will be installed into one specific room. User’s voice command is recorded and processed by the switch unit, then switch unit will communicate with the central unit using radio frequency signals. The central unit acts like the server of the system that execute the commands. Basic commands will be supported as well as light or sound alarm set up. Some of the possible risks can result in unwanted lags in system’s response, programming challenges resulting in undesired command handling, and trivial risks like electric shock or mishandling of tools. Even though, the system has the potential to bring great benefits to its users by facilitating a convenient way of interacting with a lighting system that will make the user’s day to day life worry-free.

In this document, functional requirements and non-functional requirements are listed for the system as well as for each of the components. The list includes requirements in the aspect of safety, specification, performance and others. The hardware components shall be designed and produced to meet the physical and electrical requirements. The software must be efficient and free of defect. These guidelines will be verified in prototyping stage as well as in production stage of the project. To deliver a safe and environmentally friendly development environment and final product, the safety and environmental standards are introduced. Every team member is responsible for complying to the standards.

Throughout the term the Light Matters Team will continue its research and development in the field to land the best possible solution for the system. The functional requirement document will be referred as a guideline for the development and production. A one-room basic prototype of the following proposal is expected to be working by the end of this term as per the milestones set.

Light Matters

Table of Contents

Executive Summary ii

List of Figures v

List of Tables v

Glossary vi

1. Introduction and Background 1
   1.1 Classification 3

2. System Overview 3
   2.1 Top Level overview 3
   2.2 General Requirements 4

3. Hardware Requirements 5
   3.1 Switch Unit 5
      3.1.1 General requirements 5
      3.1.2 Electrical requirements 5
      3.1.3 Physical requirements 6
      3.1.4 Environmental requirements 6
      3.1.1 Microphone 6
      3.1.2 Speaker 6
      3.1.3 LEDs 6
      3.1.4 Relay 7
      3.1.5 Switch 7
      3.1.6 Voice processing chip 7
      3.1.7 Microcontroller 7
      3.1.8 Receiver/transmitter 7
   3.2 Central Unit 8
      3.2.1 General requirements 8
      3.2.2 Communication requirements 8
      3.2.3 Physical requirements 8
      3.2.4 Environmental requirements 8

4. Software Requirements 9
   4.1 Switch Unit 9
      4.1.2 Performance Requirements 10
   4.2 Central Unit 10

4.2.1 Software Requirements 10
4.2.2 Performance requirements 11
6. Engineering Standards 11
7. Sustainability and Safety 12
8. Conclusion 13
Appendix A 14
References 15

List of Figures

Figure 1.1 LightWave System Schematic 2
Figure 2.1 Component Diagram 4

List of Tables

Table A.1 Voice Command Guidelines 14

Glossary

LED: Light Emitting Diode

Environmental Sustainability: when demands from the environment can be met without reducing its living standards capacity

Prototype: early sample, model, or release of a product built to test a concept

Engineering Standard: documents that specify characteristics and technical details that must be met by the products, systems and processes that the standards cover.

Automation: the technique of making an apparatus, a process, or a system operate automatically

Server-Client: specific model of a computer network that partitions tasks or workloads between the providers of a resource or service, called servers, and service requesters, called clients

CSA: Canadian Standards Association

IEEE: Institute of Electrical and Electronics Engineers

NESC: National Electrical Safety Code

UL: Underwriters Laboratories

PET: Polyethylene terephthalate

ABS: Acrylonitrile butadiene styrene

RoHS: Restriction of Hazardous Substances

1. Introduction and Background

Technology and communications have gone together since decades ago. We are currently living a peak in technology development. Education has become easier and more accessible with the help of the internet which gives technology the opportunity to evolve at an unbelievable rate. For instance, new handheld devices are coming out with new generations every year and their processing power is being increased dramatically in each generation. Nevertheless, technology is the human's best friend as we are not only learning it, but we are also implementing technology into applications and devices which help us in our day-to-day life.

Accessibility technology does not have to be limited to automatic doors or stair lifts, with today's tools there is much more that can be implemented to make anyone's life easier (Gupta, 2015). At the end, that is what engineers are for. Light Matters' LightWave System is designed to offer users a simpler way to interact with their homes, especially for elders and the physically disabled who can have difficulty getting from point A to point B, or when light switches are hard to reach. There are around 57 million Americans with disabilities and not enough smart home systems to suit all their needs (Walsh, 2016). Furthermore, there are times when someone is already comfortable in bed, but he/she must get up and turn off a light in the other room. The solution proposed aims at all these problems that are often inconvenient to the target users.

In addition, the natural waking up process of the human body is currently being disrupted by loud alarms that alter the user's sleep and could even result in a bad mood day. According to Dr. Ackerman, waking up the wrong way can leave a person "very groggy, very tired, and only partially recovered from the strain and stress of the previous day" (Ackerman, 2012). Waking up with lights is a more natural way that can result in stress reduction, increase in energy and other health benefits. Light Matters is offering a voice controlled lighting system that can provide convenient control of the home while helping the user's daily life to be more enjoyable and stress free.

Unlike most lighting systems in the market, the LightWave System aims to be independent instead of relying on smart phone apps. This characteristic has been set as one of the priority goals of the project and promises to be an essential strength in the market for home automation. The system will consist of LED lights, microphone, relay, voice recognition chip, receiver, transmitter and a microcontroller that will help with command and signal traffic. The figure below shows a schematic of the system's composition. It can be observed that the switches do not communicate with each other but do so with the central unit, which serves as a bridge between them.

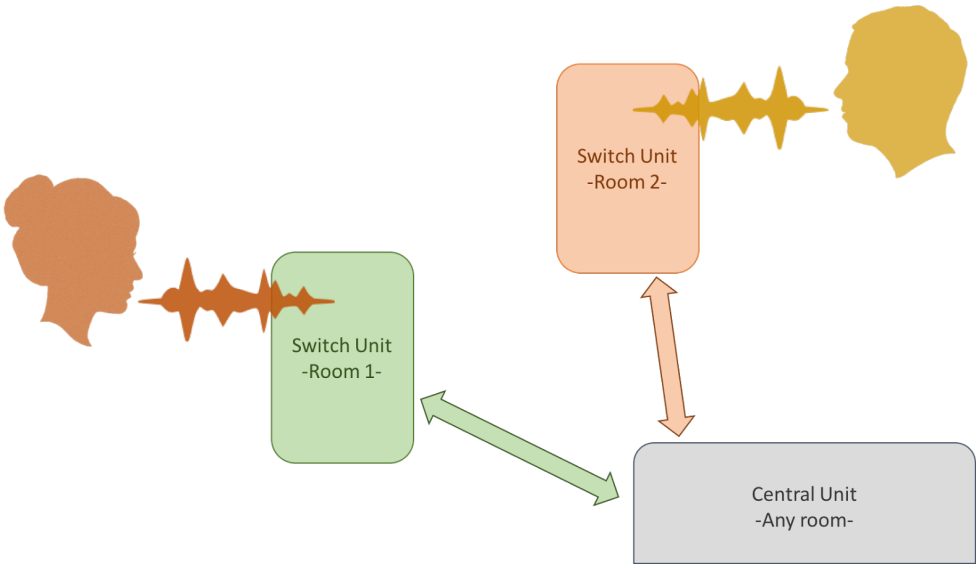

Figure 1.1 LightWave System Schematic

The present document describes the functional requirements and specifications that must be met by the LightWave System. Other than many key functionalities, the report also includes a system overview and addresses the issues of sustainability and safety. As the design content is not the scope of this report, it will serve as a guideline during the design, development and model testing of the finished prototype and product.

1.1 Classification

The following convention is used to classify the requirements into categories and rank the functional requirements:

[Rs.n-p]

Where ‘R’ is an abbreviation for requirement, ‘s’ is the section number, ‘n’ is the functional requirement number and ‘p’ is the priority of the functional requirement.

The priorities are classified as the followings:

1 - Requirements for proof of concept system only

2 - Requirements for both proof of conceptual system and the final product

3 - Requirements for the final product only

2. System Overview

In this section, an overview of the system is introduced. The main objective of the LightWave System is to facilitate the light system usage across a home using voice controlled capabilities. Users are able to control multiple lights inside of a building, typically for houses. The system also provides the ability to adjust the brightness as well as to flash the lights. The system consists of multiple components to control the lights located in different rooms. General requirements of the product are also discussed in this section.

2.1 Top Level overview

The system follows a single server to multiple clients architecture. In the system, a central unit works as the “server”, it controls the communication between the “clients”, as well as a status tracker for alarms and other set ups. There will be many switches located in every room where the light is to be controlled by the users. Each switch contains an RF module such that they can send and receive commands to the central unit. A microphone, speaker and LED light are installed inside of every switch unit, they handle the I/O as well as

provide feedback to the end users. Figure 2.1 shows the overview of the components needed inside a switch unit.

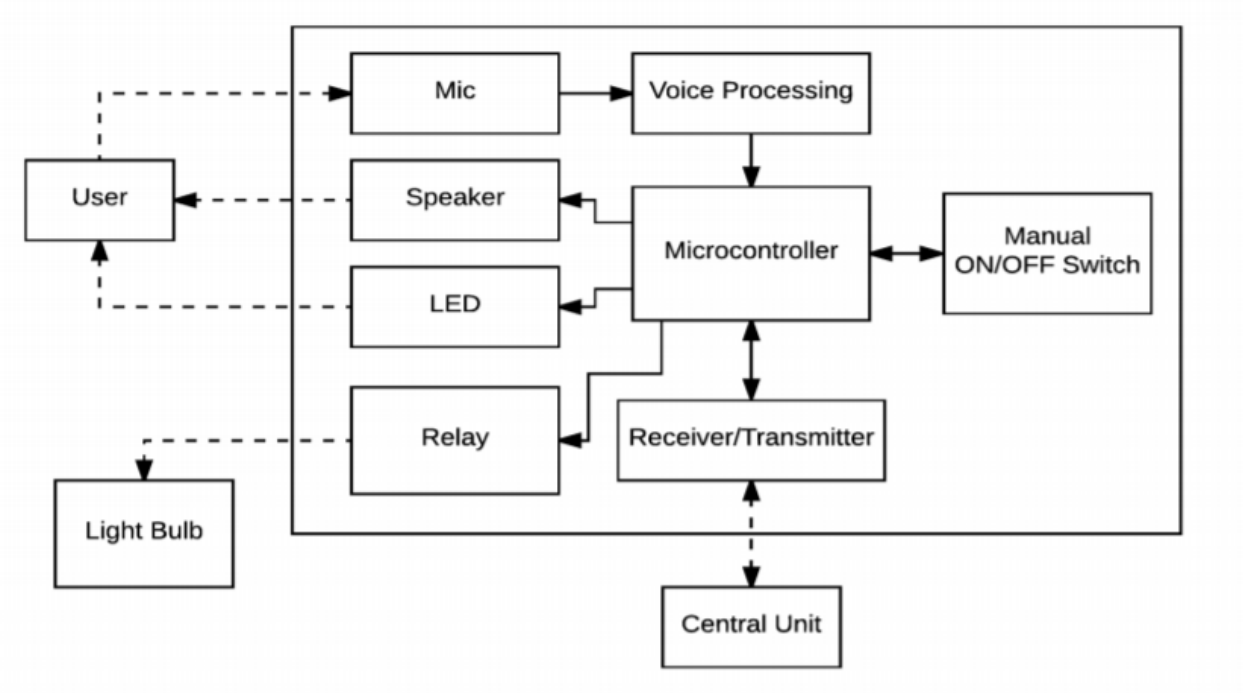

Figure 2.1 Component Diagram

2.2 General Requirements

R2.1- 1 The switch unit prototype shall cost less than $50

R2.2- 1 The central unit prototype shall cost less than $200

R2.3- 3 The user manual shall indicate the installation process and tools clearly

R2.4- 2 The system shall be able to turn on and turn off the controlled lights

R2.5- 2 The system shall be able to adjust the brightness of the controlled lights

R2.6- 3 The system shall be able to set flash alert of the controlled lights

R2.7- 2 The system shall be able to receive the voice of user and process it into programmed commands

R2.8- 2 The system shall be able to recognize voice commands in English

R2.9- 3 The user manual shall clearly indicate the list of supported voice commands

R2.10- 2 The system shall be able to install in buildings with 220V/110V power supplies

R2.11-3 The system shall be able to control at least 10 switch units without performance drop

3. Hardware Requirements

The LightWave System consists of two main components: the switch unit and the central unit. Each of these has certain hardware requirements for the product to function as desired. Estimates for power consumption, cost, functionality and size of the components are listed below.

3.1 Switch Unit

The switch unit is the most significant part of the lighting system. As presented in the System Overview section, it consists of a voice processing chip, microcontroller, receiver/transmitter, LED, switch, microphone, speaker, and relay. The unit is responsible for gathering user voice input, command recognition, communicating with the central unit, controlling the light bulb, and returning feedback to the user.

3.1.1 General requirements

R3.1-1 The cost of each switch unit prototype set shall be within $50

R3.2-2 The unit shall have a switch to be controlled manually

R3.3-3 The case of the switch unit shall be 3D printed with PET (Polyethylene Terephthalate)

R3.4-3 All the components in the switch unit will be fixed to the switch unit case

R3.5-2 The switch unit shall be connected to the central unit directly through a wireless network

R3.6-2 The switch unit shall provide feedback of the current input command whether valid or invalid

3.1.2 Electrical requirements

R3.7-3 The switch unit shall be powered directly from the home's illumination system

3.1.3 Physical requirements

R3.8-3 The dimensions of the switch unit case will be 100x60x40 mm

3.1.4 Environmental requirements

R3.9-3 The switch unit shall be functional within temperatures of -30°C to 85°C

R3.10-2 The switch unit shall be functional in the humidity range of 4% to 50%

R3.11-2 The switch unit can be installed and used in indoor spaces only

3.1.1 Microphone

Physical requirements

R3.12-2 The sensitivity of the microphone shall be -39dB ± 3dB

R3.13-2 The microphone shall be fixed on the switch unit case

Electrical requirements

R3.14-2 The maximum power consumption of the microphone shall be less than 0.8mA

R3.15-2 The maximum voltage supply to the microphone shall be less than 4V.

3.1.2 Speaker

Physical requirements

R3.16-3 The speaker shall be fixed to the switch unit case

R3.17-2 The dimensions of the speaker shall be 10x10x5 mm

Electrical requirements

R3.18-2 The maximum operation voltage of the speaker shall be 8V

Performance Requirements

R3.19-2 The speaker shall be able to output sound within 60 and 75dB

3.1.3 LEDs

Physical requirements

R3.20-3 The LEDs shall be embedded to the switch unit case

R3.21-2 The LEDs shall consist of one red LED bulb and one green LED bulb

Electrical requirements

R3.22-2 The standard operation voltage of the LED should be within the range 2V to 4V

3.1.4 Relay

Electrical requirements

R3.23- 2 The standard operation voltage of the relay is 120V

R3.24- 3 The relay shall be able to power up the light bulb to the desired intensity

3.1.5 Switch

Physical requirements

R3.25- 3 The switch shall have a rotatable knob with the light to turn on/off

Electrical requirements

R3.26- 2 The switch shall be connected to the light wiring to control the bulb on/off manually

R3.27- 3 The switch shall be able to adjust brightness of the light bulb

3.1.6 Voice processing chip

Physical requirements

R3.28- 3 The voice processing chip shall be embedded into the switch unit case

Electrical requirements

R3.29- 2 The maximum operation voltage of the voice processing chip shall be 10V

3.1.7 Microcontroller

Physical requirements

R3.30- 3 The microcontroller shall be embedded into the switch unit case

Electrical requirements

R3.31- 2 The maximum operation voltage of the microcontroller shall be 15V

3.1.8 Receiver/transmitter

Physical requirements

R3.32- 3 The receiver/transmitter shall be embedded into the switch unit case

Electrical requirements

R3.33- 2 The standard operation voltage of the receiver/transmitter shall be 5V

3.2 Central Unit

As the system uses a Server-Client architecture, the central unit is the heart of the system. Communication and signal processing is the main purpose of this component. To control multiple clients, the central unit shall have the ability to communicate with multiple switch units as well as the ability to process concurrent input signals. It will keep a record of command and feedback history. The central unit will be built in a wall with easy maintenance access since it does not interact with users.

3.2.1 General requirements

R3.34- 1 The cost of the Central Unit prototype shall be within $200

R3.35- 2 The case of the central unit shall be 3D printed with PET (Polyethylene Terephthalate)

R3.36- 3 All the components in the central unit shall be fixed in the central unit case

R3.37- 3 The central unit shall be able to record all the input commands and output feedbacks for the last 30 days

R3.38- 3 The central unit shall be powered from a home's wall outlet

3.2.2 Communication requirements

R3.39- 2 The central unit shall be turned on/off with a manual switch

R3.40- 2 The central unit shall be connected to all the switch units directly through wireless network

R3.41- 2 The central unit shall receive radio signals from the switch units after the voice commands are processed by the voice recognition system

R3.42- 2 The central unit shall be able to process radio signals sent from switch units and send control signals to corresponding switch units

3.2.3 Physical requirements

R3.43- 3 The dimensions of the central unit case shall be smaller than 120x120x40 mm

3.2.4 Environmental requirements

R3.44- 3 The central unit shall be functional within the temperatures of -30°C to 85°C

R3.45-3 The central unit shall be functional in the humidity range of 4% to 50%

4. Software Requirements

The two main components of the LightWave System have certain software roles that need to comply with the requirements listed. They need to be able to communicate with the user as well as with each other to offer a satisfying voice driven and wireless experience.

4.1 Switch Unit

The function of the switch unit is to recognize voice commands and execute them. The voice commands will be able to control the lights in the current room and in other rooms of the home. Moreover, these voice commands will be recognized after a preset keyword that will trigger the command recognition in the unit. It is important for the software to be responsive to these commands and not make the user repeat instructions multiple times.

4.1.1 Software Requirements

R4.1-2 The software shall recognize voice commands triggered after a keyword set by the user

R4.2-2 The software shall recognize commands that follow a format like in Appendix A.

R4.3-2 The software shall allow the user to turn on and off the lights in the current room

R4.4-3 The software shall allow the user to turn on and off the lights from one room to another

R4.5-3 The software shall allow the user to set up a light alarm either for one time or on schedule

R4.6-2 The software shall allow the user to set up a timer

R4.7-3 The software shall allow set up of an alarm or timer with sound, light or both

R4.8-3 The software shall track sound activity in a room

R4.9-3 The software shall automatically turn the lights off for light saving capabilities

R4.10-3 The software shall allow the user to set up light saving idle time for 30 minutes, one hour or two hours.

R4.11-3 The software shall accept multiple commands that lead to the same action

R4.12-2 The software shall give command recognition feedback to the user

R4.13-3 The software shall allow the user to set up a preferred type of command recognition feedback (LED light, sound or both)

R4.14-2 The software shall communicate its status to the central unit

4.1.2 Performance Requirements

R4.15-2 The software shall be able to recognize a voice command in two seconds or less

R4.16-2 The software shall be able to execute the command in two seconds or less

R4.17-2 The software shall give command recognition feedback in two seconds or less

R4.18-3 The software shall easily recognize different English accents

4.2 Central Unit

The function of the central unit is to serve as a bridge in between switch units to facilitate communication and manage command signal traffic. Moreover, the central unit keeps track of the switches' status and timers or alarms that need to be triggered. The bridge needs to be efficient when communicating between switches for the commands to execute within an acceptable period of time.

4.2.1 Software Requirements

R4.19-3 The software shall receive and transfer a command signal from one switch to another

R4.20- The software shall keep track of switches' states to avoid redundant execution of commands

R4.21- 3 The software shall be responsible to trigger the alarm(s) set up by the user

R4.22- 3 The software shall send signals to the corresponding switch unit when an alarm needs to go off

4.2.2 Performance requirements

R4.23- 3 The software shall process and transfer a command to the correct switch unit in two seconds or less

R4.24- 2 The software shall maintain accurate local time

R4.25- 3 The software shall trigger scheduled alarms or timers accurately

6. Engineering Standards

In this project, electrical safety is the most important thing to be taken care of. It is the team's responsibility to comply with the global and Canadian Engineering safety rule community such as IEC, IEEE and CSA Group. Environmental standards are also under the consideration of LightWave technologies, our product shall conform to Canadian national energy efficiency regulations.

Electrical Safety Standards:

1. IEC 60065 (Audio, video and similar electronic apparatus);
2. IEC 60335 (Household and similar electrical appliances);
3. IEC 60364 (Electrical installations of buildings);
4. IEC 61558 (Power transformers, power supply units and similar);
5. 2017 NATIONAL ELECTRICAL SAFETY CODE® (NESC®)

IEC (IEEE International Committee, n.d.).

NESC (NESC Main Committee, 2017).

Environment Standards:

1. CSA C22.2 No. 250.0-08
2. RoHS: Restriction of Hazardous Substance (RoHS) Compliance

CSA (UL Standards, 2016).

RoHS (RoHS Guide, n.d.).

7. Sustainability and Safety

To avoid significant damage to the environment and in case of disposal of the parts used, the team will aim to use parts that comply with the “Restriction of Hazardous Substances” (RoHS) regulations. Electronics that follow these regulations follow the restrictions below (“RoHS Guide,” n.d.):

- Lead (Pb): < 1000 ppm
- Mercury (Hg): < 100 ppm
- Cadmium (Cd): < 100 ppm
- Hexavalent Chromium: (Cr VI) < 1000 ppm
- Polybrominated Biphenyls (PBB): < 1000 ppm
- Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm
- Bis(2-Ethylhexyl) phthalate (DEHP): < 1000 ppm
- Benzyl butyl phthalate (BBP): < 1000 ppm
- Dibutyl phthalate (DBP): < 1000 ppm
- Diisobutyl phthalate (DIBP): < 1000 ppm

For the disposal of electronic scrap and other materials during the prototype and product build process the parts will be taken to a “Return-it” recycling facility for proper handling. The Return-it electronic recycling process follows the Recycler Qualification Office's (RQO) Recycler Qualification Program (RQP) auditory requirements (“The Electronics Recycling Process,” n.d.) to ensure environmental protection.

For the prototype’s and final product’s wiring the team will use components and tools from previous project classes. The materials used in the prototype will be easily recycled and used for the final product assembly.
Regarding the casing, a model will be 3D printed using either ABS or PET filaments. The first is durable and recyclable, the second is not so tough but biodegradable and water soluble (Umbra, 2016). Discussion is still undergoing for the final product’s material, but most probably the prototype’s case will be printed using PET.

The following list of precautionary requirements shall be considered to ensure the safety of the team members and users when working with higher voltages and electronic components:

R7.1-2 All wires and connections shall be covered with insulating material

R7.2-2 All the wiring shall be properly grounded

R7.3-2 The person interacting with electronic components shall always be grounded to avoid electric shock

R7.4-2 The work surface for assembly shall be smooth and anti-static

R7.5-2 Use anti-static bags to store components

R7.6-2 The voltage source for the switch and central unit shall not exceed 120V

R7.7-3 Ensure parts and casing do not have sharp edges that could cause accidents or injuries

R7.8-2 Handle tools with proper care and use protective equipment if using soldering irons

8. Conclusion

Light Matters is a new starting company that is dedicated to bring the latest technology into the users' daily life. The team aims to bring everyone a more convenient and enjoyable lifestyle. For instance, people will not even have to worry about finding a light switch at midnight. The Lightwave System will give the public the ability to control the lights in other rooms around their homes with a simple voice command.

The decision-making process for the next design phase of the project will be easier with the guidance provided in this requirements document. All aspects like electrical, physical and performance requirements shall be considered in future development stages. The prototype and final product promises to deliver environmentally friendly results while being a safe and reliable system. Following standards and safety requirements will be key in the successful completion of the project as well as a smoother transition from prototype to final product build and implementation.

Appendix A

Table A.1 Voice Command Guidelines

Keyword	Action	Variable
• • •	Turn on/off room [•]	[reference]
• • •	Turn on/off [the] lights in room [•]	[reference]
• • •	Turn on/off this room	N/A
• • •	Turn on/off [the] lights in this room	N/A
• • •	Set alarm for room [•] at [•]	[reference] [time/date]
• • •	Set alarm for [•] at [•]	[date] [time]
• • •	Wake me up [•] at [•]	[date] [time]
• • •	Notify me of timer with [•]	[light/sound/light and sound]
• • •	Dim the lights [•]	[halfway, one third, ...]
• • •	Set up [•] timer	[light/sound/light and sound]
• • •	Notify me in [•] minutes/hour(s)	[number]
• • •	Timer for [•] minutes/hour(s)	[number]
• • •	Set up [•] feedback	[light/sound/light and sound]
• • •	Wake me up with [•]	[light/sound/light and sound]
• • •	Turn off the lights in [•] minutes/hour(s)	[number]
• • •	Light Saving is [•] minutes/hour(s)	[number]
• • •	Set up light saving for [•] minutes/hour(s)	[number]

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