EXASSIST TECHNOLOGIES

February 21, 2021
Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC

RE: ENSC 405W/440 Requirements Specification for SimuSound

Dear Dr. Scratchley:

This letter serves as formal submission for the requirement specification for the SimuSound project that will be developed throughout ENSC 405W/440. SimuSound is a head accessory which will assist people with severe visual impairment or blindness by providing sufficient information to navigate their surroundings regardless of familiarity.

By using stereo vision to collect environmental information, and exploiting obstacle identification artificial intelligence, we believe SimuSound complements the proven traditional blind assistance tools such as canes and guide dogs in providing independence to its users.

The requirement specification provides a brief overview of the purpose and uses of SimuSound, and outlines some engineering standards that will be adhered to during the development process. Issues such as sustainability, safety requirements, and a user acceptance test plan will also be discussed.

On behalf of ExAssist Technologies, I would like to thank you for your time in reviewing SimuSound's requirements specification. Any feedback would be greatly appreciated and can be sent to bagnes@sfu.ca.

Sincerely,

Ben Agnes

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Chief Communications Officer
ExAssist Technologies

Requirements Specification

SimuSound

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Submitted To

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Date of Submission

February 21st 2021

Abstract

Traditional assistance methods, such as the use of white canes and guide dogs, only provide a limited range of assistance. Even the simplest tasks for an individual of sufficient vision can be an immense challenge for a blind person with currently available assistance methods. We will provide a solution that will enhance the confidence and abilities of the visually impaired to independently navigate anywhere and anytime.

This document outlines the requirements specifications for SimuSound. An overview of the system, specific requirements for each phase of product development, constraints, engineering standards, and an acceptance test plan are presented.

Revision History

Version	Date	Description	Author(s)
1.0	2021-02-21	Initial version	Michael Chambers Dustin Seah Victor Luz Michael Lin Ben Agnes
1.1	2021-03-20	Revision based on marking and updates to better define requirements	Ben Agnes

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Glossary

Term	**Definition**
FOV	field of view
FPS	frames per second
Stereo vision	stereoscopic vision; computer vision algorithm using two cameras mounted side-by-side to provide depth information similar to how human eyes function
Real Time	low latency. Device continuously collects, processes, and outputs data.

Table 1: Glossary

1 Introduction

1.1 Background

There are approximately 285 million individuals living with visual impairment and 39 million with blindness worldwide [1]. Naturally, in unfamiliar environments, people tend to be uncomfortable. For a person with blindness , this situation can even cause complete loss of independence. This can stem from an inability to see terrain changes and road markings, signage and entrances, or other obstacles. Traditional methods, such as the use of canes and guide dogs are certainly useful, but often require extensive training [2], and can be costly [3]. Another method is to use echolocation, but this requires many years of practice to be reliable and most O&M instructors are not trained to teach echolocation [4]. In a world designed primarily for people with sufficient vision, simply having a stroll outside can prove to be a challenge for a blind person with current methods, and SimuSound aims to change that.

1.2 Product Overview

Our solution does not involve altering traditional, proven methods such as canes or guide dogs as it will likely become more of a hassle than a benefit to completely replace these aids [5]. SimuSound is a wearable device that informs the user about classified objects in a given environment, such as cars, people, doorways and stairs. The system will determine the distance and position of each obstacle using stereo vision and provide feedback to users. This feedback will be in the form of simulated localized audio via bone conduction headphones and will be designed to provide feedback as close to real-time as possible. This method of feedback will result in positive improvement in a blind person’s ability to navigate in a closed environment [6] [7].

After the initial learning process, our product will be completely navigable by people who are blind. For this, we will utilize haptic and voice feedback in the system's menus. This should not be a problem for users which are blind or severely vision impaired as outlined in Holly’s blog post [8].

2 System Overview

SimuSound is a device that will inform the blind user of any objects or height changes in their paths using audio cues. The device will use a set of stereo cameras to view the area in front of the user and analyze the scene for objects or height changes. If it detects any, it will simulate an audio source coming from that object through bone-conduction headphones to the user. The user will then know of that object or height change ahead of them through natural human sound pinpointing. A high-level overview is presented in Figure 1 and a visual description is presented in Figure 2.

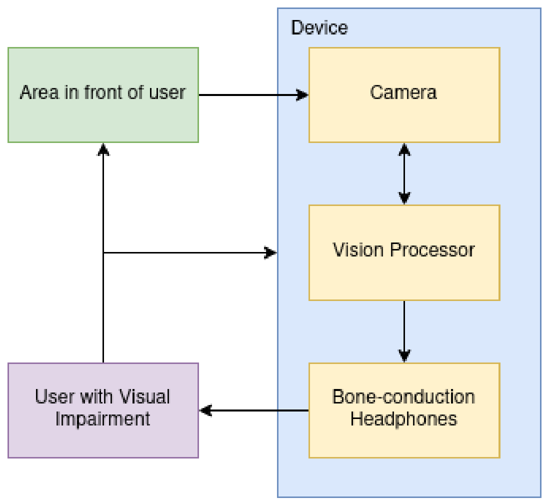

Figure 1: High-level overview of product

Stereo cameras will gather raw information about the environment in front of the user multiple times a second, feeding it to a phone or single-board computer for processing and relaying the information to the user via bone-conduction headphones. Our device will be classified as an electronic vision aid under FDA Chapter 1 [9].

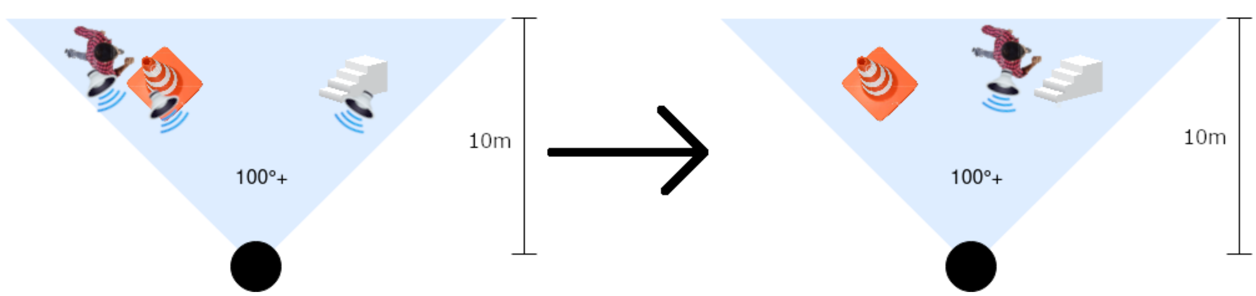

Figure 2: Visual diagram of aspects of solution - Stationary and moving objects.

3 Requirements Format

This document uses the following format for identifying requirements.

R a.b.c-d

Where **a** is section, **b** is subsection, **c** is number, and **d** is phase. Table 2, below, lists the different phases of the product and each associated symbol in a requirement ID.

Symbol	Phase
P	Proof of Concept (alpha)
B	Pre-production prototype (beta)
F	Final product

Table 2: Requirements phase symbol definitions

4 General Requirements

4.1 Functional Requirements

Requirement ID	Description
R 4.1.1-P	The device must be able to scan for objects larger than 1 meter squared in front of the user up to 10 meters away and find its distance.
R 4.1.1-F	The device must be able to scan for height changes greater than 2 meters in front of the user up to 10 meters away and find its distance.
R 4.1.2-P	The device must be able to provide audio feedback of objects detected in the form of a simulated sound that appears to be emitting from those objects at the distance detected.
R 4.1.3-P	The device must report the distance of detected objects in addition to sound localization if the object is further than 5m from the user.
R 4.1.4-P	The device must use sound localization to give the direction of detected objects or height changes within 20 degrees azimuthal and 30 degrees vertically within 3 meters to 10 meters from the user.
R 4.1.4-F	The device must use sound localization to give the direction of detected objects or height changes within 10 degrees azimuthal and 15 degrees vertically within 2 meters to 10 meters from the user.
R 4.1.5-F	The device conveys motion by producing sound for longer and adjusting the localization point as sound is produced by interpolating between positions detected from frames.
R 4.1.6-P	The device groups multiple objects within close proximity of each other together and describes them to the user as a single, larger object
R 4.1.7-P	The device must be used outdoors in the daytime or indoors in a well-lit environment.
R 4.1.8-F	The device behaves like a proximity sensor by providing haptic feedback if objects are detected within 2m of the user
R 4.1.9-P	The device must report the distance of detected objects to within 30% of the true distance.

R 4.1.9-F	The device must report the distance of detected objects to within 10% of the true distance.

Table 3: Functional Requirements

4.2 Performance Requirements

Requirement ID	Description
R 4.2.1-P	Audio output for an object that comes into the field of view must be performed in less than 5 seconds.
R 4.2.2-F	Audio output for an object that comes into the field of view must be performed in real-time.

Table 4: Performance Requirements

4.3 Reliability Requirements

Requirement ID	Description
R 4.3.1-P	The system may perform a calibration process on first startup.
R 4.3.2-P	If the device experiences a critical failure, the user should be notified and the entire system must restart.
R 4.3.3-F	The device must be able to survive temperatures up to 70 degrees Celsius and down to -15 degrees Celsius

Table 5: Reliability requirements

4.4 User Interface Requirements

Requirement ID	Description
R 4.4.1-P	The user must not have difficulty with configuring, connecting, or powering on/off the system.
R 4.4.2-P	The device must not obviously show that the user has a visual disability.
R 4.4.3-P	The device should present changes in object and height location information in a clear and non-intrusive manner such that the user can still hear other environmental sounds or conversation.
R 4.4.3-F	The user should be able to customize the content of the sound emitting from the object.
R 4.4.4-F	The user should be able to choose which category of objects are presented or ignored.
R 4.4.5-P	The device should have a simple method to turn it on and off as needed by a completely blind user.
R 4.4.6-F	All power and feedback controls are accessible on the headset.

Table 6: User interface requirements

4.5 Privacy Requirements

Requirement ID	Description
R 4.5.1-F	The device must not store the images gathered from the cameras in non-volatile memory.
R 4.5.2-F	The device must not allow the user to transfer images gathered from the cameras off the device.

Table 7: Privacy requirements

5 Hardware Requirements

5.1 Power Supply Requirements

Requirement ID	Description
R 5.1.1-P	The device must be able to operate with portable power sources.
R 5.1.2-F	The battery in the device must be rechargeable.
R 5.1.3-F	The battery in the device must be replaceable.
R 5.1.4-F	The battery in the device must be able to power the device continuously for at least 3 hours.
R 5.1.5-F	The battery in the device must have a minimum charging cycle count of 400 cycles.

Table 8: Power supply requirements

5.2 Camera Requirements

Requirement ID	Description
R 5.2.1-P	The device must have two cameras aligned horizontally to correctly use computer stereovision.
R 5.2.2-B	The cameras must record images with sufficient quality to identify objects up to 10m away.
R 5.2.3-F	The device must have a minimum of 100 degrees field of view.

Table 9: Camera requirements

5.3 Audio Requirements

Requirement ID	Description
R 5.3.1-F	The system must provide audio feedback through bone-conduction headphones.
R 5.3.2-P	The system should use an audible text-to-speech voice.
R 5.3.3-B	The volume of the audio must be adjustable with buttons.
R 5.3.4-P	The maximum volume of the audio must be less than a decibel rating of 85 decibels.
R 5.3.5-F	The sound quality of the audio must be at least DVD quality.

Table 10: Audio requirements

6 Software Requirements

Machine learning and image processing algorithms will be used to process from the camera and calculate their distance. A conceptual software system block diagram is provided in Figure 3.

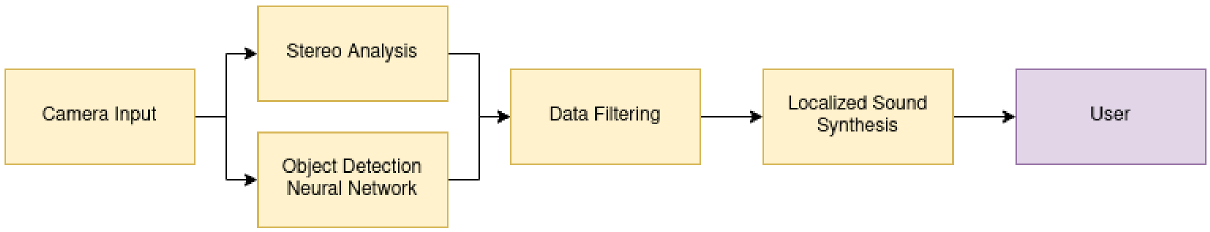

Figure 3: Conceptual high-level software system block diagram

6.1 Processing Requirements

Requirement ID	Description
R 6.1.1-P	The device must be able to detect objects that may be in the path of the user based only on camera input.
R 6.1.2-B	The device must be able to detect height changes relative to the user's current position based only on camera input.
R 6.1.3-B	The device must be able to classify objects as either the exact object name or into an object category.
R 6.1.4-P	The device must be able to simulate a sound emitting from the detected objects based on the object's position using audio output via bone-conduction headphones to the user.
R 6.1.5-F	The device should be able to persist recently detected objects such that even when previously detected objects are not currently in the device's FOV, the device has knowledge of where those objects are relative to the user and can present that information to the user.

Table 11: Processing requirements

7 Safety Requirements

Safety is our highest priority when developing this product. The device will potentially have direct contact with the user's skin, as well as hold a battery close to the user's head. Additionally, the device will be playing audio to the user via headphones, which have the potential to damage hearing if the volume is too loud or distract the user.

7.1 Safety Requirements

Requirement ID	Description
R 7.1.1-B	The device must not expose any electrically live surface to the user.
R 7.1.2-P	The device must not reach an internal temperature high enough to become a fire hazard.
R 7.1.3-F	The device must not exceed 35 degrees Celsius externally on any surface.
R 7.1.4-P	The device must not have any sharp edges or corners that can cause injury to a person.
R 7.1.5-P	The device must not emit electromagnetic radiation in such a way that is dangerous to the health of the user or any person.
R 7.1.6-P	The device must not output sound that is loud enough to cause damage to the user's hearing.
R 7.1.7-F	The device must be externally insulated to voltages of at least 12 volts where contact with other objects is likely.
R 7.1.8-F	A person with normal hearing should be able to hear a simple conversation at 70 decibels or an approaching vehicle at 85 decibels while using the device.
R 7.1.9-P	The device must be relatively lightweight so as to not cause fatigue or injury from wearing the device over extended periods of time.

Table 12: Safety requirements

8 Sustainability Requirements

Sustainability is an important consideration when designing a new product today [10]. Factors include repairability, usage of recyclable materials, and cradle-to-cradle design. Other considerations include the usage of child or slave labour,the usage of conflict minerals, or pollution in the manufacturing process.

Cradle-to-cradle design is a product lifecycle system in which the user, when they decide that they no longer need the product, will return it to the manufacturer who then reuses parts of the product to create new products [11]. This reduces waste compared to the typical end-of-life situation of current products where the user throws the product into the landfill. When designing our product, we will be simultaneously producing a plan on adopting the cradle-to-cradle system into our product lifecycle. Figure 4 graphically shows the cradle-to-cradle lifecycle.

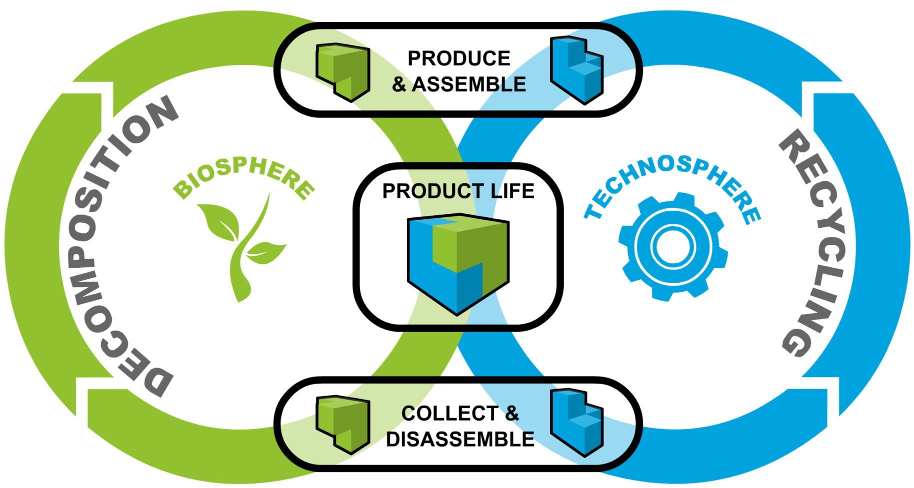

Figure 4: Cradle-to-cradle lifecycle of product. Image taken from [12]

Another factor in sustainability is planned obsolescence [13]. Planned obsolescence is a common industry practice that opposes sustainability, instead forcing users to abandon their existing products through lack of support over time. We will address the potential problem of planned obsolescence of our product by releasing all software for the device under open source licenses, and all hardware documentation as open source hardware.

8.1 Sustainability Requirements

Requirement ID	Description
R 8.1.1-F	The device should only contain electronic components that are freely obtainable by an average user.
R 8.1.2-F	The design of the device should not hinder repairability on purpose.
R 8.1.3-F	At least 80% of the components in the device should be able to be reused to produce another device.
R 8.1.4-F	At least 80% of the components in the device should be a part of either a biological cycle or a technical cycle under the cradle-to-cradle system.

Table 13: Sustainability requirements

10 Engineering Standards

Engineering Standards are guidelines set by both national and international bodies that ensure products are safe, environmentally conscious, and align with accepted processes. Below are the standards that the product will meet and conform to:

10.1 General Standards

Standard	Description
IEC 62355-2:2016	Medical Devices - Part 2: Guidance on the application of usability engineering to medical devices [14]
ISO 14971	Application of risk management to medical devices [15]
ISO 11.180.30	Aids for blind or partially sighted people [16]
IEEE 7010-2020	IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being [17]

Table 14: General Standards

10.2 Electrical and Mechanical Standards

Standard	Description
IEC 60529:2001	Degrees of protection provided by enclosures (IP Code)[18]
IEEE 1625	IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices [19]
CISPR 22: EN 55022 EMC Standard	Information for information technology equipment, ITE for the radio disturbance characteristics for electromagnetic compatibility compliance [20]
IEEE P360	Standard for Wearable Consumer Electronic Devices - Overview and Architecture [21]

Table 15: Electrical and Mechanical Standards

10.3 Systems and Software Standards

Standard	Description
IEC 62304:2006	Defines the life cycle requirements for medical device software [22]
IEEE 12207-2017	ISO/IEC/IEEE International Standard - Systems and software engineering – Software life cycle processes [23]
IEEE 3333.1.2-2017	IEEE Standard for the Perceptual Quality Assessment of Three-Dimensional (3D) and Ultra-High-Definition (UHD) Contents [24]

Table 16: Systems and Software Standards

10.4 Safety and Legal Standards

Standard	Description
ISO 60601-1-11:2015	Medical electrical equipment - Part 1-11: General requirements for basic safety and essential performance [25]
CAN/CSA-C22.2 NO. 60601-1:14	Medical electrical equipment - Part 1-11: General requirements for basic safety and essential performance-Collateral standard: Requirements for medical electrical equipment and medical electrical systems used in the home healthcare environment (Adopted IEC 60601-1-11:2015, second edition, 2015-01, with Canadian deviations) [26]
CAN/CSA – C22.2 NO. 60601-1-11:15	Medical electrical equipment - Part 1-11: General requirements for basic safety and essential performance–includes Canadian deviations [27]

Table 17: Safety and Legal Standards

10.5 Environmental Standards

Standard	Description
CAN/CSA-C22.2 NO. 60601-1-9:15	Medical electrical equipment - Part 1-9: General requirements for basic safety and essential performance -Collateral standard: Requirements for environmentally conscious design (Adopted IEC 60601-1-9:2007, edition 1:2007 consolidated with amendment 1:2013, with Canadian deviations) [28]
CAN/CSA-ISO/TR 14062-03 (R2013)	Environmental Management - Integrating Environmental Aspects into Product Design and Development [29]
CAN/CSA-ISO 14040-06 (R2016)	Life Cycle Assessment - Principles and Framework (Adopted ISO 14040:2006, second edition, 2006-07-01) [30]

Table 18: Environmental Standards

11 User Acceptance Testing

11.1 Logistics

We will hold user acceptance tests at the convenience of our volunteers/participants. Testing of our prototype will consist primarily of (specific) obstacle identification and feedback provided to the testers. At this stage, the participants can provide their views on how each part of the prototype can be improved. This will be in the form of a survey, though primarily verbal, as we expect most participants to be visually impaired.

11.2 Testing Criteria

Obstacle Identification

- Identification is real-time
- Able to detect all objects larger than 0.5 square meters and within 10 meters in front of the user
- Users can determine the approximate location (distance, height from ground) of an item by pointing their finger towards it and identifying it

Feedback to User

- Sound feedback volume is adjustable up to 10 decibels and strictly less than 85 decibels at maximum volume
- Only provides feedback for type(s) of obstacles set by the user
- Feedback is distinct from one type of obstacle to another

Comfort

- The device does not cause any discomfort to the user
- Enough air flow is given as to not cause significant heat build up over time(5° Celsius)

User Interface

- User interface is intuitive (learnable in 30 minutes)
- Users are only required to learn functionalities of a few controls

Usability

- All buttons are easily accessible
- System is not too bulky as to hinder the tester
- Load times and input responses are reasonably quick
    - Menu navigation must have a maximum delay of 2 seconds

11.3 Feedback Elicitation

Test Scenario

- Have a companion setup the system and fit it on to the tester
- Provide a tutorial for the tester to change settings of the system
- Have a tester navigate a new environment
- Record tester input as the tester is using the system
- Perform any small tweaks the tester suggests and have them do another course
- Record further tester input, whether it be for materials, sound feedback, or comfort

Survey Questions

- Did you feel the options were easy to change?
- Did you think the system can be learned within a week?
- Do you feel that this system provides a sense of independence?
- How likely do you see yourself using this system daily?
- Do you have any other comments about this system?
- How would you rate the difficulty of the setup process?
- Did you find the system to be contributing to your ability to locate objects?

12 Conclusion

ExAssist Technologies is providing a device which helps severely visually impaired or blind users to better navigate any environment. SimuSound enables these people to familiarize with their surroundings using sounds instead of relying solely on traditional methods such as guide dogs and canes.

This document defines the requirements needed for the proof-of-concept prototype, engineering prototype, and the final product. The general requirements will provide user-friendly, privacy, and security to users. The hardware requirements state the needs for our camera, battery, and headphones that SimuSound will utilize. The software requirements state the speed of processes. ExAssist Technologies strives to provide a safe and eco-friendly product as stated in the safety and sustainability requirements.

To ensure the requirements for a quality product are met, the acceptance test plan for the proof-of-concept prototype is outlined in the appendix.

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Appendix A

Acceptance Plan

Test	Description	Pass/Fail	Comments/Observations
1	The user puts on the device without assistance from an aid.		
2	The device can be powered on and off.		
3	The device has a maximum volume of 85 dB.		
4	The device has a minimum volume of 0 dB.		
5	The device's cameras have the advertised FOV and FPS.		
6	The device is able to scan for objects within the camera's FOV.		
7	The device detects changes in elevation such as a staircase.		
8	The device detects standing people, doorways, stairs, and vehicles.		
9	The user can choose objects categories to detect.		
10	The device audibly communicates identified objects to the user.		
11	The device meets all P requirements		

Table 19: Acceptance Plan