SEES PROJECT

**Spatial Echolocation Enhancement System**

**Progress Report**

University of Victoria

CENG/ELEC/SENG 399 Fall 2014

Design Team 14

Daniel Faulkner - V00778450 - SENG

Paulo Tabarro - V00810880 - CENG

Jason Lim - V00785426 - SENG

Adalberto Outeiro - V00810849 - ELEC

Rajpal Chauhan - V00762290 - ELEC

# Introduction

The goal of this project is to design a system to aid visually impaired or blind individuals in navigating the world around them. The project aims to build a device that would act as a natural augmentation to the user’s existing ability to navigate using spatialized audio cues from the world around them. Spatialized audio cues can be generated with a regular pair of in-ear headphones using Binaural Audio Filtering. With Binaural Audio, audio signals are separated into left and right audio channels and are filtered using a Head Related Transfer Function (HRTF). Depending on how well the HRTF matches the user’s head profile, Binaurally filtered audio can sound as if the audio cue is coming from the world around the listener as opposed to from the headphones in their ears [1].

# Scope

The scope of this project, and by extension, the scope of this document covers topics relating to the development of an assistive navigation device for blind and partially blind individuals. These topics include computer hardware, computer software, image processing, audio processing, acoustics, and user interface development. This document will also discuss some early design requirements of the device as well some of the early development approaches taken with the device. Additionally, we will also examine and discuss other projects that have taken similar approaches to building an assistive device for blind navigation. Finally, this document will provide a progress report of the SEES Project development to date.

# Design Requirements

The preliminary design requirements focus on hardware and usability. These are considered to be the minimum requirements to fulfill the basic use case of assisting a blind or visually impaired individual navigate an unfamiliar environment.

* **System Speed:** Must be fast enough to perform 2 binaural audio transforms (left and right ear) for a given audio signal at 44000Hz in real time. (i.e. audio runs smoothly with no skipping)
* **System Memory:** Must be able to contain binaural audio software and associated control software
* **System Capability:** Must be able to output audio to headphones
* **Sensor Capability:** Must be able to sense objects in indoors, outdoors, well lit, and dimly lit environments.
* **Feedback Speed:** The time from when the sensor detects something to when the user receives feedback must be no longer than 15 milliseconds. (~60Hz)

# Similar Projects

In the course of researching and defining the project, a number of other solutions were examined. One particular project named ARGUS FP7 was unique in that it also uses Binaural Audio for navigational cues. The primary difference between this project and the ARGUS FP7 project is that the ARGUS FP7 project relies on GPS positioning and requires pre-processed environment data in order to provide navigation information to the user [2]. The intention for the SEES Project is for the device to be a self contained unit that can gather, process, and provide feedback to the user information about the environment in real time.

# Project Status

In order to begin development on the SEES Project, the design team began by brainstorming possible designs for a device that would aid navigation through the use of synthetic echolocation. The goal was to develop an early set of prototype design visuals that could both be used as a reference later in the development of the project as well as a flexible blueprint that can be critiqued and edited as the project evolves. In this brainstorming, the team sought a balance between both feasibility and usability. The primary considerations included:

The sensors to be used for detecting visual signals (i.e. ultrasonic vs infrared)

The number of sensors to be used

The location(s) of the sensors used

The manner in which to mount the sensors

The hardware to be used for processing visual to audio signals

The software to be used for processing visual to audio signals

The design visuals and reference material produced from this exercise have been detailed in the *Milestone #1 Prototype Design Visuals* data sheet.

# Project Design

## Sensors

For the design of the project the group has brought to discussion the type of sensor that suits the requirements of the device. The two most readily available options to be considered are Infrared sensors and Ultrasonic sensors. [3] discusses these sensors in great detail; the relevant findings from this source are detailed below.

Simple Infrared Range-finding sensors supply measurements of distance from a point located in the obstacle in front of it, also known as threshold distance. While these sensors are both cheap and effective at gathering depth information at a single point, they are not very well suited for mapping a complete environment all at once. Wide range depth imaging may instead be achieved by utilizing infrared imaging in combination an emitted structured light pattern. Using the resulting infrared images, it is possible to determine the depth of an entire images as opposed to a single point. It should be noted that, infrared imaging is not ideal for use outdoors in broad daylight due to saturation of the infrared sensors. As a result, choosing to use infrared sensing has the potential to severely impact the usability of the device.

Ultrasonic sensors are based on sound, and are not affected by ambient lighting conditions. Ultrasonic sensors can be used to measure the distance to an object by emitting an ultrasonic pulse. The sensor then measures the propagation time for the echo to return back to the sensor as well as the resulting frequency. These values are then used to calculate the distance to the target. It is important to note that Ultrasonic sensors are impacted by reverberation and ghost echo. This has the potential the limit the frequency of accurate measurements obtainable by the sensor. Despite being easily handled, these sensors do not supply further spatial information from the object.

Approaching differently the problem, the group has also touched on using ready-to-use devices such as Microsoft Kinect. The Kinect uses an infrared imaging technique that uses structured light to determine the depths in the captured image. As an infrared based solution, it suffers the same limitations under daylight as traditional infrared imaging.

Similarly, technologies used for computer vision have a lot to do with our necessities. Even though they can be of unnecessary high complexity for our purpose, they can help to overcome some of our obstacles. The TYZX G2 EVS project, for example, transforms point-cloud data into efficient 2D or 3D geometric representations, avoiding problems with interference, as it is the case in IR sensors [4].

## Peripheral Design

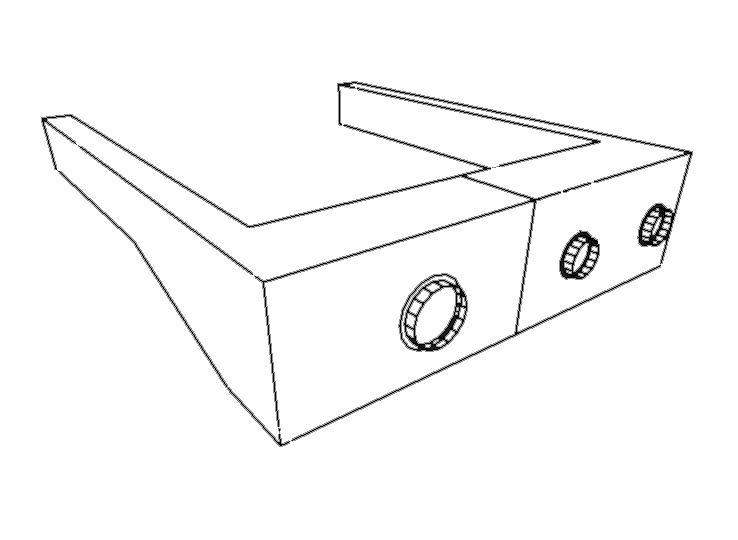
Another consideration was the design of the device’s sensing peripheral and how the sensing device should be used by the user. Some possibilities discussed were mounting the sensors on a cane or wand held in the user’s hands, on a vest worn on the user’s torso, or as part of a headset worn on the user’s head.

For the wand type system, the user uses the device by pointing it in the direction they wish to detect. This allows the user to freely sweep the wand across the scene and listen for the resulting audio cues. Because the device moves independently of the user’s head, the user is free to adjust the orientation of their head to better understand the distance and orientation of binaural audio cues. However, this introduces the need to reconcile both the device’s position and orientation with the user’s head in order to properly align the generated binaural audio cues with the world around the user. Additionally, having the user constantly sweeping the scene may introduce fatigue in the user’s arms over long term usage of the device.

For the vest type design, the sensor is limited detecting in a field in front of the user. Binaural audio cues are used to signal where in this field objects and obstacles are located. Similar to the wand type design, the user may also freely tilt or rotate their head to clarify the nature of the device’s audio cues. However, unlike the handheld, the relative position of the sensors to the user’s head can be assumed to be constant. As a result, only orientation needs to be reconciled between the user’s head and the device. One drawback of this particular design is that the device may not always be pointed in the direction that the user wishes to observe.

For the final design: the head mounted design, sensors are mounted to a headset that is worn on the user’s head. This sensor layout would be the most natural choice for replicating the natural human field of view. As the device is mounted to the user’s head, the user is free to direct the device as they would their vision. Additionally, because the device is always positioned and aligned to the user’s head, no complex calculations are required in aligning the binaural audio cues to the world around the user’s head. That being said, using a head mounted device also means that the user is limited to how much they can adjust their listening angle before the target audio cue drops out of the device’s field of vision.

Of these designs, the head mounted design was chosen to be used for preliminary prototype designs. The head mounted device avoids the need for difficult orientation and position calculations and can be used most similarly to regular human sight. While the design does limit the sound localization capabilities of the user, it does not eliminate them completely. Figure 1 shows an early mockup of how this particular design could be constructed similar to a pair of spectacles.



**Figure 1:** Prototype Design Mockup of Headset Type Peripheral

# Processing

A number of different ideas were considered for processing the visual data into Binaural Audio, ranging from a Raspberry Pi or an Arduino to a smartphone or tablet.

Having a dedicated board held some merit, as this would guarantee the device having a predetermined amount of computing power and would give a more consistent user experience which would be easier to troubleshoot. However, this would drive up potential costs for the end user, and would be another bulky device which the user would need to carry around.

Because a user is likely to already be carrying a device such as a smartphone or tablet, utilizing these to perform the calculations would save both money and space. A potential issue s that the user’s smartphone or tablet may not possess enough processing power to meet the requirements of the project. This is something that will need to be tested on a variety of platforms in order to experimentally weigh the pros and cons. However, the simplicity of using a smartphone or tablet is making that option more favourable at this time.

# 

# 

# Appendix A - Work Log

|  |  |  |
| --- | --- | --- |
| **Daniel Faulkner** |  |  |
| Date | Time (Hrs) | Description of Task |
| 09/09/14 | 0.5 | Group Formation/Meeting |
| 09/24/14 | 1 | Group Selection & Clarification Emails |
| 10/01/14 | 0.5 | Meeting With Professor Adams |
| 10/07/14 | 1 | Project and Supervisor Selection Emails |
| 10/09/14 | 1 | Group Meeting |
| 10/10/14 | 2 | Paragraph “How you envision the project” |
| 10/14/14 | 0.5 | Meeting With Professor Adams |
| 10/14/14 | 1 | Group Meeting |
| 10/19/14 | 1.5 | Progress Report |
| 10/20/14 | 2 | Progress Report |

|  |  |  |
| --- | --- | --- |
| **Paulo Tabarro** |  |  |
| Date | Time (Hrs) | Description of Task |
| 09/09/14 | 0.5 | Group Formation/Meeting |
| 10/09/14 | 1 | Group Meeting |
| 10/13/14 | 2 | Paragraph “How you envision the project” |
| 10/14/14 | 0.5 | Meeting With Professor Adams |
| 10/14/14 | 1 | Group Meeting |
| 10/19/14 | 2 | Progress Report |
| 10/20/14 | 2 | Progress Report |

|  |  |  |
| --- | --- | --- |
| **Jason Lim** |  |  |
| Date | Time (Hrs) | Description of Task |
| 09/09/14 | 0.5 | Group Formation/Meeting |
| 10/01/14 | 0.5 | Meeting With Professor Adams |
| 10/09/14 | 1 | Group Meeting |
| 10/10/14 | 1 | Paragraph “How you envision the project” |
| 10/14/14 | 0.5 | Meeting With Professor Adams |
| 10/14/14 | 1 | Group Meeting |
| 10/19/14 | 3 | Milestone 1: Prototype Design Visuals |
| 10/19/14 | 2 | Project Timeline Gantt Chart |
| 10/19/14 | 1 | Progress Report |
| 10/20/14 | 1 | Progress Report |
| 10/21/14 | 1 | Progress Report |

|  |  |  |
| --- | --- | --- |
| **Adalberto Outeiro** |  |  |
| Date | Time (Hrs) | Description of Task |
| 09/09/14 | 0.5 | Group Formation/Meeting |
| 10/09/14 | 1 | Group Meeting |
| 10/10/14 | 2 | Paragraph “How you envision the project” |
| 10/14/14 | 1 | Group Meeting |
| 10/20/14 | 3 | Progress Report |

|  |  |  |
| --- | --- | --- |
| **Rajpal Chauhan** |  |  |
| Date | Time (Hrs) | Description of Task |
| 09/09/14 | 0.5 | Group Formation/Meeting |
| 10/09/14 | 1 | Group Meeting |
| 10/10/14 | 1.5 | Paragraph “How you envision the project” |
| 10/14/14 | 1 | Group Meeting |
| 10/19/14 | 1.5 | Progress Report |
| 10/20/14 | 2 | Progress Report |

# 

# 

# Appendix B - References

[1] R. H. Y. So *et al.*, “Effects of spectral manipulation on non individualized head-related transfer functions (HRTFs),” *Human Factors*, pp. 271-283, June 2011.

[2] E. Carrasco *et al*., “Autonomous navigation based on binaural guidance for people with visual impairment,” *Assistive technology: From research to practice, assistive technology research series*, pp. 690-694, Sept. 2014.

[3] J. Fraden, “*Handbook of Modern Sensors: Physics, Designs and Applications,”* New York, NY: Springer New York Heidelberg Dordrecht London, 2010. Print.

[4] TYZX, Inc, “*Giving Robots Real-time Vision and Depth Perception for Navigation, Person-Tracking, and Surveillance”.* Retrieved October 20, 2014, from http://www.tyzx.com/PDFs/cs\_RoboticNavigation\_FINAL.pdf

Appendix C - Milestones

