September 28th, 2015

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

Re: ENSC 440 Project Proposal for an Ultrasonic Local Positioning System

Dear Dr. Rawicz,

Please accept the following document as a proposal for our Local Guidance System (LGS) project. We aim to design and implement a local positioning system that will assist the visually impaired by informing the user where they are in relation to the closest components in the system. Our project consists of ultrasonic beacons and receivers that use time of flight of the signal to triangulate the user.

The purpose of this proposal is to give an introduction and an overview to our project, some design considerations, project budget and funding sources as well as project plan and team organization.

LocalSonic consists of five talented engineering students: Andrew Chan, Justin Crosby, Yihao Zhang, Shuo Yang, and Han Shen. If you have any concerns, or questions about our proposal, please feel free to contact Andrew Chan 604-671-1028 or by email at acc37@sfu.ca.

Sincerely,

Andrew Chan
Chief Executive Officer
LocalSonic

Enclosure: *Proposal for a Local Guidance System*

LocalSonic

Project Proposal

Local Guidance System (LGS)

Project Team: Andrew Chan
Justin Crosby
Shuo Yang
Yihao Zhang
Han Shen

Submitted to: Dr. Andrew Rawicz
Steve Whitmore
School of Engineering Science
Simon Fraser University

Issued Date: Sep. 28, 2015

Revision: 1.1

Executive Summary

Technology has always been evolving towards providing a better user experience for consumers whether it is through improving a user interface or providing services to help user productivity. Smartphones are a good example; current generation cellphones contain more processing capability than many computers ten years ago. Online services to help with connecting friends globally or ordering goods internationally has never been easier.

However, innovative technology for user accessibility in a physical environment is less prominent compared to the other aspects of technological development. The most common technology of this category would be a GPS system in the form of either Google Maps or Apple Maps. Yet, these technologies do not perform well inside buildings and leave something to be desired for indoor navigation.

At LocalSonic, our goal is to provide a navigation solution for the visually impaired inside a building. Often large public structures such as universities, schools, and shopping malls are difficult to access and maneuver for the visually impaired. We address this problem with a scalable solution that can be applied to any building.

With LocalSonic's Local Guidance System (LGS), users will know where they are inside a building with a press of a button. This system requires small ultrasonic receiver beacons placed throughout a building. The user, carrying an ultrasonic emitter, will signal these beacons and the response time is then used to triangulate the user's location. The user is then informed of how far they are in relation to the closest landmark such as a door, room, or hallway and what that landmark is.

LocalSonic will research, design, test, and implement the LGS over the next 3 months to ensure seamless operation. Depending on the rate of development and available resources, changes and improvements to the designed system may be made.

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1. Introduction

Large buildings or areas such as shopping malls or universities are often difficult for people to find specific places or maneuver around in. This is especially true when the subject is visually impaired and is unfamiliar with the location.

There are several wireless technologies, such as GPS or Wi-Fi, available to guide users, but these technologies are limited by the fact that the user is indoors. First of all, we are concerned about the lack of GPS signal reception in certain indoor environments that are constructed with a material that the satellite signal cannot penetrate. Secondly, it is hard for GPS to obtain the user's altitude accurately at times, due to the absolute error of altitude measurement from the satellite in space. For instance, when a user is walking inside a building, it is nearly impossible for the existing GPS modules to tell whether they are on the ground level or second floor. Using Wi-Fi access points require that the building have several accessible Wi-Fi hotspots throughout and that the operators and users of the system are comfortable with the lack of privacy.

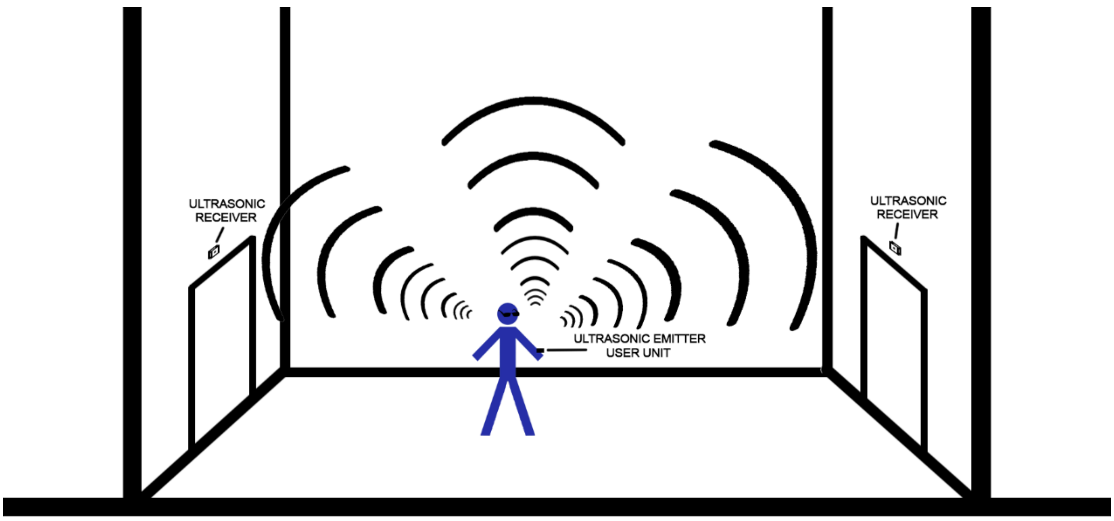

Figure 1: The LocalSonic LGS

In order to resolve the limitations of these wireless technologies in local positioning systems, a new navigation system called the Local Guidance System (LGS) is designed by LocalSonic Inc. using ultrasound. This new guidance system will help guide users in indoor destinations with high accuracy[1].

This proposal will provide an overview of our product by discussing design considerations such as alternate solutions and existing products, sources of information and funding, and project scheduling through Gantt and milestone charts.

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2. System Overview

For this project, a local positioning system for the visually impaired will be created. The user wears a device that triangulates where they are in relation to deployed ultrasonic beacons.

Ultrasonic beacons are attached above doorways and near any important building components such as stairs and elevators. For parts of the building or area that lack landmarks, additional beacons will have to be placed 4 meters away from each other so that the system will always know where the user is. The user, when concerned with where they are, will press a button connected to the ultrasonic emitter system they are carrying, which will cause the device to attempt to ping local ultrasonic beacons and triangulate where the user is.

After the beacons have received the signal, it will send information to the user device on how far the user is away from the beacons, and the user device will then calculate and inform the user with audio feedback the direction and how far away they are from the closest landmark.

Theoretically, this system is scalable and can be deployed in any building providing that it does not contain many large surfaces that prevent the placement of an ultrasound beacon.

3. Possible Design Solutions

There are many wireless technologies available that can be used in different applications of local positioning systems. One of the desired aspects for the system is that the wireless technology used has a long enough range that is suitable for public buildings and is also able to allow for accurate triangulation that can be used in buildings with multiple levels. The different technologies are explored below.

3.1 GPS

A global positioning system (GPS) is very widely used and involves triangulation using radio. Since GPS requires that signals be sent and received to and from external sources, this system is unusable in buildings where the signal is blocked due to thick walls, underground sections, and so on. GPS is also unsuitable for multi-level areas and therefore is not a good solution for this project.

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3.2 Wi-Fi Local Positioning System

Wi-Fi based local positioning systems use Wi-Fi hotspots and access points to locate the user. It uses signal strength to determine where the user is in relation to Wi-Fi beacon. This system's accuracy is dependent on the number of Wi-Fi access points and consistency, which can be costly. Buildings with large numbers of people may also bog down the system.

3.3 Radio Local Positioning System

Using radio and time of flight between nodes was an explored solution, but ultimately not viable because of the precise time measurements required to accurately determine distance between nodes. Microcontrollers available on the market with such capabilities were far too expensive for this project.

4. Proposed Design Solution

4.1 Hardware

The proposed hardware solution has two main components, the transmitter and the receiver. The transmitter will consist of a microcontroller (a Raspberry Pi in the case of the prototype), a radio transceiver, and an array of ultrasonic emitters. These components will be mounted to an article of clothing or accessory such as a hat or pair of glasses.

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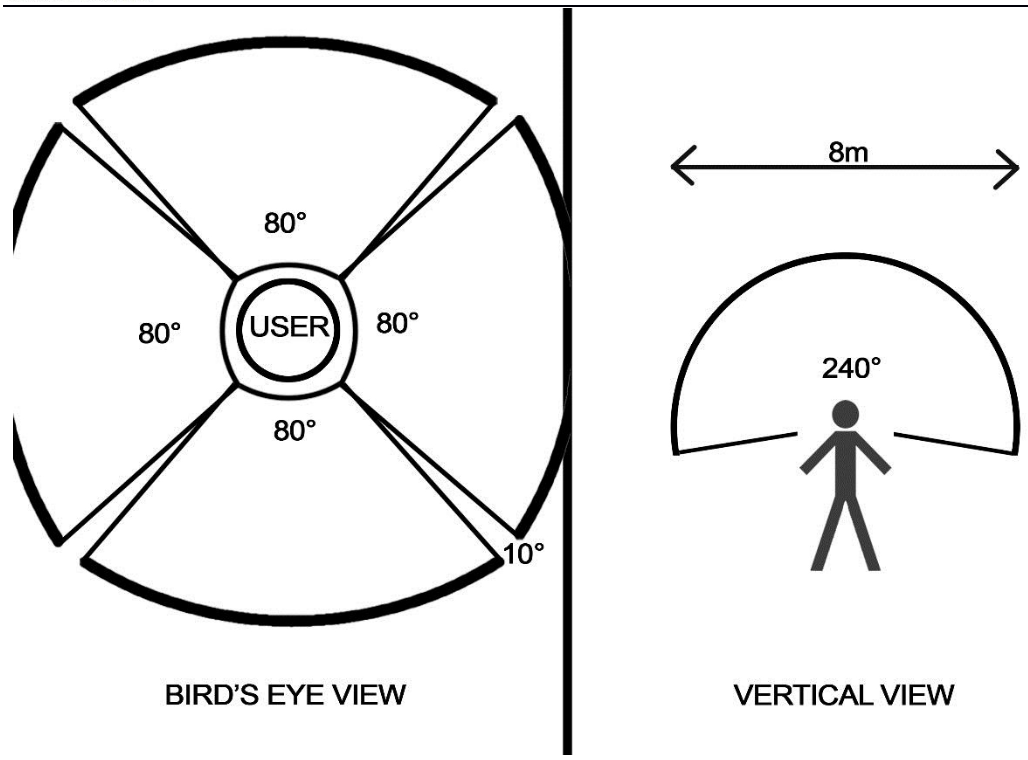

Figure 2: Angle coverage of emitters

The chosen ultrasonic emitter (MA40S4S) has an operational area of about 80° meaning that in order to attempt full 360° coverage in a hemisphere, 5 emitters are needed. These will be mounted circularly around the user. On the horizontal plane, there will be an estimated 40° of blind spots distributed evenly. An additional emitter be added to cover the blind spot but for now, the power consumption and actual cone emission angle has to be tested.

The receiver also has three components, a microcontroller, a radio transceiver, and multiple ultrasonic receivers. The ultrasonic emitter/receiver combination chosen (MA40S4S/R) have a range of approximately 4 meters. Therefore, in order for the system to always know the user's location, ultrasonic receivers must be placed at 4m intervals. To be cost effective, multiple receivers will be attached to a single microcontroller via long wires.

Ultrasonic must have line of sight for the emitter and receivers to successfully ping each other, thus it is proposed that the receivers be mounted above doors and ceiling, and the emitters be angled upwards as well. With this configuration there is the least amount of signals being blocked and not received.

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4.2 Software

To triangulate the user's position a simple time of flight measurement will be taken. First the transmitter will send out a radio ping to all receivers in the area which will tell the receivers to start counting and listening for an ultrasonic pulse. The receivers in ultrasonic range will receive the pulse and stop their counters. Since radio waves travel at the speed of light (~ 300 million meters/second) and ultrasonic travels at the much slower speed of sound (~ 300 meters/second) the radio ping will be received almost instantly and the ultrasonic pulse a short time after. The time difference between these two signals multiplied by the speed of sound will give the distance between the transmitter and receiver. Once the distance from each nearby beacon is known the location of the user is known and precise directions can be given.

Beacon locations will be stored in a matrix. The response time and distance will be then used to compare the values in the matrix for triangulation.

In the final product the user will be fed location data and directions via audio, much like GPS systems found in cars. The user will also be able to request directions to specific locations using their voice only.

5. Scope, Risk, and Benefits

5.1 Scope

The scope of the prototype is limited to the following deliverables:

- Transmitter capable of telling the user its location through audio
- Receiver that works in tandem with the transmitter to find the user's location
- Firmware for each device

Given extra time the following features will be added:

- Turn-by-turn directions and shortest path algorithm
- Voice control
- User tracking

5.2 Risks

There are a number of risks associated with this project, the first being whether or not the components selected will give an acceptable level of accuracy. Using normal C

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code on a Raspberry Pi, time measurements should be accurate to within a microsecond and, since light travels approximately 300 m/s, this should give accuracy of within 30 cm. If, however, the components selected are not able to provide accurate timing measurements, all measurements and consequently directions will be unreliable.

Specifically with the ultrasonic emitters and receivers, there are potential issues with reliably detecting a pulse. Depending on the building, there may be ultrasonic interference or the LGS may cause interference with other devices (or even animals). It is also uncertain precisely how much range these components have; potentially the receivers may have to be very close to the transmitter to accurately detect the pulse. These challenges will only be discoverable through testing.

Lastly, cost. Depending on the risks stated above, this system may be very costly to implement in a large building. The transmitter may also be a large cost for the end user.

5.3 Benefits

The social benefits for this project are significant. With the LGS, visually impaired people will be able to easily navigate new buildings and public places. While, it does not remove the need for a walking cane or guide dog, it does greatly improve their navigational ability.

This system's use case could also be expanded to include average people, providing directions in an unfamiliar place would also be useful for them. For example, a new student at SFU may have a difficult time finding their classrooms, LGS can help.

6. Market and Competition

6.1 Market

A 2009 report by *MarketsandMarkets* estimates that the indoor location market, which includes navigation, location-based analytics, tracking, and monitoring, was worth $935.05 million in 2014 and will grow to $4,424.1 million by 2019.[2] Of course, this is a rather large market and LocalSonic's LGS is targeted at a very small market. Further and more in depth development of the product to add functionality and market research is necessary before the LGS becomes a competitive product.

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6.2 Competition

There is currently no other product on the market that has the same function of the LGS. Though MIT's Cricket uses the same technology, a combination of ultrasonic and radio, to provide very precise location information (within 1-3cm), it is mostly used for robotics and research purposes.[3] The Cricket technology would easily be adaptable for the purposes of this project, however the amount of precision they have obtained through additional beacon nodes is unnecessary for this application and would just add extra cost.

Another product in the same vein as the LGS is Sonicguide, a pair of glasses that emits ultrasonic and translates the returning sound into human hear-able feedback. This technology attempts to recreate the echolocation technique used by some animals in humans. Sonicguide removes the need for a walking cane or guide dog, but does not help with identifying the locations inside a building.

7. Sources of Information

In the process of designing this project, the group will do extensive research to ensure a well-designed system. The information will be gathered form a variety of sources such as engineering course material, Internet, publications, manufacturer’s product data sheet, and user feedback.

The Internet is a valuable source of information for our project in every aspect. Since we are using common microcontrollers (Raspberry Pi and Arduino), documentation and support is readily available over the Web. Online information on ultrasonic technology such as existing ultrasonic products and projects have helped shape the design of the LGS system.

Because the project has hardware and software components which are well related to courses that have been taken by company members, course material may be referenced when designing the components. For example, we will be testing the reach and gain of the ultrasonic emitter and knowledge on IC circuit design is vital to ensure we do not overload our components. Previous courses on embedded systems and programming in C will be vital for programming our microcontrollers.

In addition, a team member works with Aarcomm Systems Inc., a company that works with radio technology and industrial electronics. This company has stated that they are willing to sponsor and provide some parts for this project. Also, during the designing period, the group will search for technical advices from SFU professors and

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the CTO of Aarcomm Systems Inc.

8. Budget and Funding

8.1 Budget

The following table outlines the estimated budget for the system. Similar components have been grouped together such as capacitors and transistors into the small hardware components category. The costs in Table 1 accounts for parts that may be damaged during testing. Some parts, such as microcontrollers, were previously bought by team members for other projects and have not been accounted into the project budget.

Table 1: Project Budget

Equipment	Estimated Cost
Microcontrollers	$80
Ultrasonic transmitter/receivers	$250
Small hardware components	$30
Batteries	$20
Case	$20
Wearable accessory	$10
Total Cost	**$410**

8.2 Funding

The cost of the finalized product will be much cheaper than that of the prototype due to the additional capital required in testing and in designing. The final cost of the system is also dependent on the size of the environment the system is to be implemented in.

The cost of this project is relatively low compared to other projects in this course. Because of a late change in technology, the Engineering Science Student Endowment Fund deadline was missed. Fortunately, Aarcomm System Inc. has taken some interest in this system because of the industrial applications this system may contain and are willing to sponsor a portion of this project and provide hardware components. The remainder of the cost will be covered by the Wighton Development Fund.

Lastly, the members of LocalSonic have accepted that a portion of the project may be funded by themselves and are financially capable of supporting this project. All purchased components will be recorded and receipts will be retained to ensure that costs are visible and accurate to all members.

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9. Schedule

9.1 Gantt Chart

The following Gantt chart is an overall timeline show our group's project plan. As there will be lots of fluctuation in estimating the time used for implementation and testing, this Gantt chart will change over time to accommodate these uncertainties.

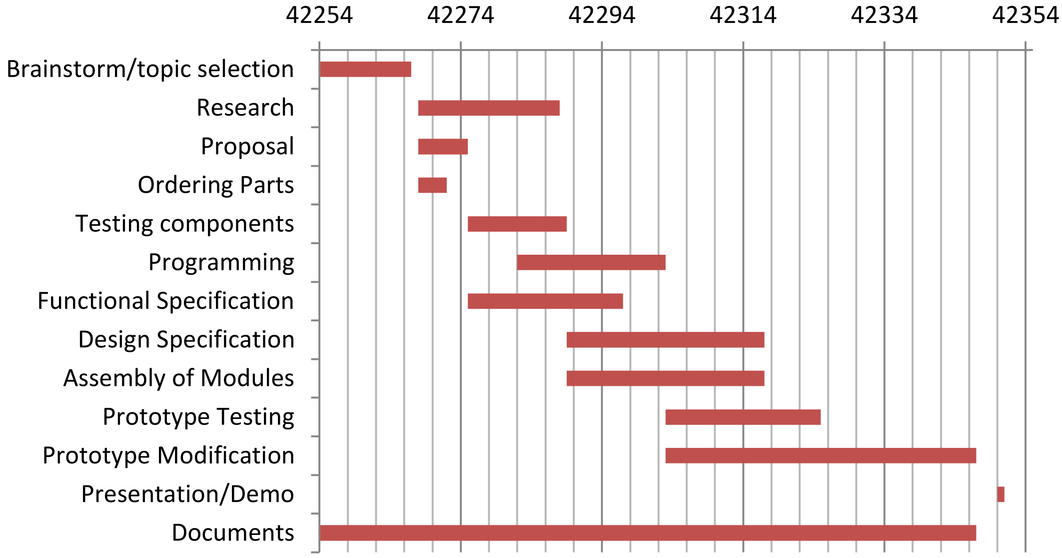

Figure 3: Gantt chart

9.2 Milestone Chart

The following milestone chart highlights all the important dates of the projects.

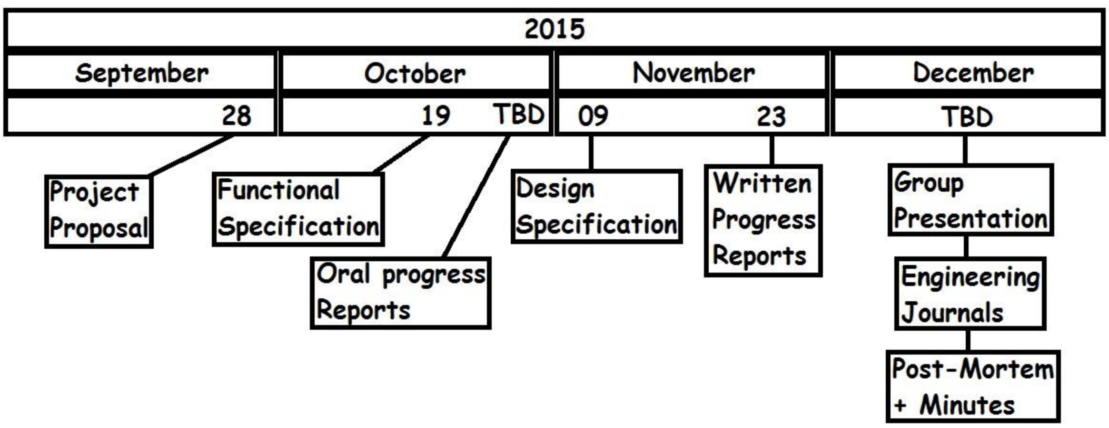

Figure 4: Milestone chart

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10. Company Organization

LocalSonic Inc. was found by Andrew Chan, Justin Crosby, Shuo Yang, Yihao Zhang, and Han Shen - five ambitious and skilled engineers from Simon Fraser University. LocalSonic believes that technology can improve the lives of many and is committed to this goal through the LGS system. This team is communicative and highly united in our vision. Every week the team will hold 2-3 meetings in order to discuss and develop ideas further. Everyone in this group has been assigned suitable job base on their individual ability and strengths.

Chief Executive Officer (CEO) – *Andrew Chan*

Andrew is a fifth year Computer Engineering student at Simon Fraser University with previous co-op experiences in Glentel Inc. and Aarcomm Systems Inc. Through work, course work, and personal projects, he has technical experience with programming in C, microcontrollers, mobile app development, and wireless communication technologies. Andrew has much experience in project management, managing projects exceeding $100,000 in Glentel as assistant project manager and co-op lead, as well as leading many school and personal group projects in the past few years. When working on projects, he prioritizes results, communication, and strong teamwork to ensure a functional and efficient team. On his free time, he enjoys a good hike or beer or both.

Chief Technology Officer (CTO) – *Justin Crosby*

Justin Crosby is a fourth year computer engineering student at Simon Fraser University, specializing in software. His work experience includes quality assurance for both embedded systems and web. Through these experiences Justin also gained skills in automation, web design, and low-level programming. Outside of school and work Justin has created a home automation system including automated lights, music, computers, and door locks, controlled with a combination of RFID and Wi-Fi. These projects and work experiences have given him a good background in embedded systems and C programming, which makes him a good fit for LocalSonic as CTO. In his spare time, Justin enjoys playing his favourite tunes on the piano.

Chief Information Officer (CIO) – *Shuo Yang*

Shuo Yang is a fifth year systems engineering student at Simon Fraser University. He was an IT technician in his last co-op term. He has strong hands-on skills and rich experience in testing and repairing hardware. He is also a quick learner and willing to learn new knowledge. Shuo Yang is very outgoing and enthusiastic; he enjoys working in a team but also can operate independently. As CIO in the group, Shuo Yang will take responsibility for how the data is processed in the project and computer systems that support the group’s goal. In Shuo Yang’s spare time, he likes to play basketball and video games.

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Chief Operating Officer (COO) – *Yihao Zhang*

Yihao Zhang is a fifth year systems engineering student at Simon Fraser University. He has finished four work terms at Broadcom. He worked as a Software Quality Engineer for the first two terms and Hardware IC-design Engineer for the last two terms. The industrial experience he gained from Broadcom are audio encoding/testing, test script development and specific PCI-Express hardware knowledge. As COO, his role is managing daily operations of the company and keeping the project on track. On the development side, Yihao will take charge of radio testing, embedded networking between emitters and beacons and mathematical solution of positioning with Andrew and Justin. His experience with Linux OS, IC-design and script development gained at Broadcom is vital for this project.

Chief Finance Officer (CFO) – *Han Shen*

Han Shen is currently in his fifth year at Simon Fraser University, majoring in Systems Engineering, and has 131/146 credits hours. As a senior undergraduate student, Han has completed two work terms that involve academic research and surgery device development. The experience he gained from his work terms are Matlab programming, openCV image processing, hardware testing, project modelling, and interpersonal skills. As the company CFO, Han is in charge of funding application, administrative duties, and hardware testing. Additionally, Han will help Andrew and Justin in developing the mathematical algorithms for positioning and assist in hardware testing.

11. Conclusion

At completion, the LGS system will be able to help the visually impaired and others navigate through a building or public area. It is designed to be scalable to any building as long as additional beacons are accurately mapped and stored in the system. The user will receive audio feedback as to how far they are away from the closest location landmark inside a building. The main components of the product include the beacon and the user device which communicate via radio.

In the marketing of the product, people who might need guidance inside a building or other public place are targeted. This system is designed to be easy to use by anyone. This Local Guidance Systems can be implemented anywhere and has much potential for growth to become a competitive product in the local positioning market. In future iterations of this project, the focus will be on guiding users to specific locations and tracking of the location of the user. These developments will not only help the visually

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impaired, but anyone who needs direct navigation to a part of a building or area.

References

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