

Department of Engineering and Computer Science, ECS
California State University, Sacramento – CSUS

CPE 190 & 191/EEE 193A & 193B Senior Design Project: Icarus

Authors: Anh Nguyen, Matthew Gorospe, Nolram Ansay, Rohit Pandit



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EXECUTIVE SUMMARY

The goal of Project Icarus is to provide a wayfinding solution aimed for those who are visually impaired but can also be accessed by others who need help navigating the California State University, Sacramento (CSUS) campus. The team came to this project idea from a meeting with Services to Students with Disabilities (SSWD). We were informed that those who are visually impaired on campus do not have many resources to go to when finding a way to navigate the campus other than a shuttle bus that drops them off at a certain location and orientation and mobility training that does not provide enough for them to navigate the campus independently. People who are not familiar with the campus also have trouble finding their way around and usually have to ask around to get directions. This project is to help provide independence in getting around the campus for people with visual impairments but also help those who are not familiar to the campus find their way to specific locations.

The team firstly wanted to design a system that can guide a person from a known location like a building, to another building. By using the main pathways of the campus, we could navigate a person, if we create a path for them to follow. Our design idea was to create a device that can instruct a user and guide them using predetermined paths. To cater to those who are visually impaired, our design would include a simple to use interface along with implementing assistive audio that can guide the user.

The Project Icarus prototype features a network of devices that help those who are visually impaired or are new to the CSUS campus with wayfinding. The Icarus team has developed two devices that can guide a user to and from preselected locations. The locations are defined by beacons signal over a region. Predetermined paths are created by strategically placing beacons along pathways and buildings of the campus and by routing beacon to beacon. Importantly, the paths that our team strategically created are widely focused in areas that most student pedestrians used to maneuver around the CSUS campus. There are two devices that a user can use - a hardware device which is suited towards those who are visually impaired, and a mobile iOS device application that can be used by anyone who needs help wayfinding. The hardware device can be worn around the belt and is supported by a strap around the shoulder. The application can be installed on any iPhone that is an iPhone 4S or newer model. Both devices initially search for a starting beacon signal. Once a starting beacon is found, a user can choose a destination among the options provided. The user will then be guided using sets of instructions that will guide a user from beacon to beacon until the user reaches their destination. Every time a user reaches a beacon, the device will update the instructions to the user on how to get to the next beacon.

If we were to expand upon this project, it has the potential to be very useful in not only the CSUS campus, but also in areas that are hard to maneuver such as theme parks and commercial areas. This device is also available for indoor and outdoor purposes. At this point in time we have met each of our feature sets for our deployable prototype. Prior to this decade people didn't understand how hard it was for visually impaired people to travel. With our device we are making people more aware of the issue while at the same time helping those who are visually impaired navigate their way more independently with our assistive device.

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End of Prototype Documentation

Anh Nguyen
ECS – Computer
Engineering
California State
University, Sacramento
Sacramento, United
States of America

Matthew Gorospe
ECS – Electrical and
Electronics Engineering
California State
University, Sacramento
Sacramento, United
States of America

Nolram Ansay
ECS – Computer
Engineering
California State
University, Sacramento
Sacramento, United
States of America

Rohit Pandit
ECS – Computer
Engineering
California State
University, Sacramento
Sacramento, United
States of America

Abstract— For our project, our societal problem is to create a series of devices that will allow the assistance of visually impaired or incoming students to traverse through the California State University, Sacramento (CSUS) campus independently. The project’s objective is to guide the user from a starting position to their destination using a set path while utilizing iBeacon technology and network communication. With our engineering skill sets, we plan to contribute into solving this societal problem by utilizing electronic hardware and software technology. In our design, we settled on a solution where we can accommodate both the visually impaired and non-disabled students. In assisting the visually impaired, we designed a portable device that has the ability to guide a visually impaired user using a Raspberry Pi microcomputer. With its ARM Cortex-A7 Quad Core processor, we are able to access the Raspberry Pi’s high end features and enable it to accomplish the task of guiding a user to their destination using Bluetooth Low Energy (BLE) and preset paths. The path consists of Estimote beacons - which have embedded iBeacon technology - that output BLE signals that can range from 1.5 to 70 meters (m). Each beacon used is stored in a database that contains all relevant information regarding the beacons. With the information on the beacons, the portable device will have the ability to create a path that leads from the user’s starting position to their destination while it outputs instructive audio to the user as they traverse through the CSUS campus. In assisting the non-disabled students, we decided to incorporate a mobile application that will cater to users who have an iPhone device. Working with the Swift programming language, we devised a user interface that performs the same functionalities as the portable device with the exception that it is leaning more towards students who are not familiar with the CSUS campus. At this stage of the senior design project, we are at the phase where the product is ready to be deployable. We achieved our objective for this project and were successful at guiding a user from their starting position to their destination on the CSUS campus. We wanted to promote awareness of assistive technology and we believe that our project has succeeded in achieving that awareness. We do not want to replace the existing tools that are used today by disabled individuals; our goal is to contribute in assisting people who lack support in the assistive technology area. Overall, our project has met our expectations and is ready to provide the needed support that the visually impaired are lacking.

Keywords—Apple, Blindness, Computer Engineering, Database, Dijkstra’s Algorithm, Electrical and Electronics Engineering, Estimote, iBeacon, IEEE Journal, Java, Market Review, Mobile Application, Parse, Programming, Python, Raspberry Pi, Server, Swift, Wayfinding.

I. INTRODUCTION

Wayfinding is a problem that every person faces in their life, but is more challenging for those who are blind or visually impaired. In a meeting with Melissa Repa, the Co-Director of Services to Students with Disabilities (SSWD), it was revealed to the Icarus team that there are not many resources available for the visually impaired to help them navigate campus besides some limited transportation services and orientation and mobility training that does not fully prepare them. The goal of Project Icarus is to provide a wayfinding solution aimed for those who are visually impaired but can also be accessed by others who need help navigating the CSUS campus. The Icarus team designed a solution that allows a way for people to be guided around campus by using easy to follow instructions that will take users from building to building.

To do this, we design a hardware device, using a Raspberry Pi 2 Model B, to guide the user to their destination the CSUS campus. The role of the hardware device is to guide the user, using Bluetooth, to their destination by following a set path. With the Raspberry Pi 2’s 900 megahertz (MHz) ARM Cortex A7 Quad Core processor and 1 gigabyte (GB) RAM, we were able to utilize its high end functionality to make wayfinding possible. On top of the Raspberry Pi 2, we incorporated into the design Bluetooth central role functionality that allows the Raspberry Pi to be the recipient for signal receiving. The hardware is utilizing Bluetooth 4.0 that operates under 2.4 gigahertz (GHz) frequency at an unlicensed industrial, scientific, and medical (ISM) band. Essentially, the hardware is receiving BLE signals that are being emitted from the beacons we are utilizing. We are using Estimote beacons that contain iBeacon technology invented by Apple which outputs BLE signals. Contained in the BLE signals are identifier values - Universally Unique Identifier (UUID), major, and minor values - that allow the Raspberry Pi 2 the capability to differentiate beacons from one another. With the identifier values that the hardware receives from the beacons, they will be use to guide the user from beacon to beacon until they reached their destination. The way the hardware will be able to identify the beacon is by accessing our third party backend database to retrieve information on the beacons. We are using a database server, Parse, which allows us to manage and modify data with its unique features. Parse has effective tutorials and documentation

that can make developing a database easier for those with no experience in database management.

Essentially, we also have a mobile application that performs the same functionality similar to the hardware device, but the solution leans towards students with no familiarity of the CSUS campus. We developed an iOS application that will only work on iPhone devices that have Bluetooth capabilities, which is the 4S model and above, and Operating System (OS) that operates at version 8.0 and above. To develop this application, we are using an object oriented programming language, Swift, to program the logic that will operate with the database and Estimote beacons. Since Apple developed iBeacon technology, iOS has access to application program interfaces (APIs) that allow easier access to programmable libraries for iBeacon technology. Parse also has tutorial that allow easy setup for an iOS mobile application, making developing the application easier for programmers.

Throughout our senior design process, we wanted to make sure that our product meets our expectations and operates the way it should. During the process, we needed to understand our problem at a technical level and how we should devise a solution while using engineering. Once we developed a strategy to solve our societal problem, our team diligently started to apply our engineering concepts to design our project. This involved developing a design idea, feature set, work breakdown structure, risk assessment, device test plan, and other concepts. The process was a definite struggle, but a worthwhile one. There were many things that we wanted to consider for our project, but the implementation of the system to the whole campus was not feasible due to the budget of the team and available time for the project. The prototype was still able to demonstrate the design idea and also meet the feature set that the team devised. Testing revealed that response time of the device to the beacon signals can take time and may need further research to get more accurate beacon regions. Further implementation of this system to the campus may need a way to maintain beacons manage system failures. This project promotes and gives awareness for the need of assistive technology and displays the power of new technology which can be used to provide accessibility and convenience for those with disabilities.

II. SOCIETAL PROBLEM

Project Icarus is primarily focusing on assisting students with visual impairment. Based on what our team knows, statistically there is a sizable amount of people who have a certain disability. According to the California State University (CSU) official website [1], CSUS enrolled about 30,000 students during the Fall semester in 2014. Within the 30,000 students, about 600 of the students have a disability. Overall, only 25 students have visual impairment. Even though the number seems insignificant, 25 students who are visually impaired is a very impacting value. With the tools that are available to the visually impaired, it is still difficult for the person to perform daily tasks without the help of others. According to Melissa Repa, the Co-Director of SSWD, CSUS has the highest number of disabled students in the CSU system, which includes visually impaired people. Knowing that CSUS enrolls many disabled students, this brought great concern that worried us. One of the problems that many students are having difficulties with is traversing the CSUS campus. With roughly over

30,000 students that are enrolled, students with disabilities have greater difficulty navigating through the campus. Usually, when the visually impaired students are given a tour, they are usually given one tour of the campus. In a way, we believe that it would be very difficult for the student to get a visual of the campus without some form of tool or method to help them remember the campus layout. Our project can provide assistance to the visually impaired and offer another assistive tool for them to use.

A. Blindness and its Effects

1) Definition of Blindness

Blindness has a very broad definition. Strictly speaking, blindness is defined as the state of being totally sightless in both eyes [2]. Blindness is usually a term that leans toward visual impairment or low vision, which means that even with eyeglasses, contact lenses, or surgery, a person still, does not have the ability to see well. Around the world, between 300 million to 400 million are visually impaired from various causes [2]. From the 300 million to 400 million people, 50 million people are completely blind, meaning they cannot see light in both eyes. Lastly, 80% of blindness occurs in people 50 years or older.

According to the International Classification of Diseases, there are four levels of visual functions [3]:

- 1) normal vision
- 2) moderate visual impairment
- 3) severe visual impairment
- 4) Blindness

When grouping moderate visual impairment, it is then consider low vision. Low vision taken together with blindness represents all visual impairment [3].

2) CSU System

Figure 1 shown below, shows the number of enrolled students in the CSU system in Fall 2014. Also the figure provides enrollment values of students who have a disability.

Campus Name	Visual Limitation	Communication Disability	Mobility Limitation	Learning Disability	Deafness	Attention Deficit / Hyperactivity Disorder (AD/HD)	Acquired Brain Injury	Psychological or Psychiatric Disability	Autism Spectrum Disorder	Temporary Disabilities	Other Functional Limitations	Services to Students with Disabilities Verified Disability	Verified Disability Total as Percent of Total Fall Headcount	No Verified Disability	Total Fall Headcount Enrollment	Total Fall FTE Enrollment	Verified Disability FTE Total
Bakersfield	5	2	23	58	2	12	5	16	6	6	19	154	1.77%	8,566	8,720	8,324.7	141.9
Channel Islands	9	2	9	52	4	72	6	45	30	3	24	256	4.35%	5,623	5,879	5,179.1	221.5
Chico	13	1	39	205	19	260	14	189	9	1	114	864	5.00%	16,423	17,287	16,251.5	782.7
Dominguez Hills	12	1	23	279	12	6	1	15	3	—	112	464	3.16%	14,223	14,687	10,972.5	337.5
East Bay	13	—	43	179	8	61	3	78	36	2	63	486	3.28%	14,337	14,823	13,017.1	408.5
Fresno	17	1	50	146	20	66	6	52	18	1	59	436	1.88%	22,743	23,179	20,138.0	365.5
Fullerton	37	2	36	161	29	191	16	178	36	102	199	987	2.59%	37,141	38,128	30,819.4	767.3
Humboldt	4	8	25	120	1	112	2	86	14	—	50	422	4.97%	8,063	8,485	7,959.6	375.5
Long Beach	37	6	106	297	28	261	24	256	62	—	254	1,331	3.62%	35,478	36,809	30,657.2	1,041.6
Los Angeles	42	11	58	231	26	79	19	135	28	13	116	758	3.10%	23,730	24,488	20,446.3	610.5
Maritime Academy	1	—	1	12	—	15	1	3	—	3	6	42	4.01%	1,005	1,047	1,124.2	39.3
Monterey Bay	6	—	28	90	6	58	3	62	21	4	42	320	4.83%	6,311	6,631	6,311.1	289.8
Northridge	39	2	107	348	158	391	30	227	74	—	109	1,485	3.70%	38,646	40,131	32,513.3	1,172.0
Pomona	18	—	39	125	16	119	1	—	20	21	87	525	2.19%	23,441	23,966	20,518.5	433.8
Sacramento	25	19	76	152	20	113	14	130	27	22	81	679	2.31%	28,670	29,349	24,098.6	531.3
San Bernardino	27	1	120	58	19	16	6	94	10	—	11	362	1.91%	18,590	18,952	16,402.4	292.9
San Diego	15	18	145	237	20	342	17	293	31	—	98	1,216	3.63%	32,267	33,483	29,814.8	1,061.7
San Francisco	37	24	46	236	10	35	—	46	3	—	585	1,022	3.47%	28,443	29,465	24,499.4	822.1
San Jose	29	56	80	406	32	—	—	—	—	—	530	1,133	3.46%	31,580	32,713	26,525.1	872.5
San Luis Obispo	13	—	21	93	11	127	8	96	5	433	93	900	4.46%	19,286	20,186	19,625.7	843.8
San Marcos	9	4	28	68	23	111	8	116	35	3	54	459	3.78%	11,695	12,154	10,154.8	358.3
Sonoma	5	6	7	148	15	154	11	80	23	52	89	590	6.35%	8,700	9,290	8,468.9	539.3
Stanislaus	9	—	16	48	6	22	4	60	6	—	31	202	2.23%	8,843	9,045	7,709.8	159.1
System Total	422	164	1,126	3,749	485	2,623	199	2,257	497	666	2,826	15,093	3.29%	443,804	458,897	391,531.8	12,468.6
International Programs	—	—	—	—	—	—	—	—	—	—	—	—	—	509	509	509.0	—
Cal State TEACH	—	—	—	—	—	—	—	—	—	—	—	—	—	794	794	710.0	—
Total	422	164	1,126	3,749	485	2,623	199	2,257	497	666	2,826	15,093	3.09%	445,107	460,200	392,750.8	12,468.6

Note: The emdash (—) represents a zero total in the above table. Numbers for full-time equivalent students may not add to total due to rounding.
Verified Disability > 3% of total headcount reported to IPEDS as of 2009

Source: CSU Enrollment Reporting System, Student (ERSS)

Fig. 1. Number of enrolled students in the CSU system [1].

As it has already been stated, there were 29,349 students that enrolled for the Fall 2014 semester. Out of the 29,349 students, 679 students have a certain disability. Finally, only 25 students from the 679 students were visually limited or impaired. As we were told by SSWD, CSUS has enrolled roughly over 30,000 students in the 2015-2016 academic year. With the large increase of student enrollment at CSUS, there is a slight chance that a handful of the students that enrolled in that academic year will have a disability and it can be a visual disability. Seeing that CSUS has a large amount of disabled students in the CSU system, this is impacting to the college campus itself because CSUS only has much to offer in terms of assistive tools to the students with disabilities. Without these assistive tools, this hinders and limits the student's college experience.

3) Available Technology

During the preliminary stages of our team's designing stage, we had to make observations of the available technology. Two items that showed up on most of the assistive sources that we looked into were braille printers and GPS systems [4].



Fig. 3. Top of the line braille printer [4].

Individuals that have severe loss of sight rely on hearing and feeling as a way of understanding their surroundings. The braille printer allows for a convenient method of producing readable text for the visually impaired. Unfortunately, this product has a high cost. The braille printer shown in Figure 2 shows a high end braille printer with a cost as high as forty five hundred dollars.

Other popular components are systems that utilize Global Positioning System (GPS), which essentially relay regional information to the user, notifying them of their general location. However, GPS is very inaccurate for short distances, and can cause harm to the visually impaired. For instance, a GPS routing system can tell a visually impaired person that there is a road 10 feet (ft) away when in actuality the road is only 5 ft.

As far as available technology, one of the common tools that visually impaired individuals utilize is the walking cane. The cane allows the person to feel the ground in their frontal area as they walk.

There's a diverse amount of resources available for visually impaired individuals ranging from certain programs or even software. There are various softwares that are capable of interpreting symbols. Many places have utilized this type of

software to allow text to speech. Colleges generally have departments that are in charge of ensuring that students with disabilities such as visual impairment are accommodated properly.



Fig. 2. White cane [5].

B. Understanding our Societal Problem

Over the course of the design project, our team was able to broaden our understanding of the societal issue to which our design pertains to. At this point of our project, we now have a better perception of the societal problem and how to accomplish the engineering solution to the problem. The solution that our team has designed, so far, is not a perfect solution to the societal problem, but it is another alternative for the visually impaired person to assist themselves and abolish their dependency on other people. There were steps taken to arrive where our team is currently and this directed us into understanding exactly how the problem affects visually impaired people and how we plan to assist them.

1) Existing Solutions

As we were designing our project, we researched several existing solutions that are available to aid a visually impaired person. With these existing solutions, this helped us understand the experiences of a visually impaired person and how our team can design a solution that can accommodate their needs. Looking into current works that are in progress we hope to broaden our insight to the problem that we are addressing.

a) RFID Tags

The European Union's Institute for the Protection and Security of the Citizen (IPSC) in Ispra, Italy designed a solution where they, "embedded 1260 RFID transponders into the sidewalks of Laveno Mombello, in the north of Italy, and linked them together in a network called SESAMONET" [6]. They are utilizing radio-frequency identification (RFID) tags [6], which are used wirelessly with electromagnetic fields that transfer data on attached objects.

In their solution, the user will have an antenna that will activate the RFID chip as the user passes over it, relaying its unique tag number to a smartphone. The phone will contain a database of navigational information that will map the tag numbers location. With that, the user will receive specific information about the position and surroundings through a Bluetooth headset.

b) Wayfindr

Wayfindr is another solution to assist visually impaired people to travel independently. They used "off the shelf" products that utilize BLE signals. They used Estimote beacons that uses iBeacon technology that transmit BLE signals [8].



Fig. 4. RFID [7].

Placing the beacons in a predetermined path, the visually impaired person is able to help navigate themselves to these beacons, eventually leading to their destination.

c) Our Approach to the Design

As we approached our design, our team needed a clearer idea of how a visually impaired person operates when they are alone. In our research, we found that people have performed numerous tests to understand how a visually impaired person operates under certain conditions. Figure 4 shows the participants who were involved in the experiment and describes the tools they were using, the city they are in, and what caused their condition. The goal of this test is to understand the experience that the visually impaired person has to endure as they act independently. The experiment also analyzed several navigation strategies that a visually impaired person uses as they face unexpected obstacles. When reading this document, we realized that the visually impaired person needs to have some form of visual representation or picture of the area that they are traveling. In our design idea, we believe that we need to



Fig. 5. Estimote beacons [8].

be able to give a good understanding of the CSUS campus layout. Once the person has the understanding of the layout, the visually impaired person can navigate themselves without assistance. This involves us searching for paths that may cause problems for the person when they travel alone through the campus. This will be an effective way to assist the person because we will be dictating to them obstacles that may hinder their navigation to their destination. This way, they can feel at ease when they traverse the campus knowing that they have something guiding them along the way. A

similar implementation, we want to incorporate that was utilized in Wayfindr is to have predetermined spots that the user can go to using “signals” as their guide to navigate the campus. This will, in turn, reduce the chances of getting lost, knowing that the way points will guide them to the correct location.

ID	Sex	Age	Aid	City	Vision Impairment	ID	Sex	Age	Aid	City	Vision Impairment
C1	M	23	Cane	Suburban	Continued vision loss since age 14	C16	F	59	Cane	Suburban	Blind from birth
C2	M	27	Cane	Urban	Blind from 6 months	C17	M	60	Cane	Suburban	Blind from age 3
C3	F	28	Cane	Urban	Continued vision loss since age 8	C18	M	60	Cane	Urban	Blind from birth
C4	M	30	Cane	Rural	Blind from birth	C19	F	64	Cane	Urban	Continued vision loss since 20's
C5	M	30	Cane	Suburban	Born legally blind	C20	M	75	Cane	Rural	Blind from birth
C6	F	36	Cane	Urban	Light perception to total from age 24	D1	F	28	Dog	Urban	Blind from birth
C7	M	42	Cane	Urban	Blind from birth	D2	M	47	Dog	Rural	Legally blind to total from age 24
C8	F	45	Cane	Urban	Color perception to only light at age 44	D3	F	48	Dog	Suburban	Low vision to total from mid-30's
C9	F	45	Cane	Suburban	Blind from birth	D4	M	48	Dog	Suburban	Low vision to total from age 24
C10	M	48	Cane	Urban	Blind from birth	D5	M	56	Dog	Urban	Sighted to continued vision loss
C11	F	49	Cane	Urban	Blind from birth	D6	F	60	Dog	Urban	Blind from birth
C12	F	50	Cane	Suburban	Continued vision loss since age 30	D7	M	62	Dog	Urban	Blind from birth
C13	F	55	Cane	Rural	Low vision to total from age 9	I1	M	29	In-Transition	Suburban	Blind from birth
C14	M	55	Cane	Suburban	Blind from age 2	I2	F	38	In-Transition	Urban	Blind from birth
C15	M	56	Cane	Suburban	Low vision to total from age 8	I3	F	41	In-Transition	Urban	Blind from birth

Fig. 7. Number of participants in the experiment with data pertaining to them [9].

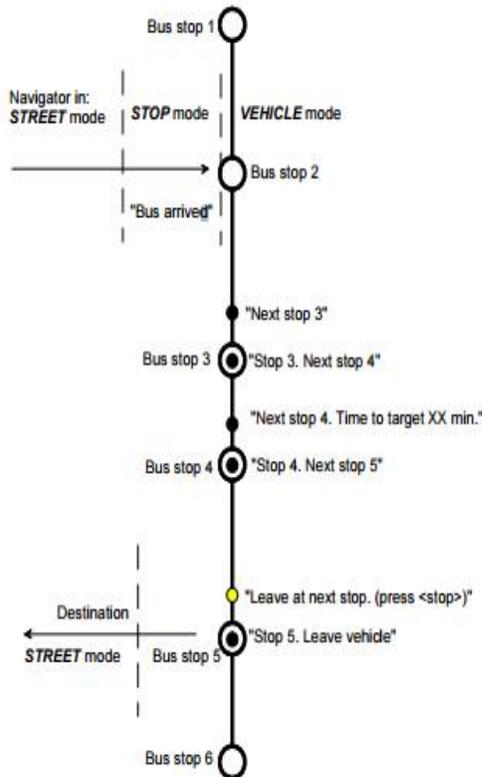


Fig. 6. NOPPA [10].

NOPPA: Navigation and Guidance System for the Blind in Finland is a 3 year project for personal navigation system for the visually impaired. NOPPA is part of Ministry of Transport and Communications Finland's Passenger information program that helps to improve the accessibility of public transport information. Since a visually impaired person is heavily reliant on hearing, it is important to create a device that is complementary to their everyday practices to help ease their travel [10]. The Figure 7 above represents how the NOPPA system works in Finland to where a visually impaired user can get to a bus station and tell the bus when to stop, walk out and reach their destination. NOPPA called this the "unbroken trip chain" since the user is being guided through a predetermined path. After reviewing this document, we noticed that this system is very similar to Wayfindr and we want to incorporate their idea into our own. NOPPA is using a mobile application that can aid a visually impaired person to their destination. Their system contains a server that stores necessary information on how to guide the user correctly. Since most visually impaired people have access to smartphones, we can use the functionalities of smartphones to offer assistive guidance to them. There are already existing functionalities in smartphones that are user friendly for visually impaired people, but we want to be able to go beyond what is available on smartphones and develop a solution where the visually impaired can use their smartphones more often and guide them to their destinations on a daily basis.

III. DESIGN IDEA AND THE FEATURE SET

A. Design Idea

In our research, there were existing products that help guide visually impaired people to their destinations. But, the one that captured our attention was the Wayfindr [11], a beacon device created by engineers in London, who are involved with the Royal London Society for Blind (RLSB) that guides people accurately to their destinations by speaking to the user.

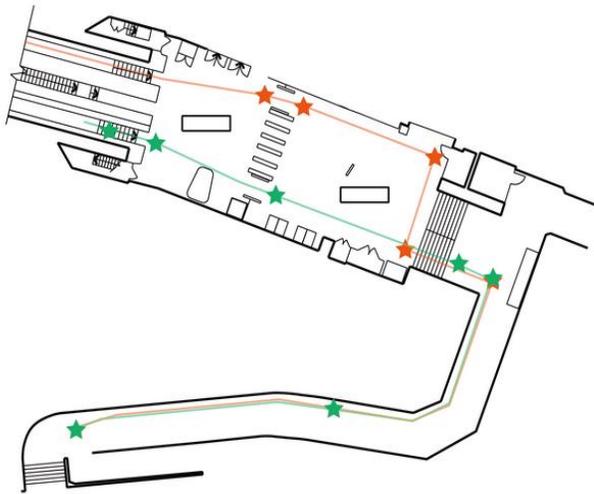


Fig. 8. Map of the London subway station with beacon locations [11].

How the Wayfindr works is that it has several beacons placed in certain locations, which in their case is the London subway station in Figure 8. Each beacon is different than the other when it comes to giving directions. Meaning, each beacon will have a certain way of reaching that beacon.

For example, taking the stairs or walking a few feet to the next beacon. The beacons are used to tell the user that they have reached the designated beacon and are getting closer to the destination. Wayfindr uses a mobile application that guides the user through the beacons. The user will have an audio device connected to the mobile application so that they can hear their current location and direct themselves to the next location. The mobile application will then tell the user through the audio device which beacon to go to. Once the user reaches their pinpointed beacon, the beacon will then sound off, notifying the user that he/she reached their first destination. The user will continue to navigate through a series of beacons until the user reaches their final destination.

By observing this knowledgeable approach, we want to design a solution that is very similar to this. We want to use numerous beacons that will guide the students on campus to his/her chosen location. Like Wayfindr, each beacon will have a specified way to getting to the beacon depending where the beacons are placed. To figure out where to place the beacons, we would need to survey the CSUS campus to find possible locations to place our beacons. In our design, the iBeacon will communicate with both the mobile application and hardware device, which will direct the user to the beacons and lead the user to his/her destination. The devices will continue to direct the user to each beacon until the user reaches

their destination. Additionally to our project, we want to be able to find the shortest path possible to the chosen destination by the user. One way to approach this problem is to measure the distances to every possible location on campus. Once we figure out the distances in each location, we will implement a computer programming algorithm that will calculate the shortest and fastest distance to each destination. This is efficient to our design because there are dozens of possible routes that a disabled or non-disabled student can take to get to their destination. This routing algorithm primarily focuses on finding the fastest and shortest path, which is perfect for what we want to implement in our design. This will save time for the person that is navigating through unfamiliar territory. Just like Wayfindr, we will use an audio device or output to speak to the user. We will incorporate sounds that will alert the user that he/she is either getting closer to the pinpointed beacon or has reached the beacon. The sounds from the audio device will help the disabled student know that he/she reached their chosen destination.

In large, the approached idea is well-organized and effective. The ideas that have been brought to mind are very efficient and easy for students to travel around campus. The solution we thought of fit our qualifications and these ideas apply to our design. There are other possible designs, but we will implement what we have and if possible, add the other solutions we have discovered that may help with our design.

1) Mobile Application

In this design, we want to implement a mobile application that will allow the user to communicate with the beacons. There were many solutions that can be implemented into our application, but our main focus is to keep it simple enough where the person can use it without complications. The application will be programmed in the iOS platform for users who have an iPhone mobile device. The application will be programmed in an iOS programming language familiar to our group, which is Swift. Another iOS programming language, Objective-C, can be implemented in our design as well if the situation arises. Mainly, our application will be using the Swift programming language because of its simplicity and familiarity. Overall, the application can be used by either disabled or non-disabled students.

The way the mobile application will work is that it will ask or prompt the user for a location to go to. The user will have a list of locations where the user can choose from. Once the user has chosen their destination, the application will analyze and choose a path that will be the fastest and shortest route to the user's desired location using a routing algorithm. The routing algorithm data will be stored in a server where the mobile application will have access to and be able to manipulate the data. With the routing algorithm, the application will get the routing data and navigate through the necessary beacons that the algorithm calculated. Once the user starts making his/her way to the destination, the mobile application will notify the user if he/she reached the pinpointed beacon that leads to the chosen location. The way that the user will know if he/she reached a beacon is through an alert sound or some sort of audio output. When the user finally reaches the beacon, an audio output will notify the user of its current location. The mobile application will continue to guide the user through each pinpointed beacon until the user reaches the desired location.

In our application, we are integrating many possible features that will mainly tailor to non-disabled students. In the application,

instead of having a map of the CSUS campus, it will have a list of all the buildings on campus for the user to choose from. This will make it easier for a visually impaired student to use because they have no knowledge of the map, making it difficult for the blind student to use the application. By making it a list than a map, the user can pick from the list of buildings on campus and the application will find the quickest route to the chosen location. But, the most crucial part of the mobile application is the routing algorithm. This is how the user will actually get the routing information to the location. The routing algorithm will have to calculate the shortest and fastest path out of all the possible paths that can be made to get to the chosen location. The efficient aspect of the routing algorithm is that there are many short and fast paths that can lead the user to his/her chosen location, but essentially it will pick the best one. However, there are certain constraints that make implementing the algorithm very difficult. One of the challenging aspects of the routing algorithm is actually programming the algorithm. There are many possible locations to consider when programming the algorithm. So, there is a large room for error and it can make programming the application very difficult to do. Another problem that can arise in the application is if the data is not received correctly from the database. Even with careful testing, something can still go wrong when it is actually implemented. If it obtains incorrect information from the server, the user will get incorrect directions to the beacons and the user will not get to the destination accurately and it would waste time, which defeats the purpose of the application. The least probable cause would be if the application crashed. If the application were to crash for any reason, we would have to find the malfunction in the program and figure out a solution.

There are many other solutions and ideas that can be applied to the mobile application, but the ideas mentioned are what will constitute the design of the application. The ideas targeted the main points of what our application should be doing for the user. Throughout the programming process, there will be a possibility that other ideas will be employed into our design, but again, our application will be as simple as possible for the user to use. The goal for the application, overall, should be able to direct the user to the beacons and destination in a fast and safe manner.

2) *Dijkstra's Algorithm*

Created by Edgar W. Dijkstra, Dijkstra Algorithm is a routing algorithm that calculates and formulates the shortest path from one position to all possible positions [12]. There are many routing algorithms that can be used in our design, but Dijkstra's Algorithm

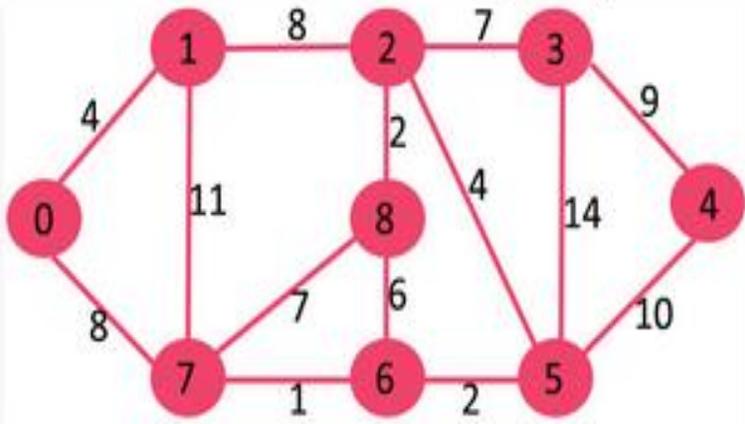


Fig. 9. Implementation of Dijkstra's Algorithm [12].

is simple and easy to implement because the concept is familiar in our group and we understand how to apply it. It is one of the most popular algorithms that are used today as a basis of learning and implementation. And as a short routing algorithm, this will calculate the shortest route possible out of all the possible routes that are available on the CSUS campus, which is one of the goals that our design should achieve. So, we will use this particular algorithm for this mobile application because it is guaranteed a shorter and faster path.

As it is already mentioned, the algorithm will generate a short path to a destination of any choosing. Wherever the user's starting and end point is, the algorithm will create a path in a short and timely manner. In Figure 9, it demonstrates the implementation of Dijkstra's Algorithm and possible routes.

How the algorithm works is it develops the shortest path by generating the shortest path tree (SPT). The SPT will contain two sets, one set that contains vertices in the SPT and the other set will have vertices not in the SPT. In every step of the algorithm, it will find a vertex in the set with no vertices and has the minimum distance from the starting point, which is referred to as the source.

In detail [12], this is how the algorithm is actually performed:

- 1) Creates a set that keeps track of the vertices in SPT, whose minimum distance from the source is calculated and finalized. From the initial start, the set is empty.
- 2) Assigns a distance value to all vertices in the input graph. Initialize all distance values to infinity. The reason the value is initialized to infinity is because it is easy to cope in situations where the problem is not feasible [13]. Meaning, there is no path from one spot to another. So, if there is no direct link from one spot to another, then it is equal to infinity. Then we assign a value 0 to the source so that it signifies the starting point.
- 3) While the set does not include all vertices
 - A) Pick a vertex which is not in the set that has the minimum distance value.
 - B) Include the vertex in the set
 - C) Update the distance value of all adjacent vertices. To update the distance values, the algorithm would iterate through all the adjacent vertices. For every adjacent vertex, it would have to do a mathematical calculation to find the value with the least distance from the source and update the set.

Generally, this is the most crucial and important part of our design. The goal, again, is to find the shortest and fastest path to the user's destination without the user having to think of a possible route. This algorithm should handle majority of the work and hopefully direct the user to the destination correctly. Since our group is dealing with possible routes on the CSUS campus, it will be a challenge to program this algorithm. But, this algorithm, by far, is the most efficient way of finding a path without difficulty.

3) *Surveying and expedition of the CSUS Campus*

Our project will require a survey of the campus of where we can place our beacons and what areas we want to landmark for those using our device. This will essentially determine the paths for the visually impaired person. We need to find paths that are possible for the visually impaired person to navigate through. As we survey for possible spots on the CSUS campus, we want to make sure that the path is manageable by the visually impaired person and he/she will be able to follow the path. We are not going to choose paths

that will lead them unnecessary territory like grass or rock filled grounds. It will mainly be clear paths that will lead to their destination as simple as possible.

4) Software and Computer Programming

a) Xcode

Xcode will be the primary software compiler for creating the mobile application for our device [14]. This application will contain a list of the campus buildings for those who want to use the device for help in navigating the campus. The application's main purpose will be to aid the non-visually impaired and will feature audio output that will play when passing a beacon. Xcode is an Integrated Development Environment (IDE) made by Apple and is used to create applications for Apple products using iOS or OS X such as the iTouch, iPhone, Macbook, or iPad. This program also features a suite of software development tools that can be used in the application [15]. One of the tools included is the interface builder, which allows the user to map out the application being made. This feature allows the user to keep track of what the application interface will look like if a person downloads the application and uses it. Xcode is currently on version 7.0 and supports many different programming languages such as C, C++, Java, Objective-C, and Swift.

b) Swift iOS Programming Language

Swift is an object-oriented programming language created by Apple and is used for platforms such as iOS, OS X, and watchOS [15]. Swift will be primarily used in our project to create an application to be used on the iPhone device. If there is a need, we can also incorporate Objective-C iOS programming language into our application. Both languages can be used in coherence with each other even though they have different syntaxes. The programming language syntax and style has influences from C and Objective-C. Swift also has a new iteration called Swift 2.0, which further improves the Swift programming language [15]. Again, Swift is going to be the main programming language we use when utilizing Xcode because of its simplicity for beginner programmers.

5) Electronic Hardware

a) Python Programming Language

Python is an interpreted, object-oriented, high-level programming language with dynamic syntaxes. With its high-level implementation and dynamic syntaxes, it makes it powerful for Rapid Application Development, as well as for use as a scripting language to connect existing components together [16]. Python is a programming language that is easy to learn and understand and it will be our primary tool in programming the logic in our hardware because we utilize extra hardware in our design that needs a script for it to make it functional. This is something our team learned as we design our project, but Python is an effective and powerful programming language to use in our project.

b) Bluetooth

Bluetooth is a way for devices to communicate wirelessly. It operates at the range of 2.4 to 2.485 gigahertz (GHz) in the industrial, scientific, and medical (ISM) band and used to exchange data over short distances. Bluetooth was invented in 1994 by Ericsson. This technology runs on low power and is very secure.

Devices with Bluetooth functionality can connect to each other by "pairing" as long as the devices are in proximity. The devices

create an ad hoc network, which users can enter and leave. Each device can also connect to seven other devices in the network and connect to several networks at one time. [17] Bluetooth has adaptive frequency hopping capability that reduces interference with other devices using the same spectrum by adjusting the frequency of the signal in the range of the band at 1 MHz intervals. The operational range of Bluetooth depends on the class of the radio used on the device. The most common class is Class 2 that has a range of 10 m and use about 2.5 milliwatt (mW). This shows the low power consumption of Bluetooth technology.

c) Hardware

We have several choices for what we want to use as part of our hardware section. We will primarily be working with the Raspberry Pi 2 Model B, which has 1 GB of RAM and an ARM Cortex A7 900 MHz CPU. How we will be implementing is by using multiple adapters to actually enable Bluetooth scanning and an internet connection to the database server. We will then need to figure out a program to run through the Raspberry Pi to make this all mesh together. That means we will need to find specific libraries that actually enable Bluetooth scanning on the Raspberry Pi such as "PyblueZ." We will also need to configure the Raspberry pi to actually connect to the network, since our project requires that the device be connected to the internet in order to access data from the server. We will be utilizing the ASUS Bluetooth adapter and the Edimax Wi-Fi adapter. There are multiple programming languages that we could implement into the hardware, but we will most likely be choosing Python since it will be much easier to integrate than using C language.

One of the unique aspects of our project is that we will have digital landmarks. By using iBeacon technology, we will have the Raspberry Pi recognize the signal and be able to differentiate between regions of the campus and also be able to assist anyone who is trying to navigate the campus. We will be using Estimote beacons that utilize iBeacon technology for the Raspberry Pi to recognize. The iBeacons that we have seen on the market have a range of 40 to 70 m approximately [18]. With that constraint we now have an idea of how many we might need when we survey the campus. All the beacons will act as a network that will give the Raspberry Pi an idea of which region they are in [19].

B. Feature Set

Obviously, the project's goal is to guide a visually impaired or non-disabled student to their destination without any form of assistance. In our feature set, it includes aspects that will help design our project:

- 1) Common Database
- 2) Region Beacon Awareness
- 3) Assistive Guidance
- 4) Visually Impaired Assistive Guidance

Each feature has a specific concentration that will play a part in solving our societal problem. At the same time, they are broken down to further levels to explore their functionality and responsibilities that will be involved in designing each level.

The common data base is a very important section of our project. We are using a third party backend, Parse, which provides free data storage and management services. We will be storing important beacon data within the server. The portable device utilizes REST API which is a programming protocol that allows us

to get responses from the Parse server. A network connection is needed to allow this type of communication to occur.

Each of the Estimote beacons is positioned to cover a specific region of the campus. So with the instance the user comes into a region of a beacon, the mobile application and the portable device should notify the user of where they are and what they need to do to get to the next beacon. The beacons have maximum optimal range of transmitting. In our project we will be using settings that are below 50 m.

Our project is essentially divided into two areas, the mobile application and the portable device. The mobile application is geared towards new and incoming students that are unfamiliar with the campus. The application currently operates on the iPhone which utilizes Bluetooth and Wi-Fi in order to function properly.

The portable device is geared towards visually impaired users. The most important part of this area of the project is that the instructions are given in an audio format. Since the user type for this device is the visually impaired, it is very important that we assist them in the most efficient way possible.

The feature sets shown in the “punch list” on table 3 provides a description to the functionality of each feature and the metrics behind them.

Feature Set “Punch List”

Table 1

The “punch list” for the feature set

Feature Set	Metric
Common Database	The database will store information of the beacons used. Both the mobile application and portable device will access the common database and be able to retrieve the same information.
Region Beacon Awareness	The beacon will output a signal that both the mobile application and portable device can receive to identify and discriminate between different beacons.
	A beacon will represent a region that the mobile application and portable device will detect and will be at least 70 m away from a building or area associated with the beacon.
Assistive Guidance	The application can access the common database to retrieve beacon information.
	The application can guide a user from a starting beacon transmission region to an end beacon transmission region by providing a predetermined path and giving sets of instructions to prompt a user to reach each preset beacon region until a user arrives to the beacon region selected. The user will arrive to the destination once receiving the transmission signal of the end region beacon.
	The application will only work in the proposed

	area and only along the main pedestrian pathways of the selected area.
Visually Impaired Assistive Guidance	The portable device can access the common database to retrieve beacon information.
	The portable device can guide a user from a starting beacon transmission region to an end beacon transmission region by providing a predetermined path, incorporating assistive audio, and giving sets of instructions that are accessible to those who are visually impaired to prompt a user to reach each preset beacon region until a user arrives to the beacon region selected. The user will arrive to the destination once receiving the transmission signal of the end region beacon.
	The portable device will only work in the proposed area and only along the main pedestrian pathways of the selected area.

IV. FUNDING

From entering the first semester of our senior design course we understood that moving on with our project that we would have to spend a certain amount of money. These are the many things to consider when making decisions within the senior design process. With four full time engineering students that were working with minimum wage jobs, we basically had a very slim budget to work with.

We saw that there were several opportunities to apply for funding opportunities but some of the issues that we ran into are that these grants weren’t going to begin until after the first semester of senior design. This was until we found out about the University Enterprise Incorporated (UEI) Grant program. Our team had attended the orientation to find out more about the grant. The UEI grant program is one of many CSUS opportunities for campus projects, which fortunately enough, applied to our senior design project. We followed through with the application process and in the end we actually were approved for seven hundred dollars. We would really like to express our appreciation and gratitude to the UEI department for giving us this opportunity.

The project was inexpensive in terms of cost. The table below shows the prices of all the components that our team used in the project.

Components List

Table II

The list of components and cost need for the project

Items	Cost
4 Estimote Beacons	\$500
Edimax Wi-Fi dongle	\$9.95
ASUS Bluetooth dongle	\$25.99
PiTFT Plus 320 x 240 2.8" Screen	\$44.95
Raspberry Pi 2	\$37.99
DE World Battery Pack	\$19.99
Total	\$638.87

V. PROJECT SCHEDULE AND MILESTONES

The group has made great progress and we have completed the project by implementing approximately 1000 hours within the past year as a group to complete our tasks. The tasks that need to be completed for our project include an Assistive Guidance system, Visually Impaired Assistive Guidance System, Common Database, and a Region Beacon Awareness. The tasks needed to be done for the project are split between the team and a project timeline was made to manage the tasks.

A. Project Schedule

1) Assistive Guidance

Anh Nguyen, who is one of the Computer Engineers in the group, will be responsible for handling the software and hardware aspect of the Assistive Guidance of the design. The aspects from the Assistive Guidance will include a user interface that the user will use, data manipulation from the server, communication with the beacons, and a mobile device that will implement the user interface.

a) Software

In the software feature of the design, we are creating a user interface that will be in a form of a mobile application. In the first phase, the mobile application will be programmed in the Swift programming language, which is used for the iOS platform. The mobile application will be programmed on application developing software called Xcode, which is only available on Apple computers. Essentially, the role of the application is to obtain routing data from the server and guide the user to his/her destination. In the end, the user interface will be created using a programming tool and it will communicate with the server to retrieve routing data so it can be used to guide the user to their destination.

b) Hardware

With respect to hardware, the only hardware that is being involved in the design with respect to the Assistive Guidance is the mobile device. We will be using an iPhone device to utilize our iOS mobile application. The only thing that the Assistive Guidance needs to do is work in parallel with the beacons. The core of the hardware will consist of the Raspberry Pi.

c) Communication

The objective of this aspect is to communicate with the server, which contains all the routing information needed to guide the user to their destination. The mobile application will communicate with server so that the server can relay information to the application. Then, the application will use that data, manipulate it, and guide the user the respective destination. Generally, the application will use an algorithm that will calculate the path to the user's destination in a fast and short manner.

2) Visually Impaired Assistive Guidance

The hardware aspect of the project will be handled by Matthew Gorospe, who is the Electrical and Electronics Engineer of the group. This will essentially be the counterpart of the mobile application, but more geared towards the vision impaired. The guidance will engage the user to interact with the device; with a request to a specific building.

a) Physical Device

This area of our project will assist the user on getting to where they need to go. We will be using a controller to manipulate the data stored in the server. During the testing phase, we will be using a Wi-Fi shield and a Bluetooth shield that enables communication among the Estimote beacons and directional storage server. We plan on having the device fully wearable and self-powering.

b) Audio

We will be implementing a speaker on the physical device for the user to receive the directions. The directions will be stored onto the server, where the controller will retrieve the requested directional file. These files will be pre-recorded into certain files.

c) Power

For the first phase, testing our controller will be hardwired to a power source. We will be researching a proper battery source that will be an efficient choice to allow the device to be self-powered. The more shields that we add to our device, the more power we need to account for. We are thinking about a 9 volt (V) battery or possibly something smaller.

d) Form

The majority of the hardware will be located on the breadboard. Our plan is to design a compact version of the first phase prototype. This will be the overall presentation of the wearable device. We have plans on implementing a voice recognizer by using a voice shield. This will be the general interaction from the user to device.

e) Communication

The device will need to communicate with the Estimote beacons through lower power Bluetooth; the proximity data will be utilized here. The device will be acting as a medium between the beacons and the server. The device will be using a Wi-Fi shield in order to retrieve data from the server.

3) Common Database

Rohit Pandit, who is another Computer Engineer in the group, is responsible for implementing the Navigational Routing Server. This server will incorporate all the routing information to help both the blind and new students in the California State University, Sacramento (CSUS) campus navigate to their desired location.

a) Setting up the host

In order to work on the server, we have to setup the server system. This also includes learning the code to implement the server and researching different types and applications.

b) Database Management

Database management is another skill set on its own and there is currently more research that needs to be done on this section for our group because we still have very little experience with database management. The database management system will help allocate information about the beacons to the wearable device and mobile application. The database management will also need to be updated with the additional beacons during the second phase of the project.

c) Surveying Campus

As a group, we will need to survey the campus to locate the best locations to place our beacons and make sure the beacons are in a safe and reliable location that has very minimal obstruction area. As of now, we will be using the Engineering building to place our beacons and test our design. In the second phase, we will survey the different parts of the CSUS campus to incorporate and challenge our project.

d) Communicating to the Interface

Once the server is complete, we will need to connect the information with the Blind Directional Guidance and Assistive Guidance to provide the user with the correct information. The server will be communicating with both the Assistive Guidance and Blind Directional Guidance so users can retrieve a faster feedback

4) Region Beacon Awareness

Nolram Ansay will be in charge of the beacons and communications to the devices. He will be working on the application with Anh to get the beacon to send information to the application and Matthew to get the wearable device to take information from the beacon. He will also work on the server communication to both the application and the wearable. His main focus will be the communications between the devices and making sure the beacons are working as needed. The beacon product is already researched and purchased.

a) Hardware

Since the beacons are off-the-shelf, the first few tasks are to test the products and check the functions provided in the product and ensure the product will provide us what we need in the project. Some of the functions are power, range, and Bluetooth connection. These functions need to be tested and then integrated to the User Interfaces (UI); to ensure the entire project works. To take advantage of the product, we must make sure we know all the capabilities of the product. Once we are familiar with the product, all that is needed is to make it work with our own UI. If needed in the next phase, the team will try to find other products that will enhance or improve what we already have in place.

b) Software

Not much software is involved with the beacons itself other than using the software made for the product to adjust the settings. The beacon comes with a SDK, which will be used to create the mobile application and provide communication with the wearable device. Some software will be involved for the communication aspect,

which includes Xcode and Java. It will also need the Python for the Raspberry Pi. It will be done once we ensure those devices get the proper data needed to function.

c) Communication

Communication will be the most important part of the project. Without the beacons, the UI will not work at all. The beacon devices must be able to effectively communicate to both the wearable device and the mobile application. The beacon needs to send the correct data like UUID and distance. Most of the first phase will be making sure the beacons can communicate to the UIs. The beacons must be configured to send the right information, and the UIs will need to make sure they can receive and use the information that is being sent. Both of the phases of the project will consist of testing the communications between these devices and the server and also trying to improve them.

d) Power

Power is not much of a problem for the beacons because the beacons already come with battery power, which is advertised to last about three years. It would be beneficial to test the product and make sure the product can at least last a year. The team will run a few tests for the beacons and test battery life for verification.

*B. Milestones**1) Assistive Guidance*

For our group to implement the Assistive Guidance, Anh Nguyen met its functions by breaking down the tasks into the following sections

a) Communication

A very crucial part for this section includes establishing a communication between the assistive guidance and the common database. Without this feature we would have not been able to guide a user to their destination. The application is able to communicate with the database and beacons in the project. This process took about 21 days to complete

b) Software

The software section was very critical, we had to code a routing algorithm, establish communication, create a voice prompt, and include a user interface. We were able to create the desired user interface for the project and is fully functional. This process took about 145 days to complete.

2) Visually Impaired Assistive Guidance

For our group to implement the Visually Impaired Assistive Guidance, Matthew Gorospe met its functions by breaking down the tasks into the following sections.

a) Microcontroller

Locating the perfect microcontroller and coding it to include the routing algorithm, and establish a communication to the common database for this project was a process that took longer than we expected and put our group behind. We tried a variation of microcontrollers until we were able to locate one that had a central role. After choosing the final microcontroller, we were able to design the functions needed to complete this aspect and is fully functional. Being able to establish a microcontroller that would fit for our project took about 120 days to complete.

b) Communication

The communication process was another section that helps our visually impaired assistive guidance and our common database to communicate. Without this feature we would have not been able to guide a user to their destination. The hardware has access to the server and is able to retrieve information from the database. This process took about 11 days to complete.

c) Power

A key point that we wanted for our visually impaired assistive guidance was for it to be portable. In order to achieve this we had to find a portable power source. We wanted the power source to last approximately 8 hours. To accomplish this we tested 3 different batteries that were easily accessible to us. In the end, we were able to find a suitable battery pack that meets the required 8 hour school day. Testing the 3 different power supplies took about 17 days.

d) Form

Setting up how a user will be able to carry the visually impaired assistive guidance was important because we wanted the user to feel comfortable and be able to easily hold the device, especially since they needed 1 hand free at all times. Overall, we were able to build a casing that is portable and easy enough to carry around. Building the form to make the device portable took about 21 days.

e) Audio

The audio system is a process that was worked on last since this was a feature that was important. We wanted to make sure that the voice was efficient and clear enough for the user to understand as they traverse the campus. So, we were able to provide voice audio on the hardware and is able to provide and clear and understandable instructions to the user. This process will help the user listen to where to go. This process took about 20 days to complete.

3) Common Database

For our group to implement the Common Database, Rohit Pandit met its functions by breaking down the tasks into the following sections

a) Setting up Host

For our visually impaired assistive guidance and assistive guidance devices to help navigate a user we had to implement a server which contained a database. We were able to set up a server by creating a user account for our server and having access to the data. Setting up the host took approximately 1 day.

b) Database Management

Now that the Server was setup we had to input the information we wanted to store in it. The information that was stored includes the beacon name, a UUID, Major and Minor values, as well as the adjacent edges for each beacon representing how far the other beacons are from the current beacons location. Overall, we wanted to be able to manage our data and with the features of the Parse server, we are able to modify and manage our data. Setting up the database took approximately 44 days.

c) Communicate to User Interface

Now that the information was placed in the common database we were able to transfer this information to the visually impaired assistive guidance and assistive guidance devices. We verified this

by outputting the response of the server of both devices to a computer terminal. This process took approximately 32 days to set up on both devices.

4) Region Beacon Awareness

For our group to implement the Region Beacon Awareness, Nolram Ansary met its functions by breaking down the tasks into the following sections

a) Purchasing beacons

For our region beacon awareness we needed a device that was based as a peripheral hub, something that could transmit information. Essentially, we decided on the Estimote beacons because the device was able to provide the necessary functions needed for the project. Researching and purchasing this device took approximately 30 days

b) Hardware

Now that we purchased the beacons we had to test the beacons functionality, and make sure that it was able to get picked up by our visually impaired assistive guidance and assistive guidance devices. We were successfully able to transmit a signal from the beacon so that it can be received from both devices. This was accomplished by using the Estimote application to control the settings on the beacons. This process took about 30 days

c) Software

After the devices were able to pick up the beacons we had to test how reactive the beacon was and know what range to set the beacons at. When we performed the necessary tests on the beacons, we were able to find the values needed to configure the transmission region values for the beacons so that both the application and hardware can receive the signal. Configuring this on the beacons took approximately 21 days

d) Power

Once we were able to set a range of knowing when to pick up a beacon, we had to test what the most optimal power settings were. The beacons have different ranges between 1.5 m to 70 m, the higher the range the more power it is consuming. Keeping the beacon at 70m they will last for approximately 3-4 years. So keeping it at a lower range not only increases its power, but also increases its accuracy and lifespan.

VI. PROJECT WORK BREAKDOWN STRUCTURE (WBS) AND SCHEDULE

Associated with our project is a feature set that will aid us in solving our societal problem. Mainly, our Work Breakdown Structure (WBS) breaks down our feature set to different levels that will accommodate our engineering solution and the team's skill set. The WBS focused on the most important aspect of the project, which is assisting the visually impaired and non-disabled students navigate through the CSUS campus through electrical and computer engineering. Much of the focus of the WBS is pertaining to the hardware and software aspects of the project, but every feature in our project plays a role in forwarding our design.

A. Breakdown Structure

In table 4, it shows the overall breakdown structure of our design for the project. The features mentioned on the table primarily focus on the hardware and software aspects of the

project. As mentioned, these features are broken down further to their sub-levels so that our team can explore how to approach the design in hardware and software.

Work Breakdown Structure

Table III

The level breakdown of the design

Level 1	Level 2	Level 3
Network 1	1.1 Region Beacon Awareness	1.1.1 Hardware 1.1.2 Software 1.1.3 Communication
User Interface 2	2.1 Visually Impaired Assistive Guidance	2.1.1 Microcontroller 2.1.2 Bluetooth 2.1.2 Power 2.1.3 Audio 2.1.4 Form 2.1.5 Communication
	2.2 Assistive Guidance	2.2.1 Hardware 2.2.2 Software 2.2.3 Communication 2.2.4 Calculate Shortest Path
Data and Information Handler 3	3.1 Common Database	3.1.1 Setting up Host 3.1.2 Communication to User Interface (UI)

locations that will incorporate several buildings at one point. We will strategically position the beacons to designated zones of the CSUS campus that will allow the beacon to transmit data to the application or wearable device with the least amount of interference and the appropriate range. We will also be taking into account for trees and proper elevated areas. Some of the things we will consider when purchasing a beacon will be the following:

- Communication type – Bluetooth.
- Reliability in sending data, range, and size.

Much of the hardware research has been done, so our objective is to decide where we need to place the beacons so that they can operate correctly with the wearable device and mobile application.

b) Software 1.1.2

As far as software is concerned, the only thing needed for the beacon in terms of software would be to program the beacon for certain specifications such as range and ID used to differentiate the other beacons. Since we will be using some type of product for the beacon, we will be utilizing software that is compatible with it. The beacon only needs to send information, so there will not be any computer programming for receiving any data. The mobile application and wearable device will be performing majority of the work

c) Communication 1.1.5

Communication by the device depends on what off-the-shelf product we will be using. The option we are planning on going is through Estimote beacon with Bluetooth communication. This allows for a decent range in “walking ranges” of 40 to 70 m. This is good for our implementation in which we will be using several devices in certain proximity from each other and are also ranged long enough for a user to get from one general location to another; for example, going from the center of the library quad to the front entrance of the student store on the CSUS campus. Communication will mostly be measured and tested using the mobile application and wearable device, but we will still need to make sure the locations of the beacons are in proper ranges of the user and that the signal is not being interfered by environmental or outside sources. Communication will be an ongoing concern through the project and we will take the needed measures to make sure that communication is operational in our project.

2) Visually Impaired Assistive Guidance 2.1

The wearable device is geared towards students that have vision impairments. Multiple forms of communication will be occurring for the user and the wearable device. The user can request directions from the wearable device and the wearable device has to simultaneously relay information from the beacons to the main server. There will be a great deal of data being moved as the user makes their way from one beacon to another. The wearable device will be compact; small enough to embed with the user’s backpack. The targeted battery life expectancy is to be one school day.

a) Microcontroller 2.1.1

This will be the primary handler of information for the wearable device. This component will guide the visually impaired user through the CSUS campus. The microcontroller will have a fast response to the user’s request. This component is located in the middle of the network, which means that there will be communication between the beacons as well as direct communication with the server.

1) Region Beacon Awareness 1.1

This is the overall plan to break down the tasks for our design. Each level plays a role in our project and they will be further explored as we continue through our first phase of our design. These will also, eventually, be improved on as we reach our second phase of our project.

The overall purpose of the beacons placed around the CSUS campus is to communicate data and information to the mobile application and wearable device. The wearable device will act as a medium within our network. Data from the beacon will be sent to the microcontroller to be handled. The microcontroller will then call the directions, which are stored in the database to assist the user.

a) Hardware 1.1.1

The beacons will be implemented by using an off-the-shelf product that will be able to send data in a range of 40 to 70 m, which is also approximately 131 to 230 ft. The data and information needed from the beacon includes the presence of a beacon, the range of the beacon, and data that will differentiate one beacon from all the other beacons. We will implement numerous amounts of these beacons throughout the CSUS campus in specific

b) Bluetooth 2.1.2

Data will be transferred in between the beacons and the controller through low strength Bluetooth signal. The proximity data, RSSI, is the distance between the user and the pinpointed beacon. This feature is primarily used through the beacons, which allow the controller to detect zone locations.

c) Power 2.1.3

The controller and the beacons will have their own separate power supply. We plan on providing the user with a charge that will last a full school day. We want the device to be lightweight, portable, and long lasting. In terms of testing, we will be trying out variations of AA and 9 volt (V) batteries. We also have the option of using bigger battery packs from vendors such as Anker. The beacons have no issue with power since they use low power Bluetooth signals. Also during testing we will have the beacons on their lowest power setting, they will generally last about 2-4 years. There are many factors to include that affect the battery life such as that the wearable device has to maintain a strong connection to the beacons in order for the device to function properly. All in all, that will require a large sum of power to incorporate the strong connection to the beacons. Also, there has to be enough battery power for the Wi-Fi and Bluetooth dongle to operate properly, in order for the controller to communicate with the server. This feature will require a thorough design process since the user will be walking with a battery attached to the controller. In our design, we need to come up with a battery type, which will then give us an idea of how we can position the battery to the controller.

d) Audio 2.1.5

The audio files will be stored on to the server where they will be called upon request from the controller for the user to receive. The wearable device will have either a speaker or headphones to output the audio files to. The Raspberry Pi microcomputer is equipped with a text to speech feature that our group will utilize in the device.

e) Form 2.1.6

The overall size of the device should be light and compact or condensed. The controller, attached dongles, and battery should be small enough to fit into the user's backpack comfortably while also being portable. For the first phase of our design, we will be encasing the controller with its attachments. Once we reach our second stage of our design, the device will consist of a form much more optimal than the previous phase.

f) Communication 2.1.7

Multiple devices will be communicating with one another. The beacons will be using Bluetooth signals to send proximity data to the controller. The controller will incorporate a Wi-Fi shield that will allow direct communication to the main server. Data transfer is essential within the network, since the data ensures that the user receives the right directions to the beacons. This topic consists of hardware and software performance.

3) Assistive Guidance 2.2

The intended target group for this specific feature is for non-disabled. The mobile application should be fairly easy to utilize and user friendly for all students. The overall role for the mobile application is to allow users to conveniently navigate through the CSUS campus without assistance of another person. The objective

of the application is to reduce the confusion among incoming or transfer students who are unfamiliar with the CSUS campus. The application will allow the user to designate their destinations with the shortest route.

a) Hardware 2.2.1

In the hardware aspects of the mobile application, there are two types of mobile devices that can be utilized by the user. The user will be utilizing an iOS application on an iPhone device. If the user has a different mobile device that is not running an iOS platform, the user will not be able to use our mobile application feature.

b) Software 2.2.2

The majority of the design for the mobile application will be heavily based on software. The software in the mobile application will perform a majority of the work to guide the user around the CSUS campus. When operating the mobile application, the user will be prompted to select a location on the CSUS campus to go to. Behind the scenes, the application will be receiving routing information or data from a server - hosted cloud server - that will contain beacon information. Based on the information received, the application will use that information and guide the user to a series of beacons until the user has reached their final destination. Above all, the goal of the mobile application, in terms of software, should be able to receive the correct routing information or data so the user is guided correctly to the beacons while at the same time, being safe and fast.

In this part of the mobile application design, this is the most crucial part to address because this is where the application will actually be performing all the necessary functions to navigate the user through the CSUS campus. We will need to consider for many outcomes that are involved in this feature. Most importantly, we need to make sure that the data or information the application is receiving from the server is correct and accurate. If for some instance the data is incorrect, we cannot assume that it was a programming error in the application or the server is not sending back correct information. So, there will be a large amount of debugging and error fixing involved in the software feature. Another thing to consider is the communication between the server and beacon. The application needs to be able to establish a connection between the two so that the application can receive routing data or information to guide the user to his/her chosen destination. If the application fails to communicate, then the mobile application cannot do its part in directing the user to the destination on the CSUS campus.

c) Communication 2.2.3

The mobile application will need to be able to communicate to the server and beacons so that the user can get to the destination in a timely manner. When the mobile application communicates with the server, the application will retrieve the routing information and use it to navigate the user through the CSUS campus. The beacon will be set up to know when the user is heading to a beacon based on the routing information. Mainly, the role of the application, with respect to communication, is to establish efficient communication between the server and the beacon so the application can direct the user correctly.

The work involved with the communication aspect is dependent on the software. The communication feature is part of the software and it functions through that aspect. When the communication is

established between the application, server, and beacon it should be relaying the correct information to each other.

d) Calculate Shortest Path 2.2.4

The application will also be performing the shortest path algorithm to create a path from the starting point to the destination. This path will be used throughout the process of the navigating until the user decides to go to a different location.

The algorithm that our group will be using to create the path from the starting point to the destination is Dijkstra's Algorithm. Essentially, the algorithm will calculate the shortest path to all the nodes in a graph. With our application, we will not only route to one destination, but to all destinations, this is efficient because the user will not have to worry about finding the path to one destination. Having the mobile application calculate multiple paths gives the project more reliability.

4) Common Database 3.1

The main role of the server is to store information about the beacon; specifically their UUID, major value, minor value, and distances from other beacons. When the user goes into the application on their mobile device or uses the wearable device, the server will be communicating information with the user. The user will be prompted by the mobile application or wearable device on where they would like to go. Once the application is able to get the request of the user, the data is used with respect to the server so that it can relay information back to the application so that it can guide the user to their destination. Mainly, the server will act as a database for the application and the wearable device.

a) Setting up the host 3.1.1

For this project we will be hosting our server using a cloud backend. The cloud server is a more desirable alternative in guiding the user to their destination because there is no work involved in setting up a cloud server and it is easy to manage. To setup the server we only need to setup an account with the cloud server and setup the database. Our team will be utilizing a free cloud backend called Parse. Parse is an easy cloud server to use and the manufacturer has excellent user guides and tutorials that can help new user in operating their own Parse server. The reason we need a database is because we have multiple beacons on campus and is inefficient to store all the beacons on the mobile application or wearable device. Having the cloud backend will save our team time in programming and fixing programming errors.

b) Communication to User Interface (UI) 3.1.2

As the last feature for our database, we will need our database to communicate with the mobile application and the wearable device as user interfaces. In order to communicate to these devices, the application or wearable device needs to be connected to the network. The only way for the mobile application and wearable can access the server is through an Internet connection. Without the network, there is no way for the application and wearable device to get the routing information needed for creating the path.

hours for the whole year. Essentially, each team member contributed about 250 to 300 hours of work into the project for the whole year and was able to successfully finish their feature set in the appropriate needed time. For both semesters, the total amount of hours from the whole team was about 1100 hours as it is seen in Table IV.

B. Schedule

The table below shows the total amount of hours each team member contributed into designing the project. We split the time with accordance to each semester then adding the sum from both semesters for each team member to yield their total amount of

Task Hours

Table IV

Total Hours between group members

Team Hours			
Team Members	Fall 2015 Hours	Spring 2016 Hours	Total Hours
Rohit Pandit	117.8	91.5	269.3
Anh Nguyen	149	161	310
Nolram Ansay	181	118	299
Matthew Gorospe	119	109	228
Total	626.8	479.5	1106.3

In Table V, it shows the total amount of hours that Anh provided for the mobile application aspect of the project. The time he provided covers both the Fall and Spring Semester.

Feature Set Hours

Table V

Anh's Feature Set Hours

Assistive Guidance			
	Fall 2015 Hours	Spring 2016 Hours	Total Hours
Communication	168	0	168
Software	240	232	472
Total	408	232	640

Table VI shows the total amount of hours that Rohit contributed for the database aspect of the project. Both the Fall and Spring semester are included in his time contribution for the project.

Feature Set Hours

Table VI

Rohit's Feature Set Hours

Common Database			
	Fall 2015 Hours	Spring 2016 Hours	Total Hours
Setting up Host	8	0	8
Database Management	352	80	432
Communication to User Interface	56	0	56
Total	416	80	496

With respect to Nolram’s contribution to the project, Table VII shows the total amount of hours he committed to the beacon hardware. The total amount of hours from the Fall and Spring semesters are included.

Feature Set Hours

Table VII

Nolram's Feature Set Hours

Region Beacon Awareness			
	Fall 2015 Hours	Spring 2016 Hours	Total Hours
Purchase Beacons	136	48	184
Hardware	120	96	216
Software	40	48	88
Communication	216	0	216
Power	0	32	32
Total	512	224	736

In terms of the hardware aspect of the project, Table VIII shows the amount of hours Matthew contributed to the project. It includes the time he spent on the hardware from the Fall and Spring semesters.

Feature Set Hours

Table VIII

Matthew's Feature Set Hours

Visually Impaired Assistive Guidance			
	Fall 2015 Hours	Spring 2016 Hours	Total Hours
Microcontroller	960	0	960
Audio	0	240	240
Power	0	160	160
Form	0	160	160
Communication	88	0	88
Total	1048	560	1608

VII. RISK ASSESSMENT AND MITIGATION

Mainly, the team thought about the risks involved in our project and how we will be trying to negate those issues. It is imperative that we think about the risk involved and understand how each risk plays a role in possibly delaying our project. Even if the problems are small or large in scale, we cannot underestimate how those risks will cause our team problems during our design phase. Problems can most likely occur during the implementation of our design. The team needs to assess each feature set and examine the risk behind them and see if there is a way to possibly negate those issues.

The goal is to see that there will be problems in each design and to figure out a strategy on how to handle those problems. The solution to handle those problems will either be simple or out of our control, but the thing to take from this is that our team will know ahead of time that problems will arise and are prepared to

Risk Matrix

Table IX

The Risk Matrix of our Project

Probability	Crash/Software Update				Communication
				Power Distribution	
		Routing Algorithm	Interference		Stolen
		Security			
					Impact

handle that problem.

A. Risk Matrix

Referring to Table V, there are three different colors referring to the probability –Table VI– of each risk and its impact – Table VII – on our project. Starting on the left hand side, “Crash/Software Update”, it is in the upper left hand corner because this issue is more likely to happen to our group but will not cause our group much issue whereas at its counter opposite on the upper right hand side you will see “Communication” as a high probability risk in which our devices cannot connect to each other. This can cause a major concern for our group. This one factor can jeopardize our project. Security is towards the lower end of the table because CSUS has a great security system, which gives it a lower probability and a lower impact on our project because we can always encrypt the code as well as add extra precaution.

Likelihood and Probability

Table X

Level of Likelihood and Probability

Level	Likelihood	Probability
Green	Not Likely	.1
Yellow	Likely	.5
Red	Near Certainty	.9

Impact

Table XI

Level of impact towards our project

Level	Impact
Green	Minimum or No Impact
Yellow	Limited Impact
Red	Will Jeopardize Project

B. Mobile Application

The overall role of the mobile application is to guide the user to their destination on the CSUS campus through a user interface. The application will provide calculated routes that will navigate the user to their destination in a timely manner. In this aspect of the design, there are certain risks that may hinder the operation and functionality of the application. However, there are mitigations that will counteract and resolve the risks involved.

1) Application Crash

One thing that can occur when utilizing the application is if it crashes. In computer terms, any form of software application that crashes during execution means that the application stops functioning properly. Crashes are likely to occur in the application, but it is something that cannot be ignored. There are many ways to cause a crash in a program. However, a significant example of an application not functioning properly is if there was a software update. A software update can provide improvement to the software or disrupt a certain part of the application. Usually, an update is applied if there is a bug fix or problem in an application and patches, from the update, are there to resolve them. However, the updates can affect parts of the application that do not need to be fixed. In our case, if an update were to occur, possibly a line of code in our application can work differently or the same depending on the update. Most of the time, the update should not change how the code is operated. The update usually improves certain aspects of program. One thing about software updates is that it can do much harm then it does well. In general, it is a rarity that an application crash will occur from an update.

Another way for the application to crash is through a programming bug. A programming bug is a code error in the program. A programming bug can be viewed in two ways. Bugs can be easy or difficult to handle. Obviously, if it is an easy bug to see and fix - misspelling, missing a semicolon, then the bug will be handled in an easy fashion without having to examine the problem deeply. Now, if the bug was difficult and not obvious to the programmer, then the programming bug will be handled differently

depending on the problem. For instance, if the program compiles and executes correctly and while using the application it suddenly stops working, it would be difficult to find the problem because the source code compiled correctly and there are no source of error from the compiler. The compiler may not have found an error in the code, but the program itself must have had a problem, internally, in the system where the compiler could not detect it. The overall idea that the program will crash because of a bug is more likely to happen. As additional code is being added to the program, chances are that it will most likely crash if the program is not written correctly.

Lastly, a problem that can cause the mobile application to crash is the routing algorithm. This aspect was already discussed previously, but this problem is more towards the algorithm itself. What can likely happen in the algorithm is it can obtain incorrect data to calculate the routing path. If the algorithm acquires the wrong data, then the user will be utilizing incorrect routes to navigate the CSUS campus. The algorithm, in terms of bugs, is no different from any other program. If the bug is easy to correct, then there will not be any problems in dealing with the problem. Otherwise, there will be time spent in finding the solution to the bug.

Although application crashes are likely to happen, there are mitigations that will help resolve the application crashes. In terms of the software update, the only way to tackle this problem is to research the update that has been applied. The manufacturer who created the update will post a description of what is being fixed and improved on. Again, depending on what was being fixed or patched, the code will either be affected or not. After discovering the changes to the program, there may be changes needed if the program was affected.

To approach the programming bug, this involves debugging and testing. Debugging is a way for the programmers to probe each line of code and see what exactly is being performed in the application. The debugging process can vary depending on the difficulty of the problem. It can either be a short or long process. Typically, a way to approach the programming bug using a debugger is to run the code first and see where the problem lies in the application. After seeing the problem, the debugger will go line by line and see exactly where the problem is in the code. This is a more direct approach to solving the problem. Another way to go about this problem is going onto the Internet and researching the problem. Chances are that people who had this problem will most like post the problem online and people can refer to it if they also have that specific problem. That is the more current way of approaching problems, but it is more of a last resort if the problem is difficult to resolve. Either way, these mitigations will give you the results needed to fix the problem.

2) Communication

Communication is the most influential aspect of the mobile application. The application needs to communicate with the server and beacon so that it can function properly. The server will store all the routing data and information needed by the application so that it can calculate the path and guide the user to their destination as accurately as possible. The beacon is also essential to the application because the information on the beacon dictates how the application will handle the data and information. Without the established communication from the server and beacon, then the project will not function correctly. One thing that can go wrong is

if the server were to malfunction. Meaning, the server crashed during execution. Since the design will involve a third party server - someone has designed this server, there are two ways that the server can crash. Either the whole server itself goes down or we have no control over it or if the data handling between the server, beacon, and application causes an error during execution. One of these can likely disrupt the communication, but the most likely of the two is the data handling between the server, beacon, and application. If the entire server were to go down, there would be much involved to stop the server from functioning and providing service.

If any of the two scenarios were to occur, there is a way to mitigate the situation. If the entire server is down, we would have no control over that. The only way to solve that problem is to contact the manufacturer and alert them that their server is not functioning and they need to resolve that issue. This can cause a delay on our application if the user wants to use it. And we cannot determine how long the server will be down for because it is not within our control. Now, if there was an error in data handling, then that is something we can check upon. Usually, if there is a problem that involves data handling error, the user would report the issue to us by issuing a requested error report. Once they sent an error request, the error will be described to us and we can handle the problem depending on the error. And just like it was mentioned previously, the problem can be easy or difficult. To reemphasize, since communication is the basis of our project; that is if communication does not function between our hardware and software in our design, then the project will not work.

C. Wearable Device

The primary functions of the portable device are to let the user know where they are, give directions, and be able to connect to the network of devices. There are numerous risk scenarios that arise in this area. One of the topics that are related to risk is the amount of functions that we are planning to include in this area. Our group is currently looking into more functions to our project. Although adding more functions to the project would be great, it would also add more risk as well.

The Estimote beacons, which use Bluetooth 4.0 have some of the best reviews and have reliability. A lot of the applications that are used with the Estimote beacons are usually through a mobile application. We are planning on having a mobile application and an actual physical device. Even with beacons we run the risk of compatibility with the shields that we purchased. We will have to use alternate methods of making sure this project works properly if some of the risks happen. There are several alternate ways of going about this project if the beacons do not work out. We could always revisit using the concept of GPS. Although we are not at the stage of specific campus guiding, the GPS would not be a bad alternative. We would have to survey the area and set locational zones to let the microcontroller know when to notify the user of where they are. We lose a few meters of accuracy when using GPS, but it would get the job done in our case.

One of the risks that we really need to look into is the power distribution. We will be using multiple shields that require a certain amount of voltage to operate. We have seen in our previous courses of how certain devices have trouble operating properly when they do not have enough power being received. In order to prevent this from being a problem, we need to determine how

much our wearable device needs. That means looking into the required data sheets of each shield. This will give us insight on how we should approach this type of problem once we are in the second phase. This also brings up another issue of the topic of size. The battery size could determine the dimensions of the overall presentation of our device. Our team would have to discuss the tradeoffs with the decisions that we have to face. We could either make it a large device that could have long battery life or we could have a compact device with short battery life. These are issues that we have to take account for; this could also have an effect on how the user perceives our device. The trend in the world of technology is that everything is getting faster and smaller.

Wi-Fi also plays a big part in our project. This will enable our wearable device to access the server and request for the directions. If we don't have that connection, then the user will not be able to receive directions. To prevent this from occurring, we will have to notify the user that they are operating in a weak connection region. This function operates to warn the user that they are moving away from the campus. The device is solely supposed to operate in the campus only. The beacons will primarily be used for directional guidance. Also, since the user is visually impaired, it will also be a good way of notifying that they are leaving the campus ground.

D. Server

The server is a crucial part for the wearable device and mobile application because it will be holding valuable information to help the visually impaired students get around campus. The server will be holding information such as the beacons' identifications, beacons' names, and distances between each beacon.

As described in the *Application Crash* section, any form of software application that crashes during execution means that the application stops functioning properly. When referring to a crash, our group needs to know if it is a software update crash or if there is an error in any part of our routing algorithm or any other code.

If we have an issue with the software updates, we might not notice it right away due to an automatic update that occurs. To solve for this, we will need to look at the manufacturer's site and see if we have the most up to date application and check what changes were made from the last update. At this point, we can either choose to downgrade our application to the older version or fix the new issues that were caused by the update. Upgrading the software is going to be the most likely route, because whenever there is a software update, it is normally due to good reasons such as security, and software bugs.

A risk that is more likely to happen and our group will be spending most of its time will be in the coding stages. Most of our project is based on software for the first part. Whenever a code is being written, it is almost never going to compile on the first time. This can be due to a semicolon or a misspelling, which is often the case. We will be writing large amounts of code when we need to keep track of what sections work and build up our code. There are times that the code compiles one-hundred percent, but the output is not correct so we need to go back and check by visualizing what is happening within our code. To minimize our time and efforts, we will need to use a debugging system.

Another important risk issue includes the setup of the server and database. If the server was not setup properly, we can have issues connecting it to our wearable device. Luckily, this is not as big as a problem as it seems to be because we can always go into the

settings and change things around. This does take some research and time, deviates us from our scheduled tasks and slowing our group's progress.

If a student has their Bluetooth on, they will be able to detect our beacons. Having so many students being able to locate our beacons causes a security threat. Our group still thinks security is a medium factor due to the high security CSUS offers here on campus. Some examples of how secure the campus's network is when our group tries downloading software onto our Raspberry device, and we are unable to due to authentication issues. However, we can still run into issues with students trying to hack our beacons. There have been issues with beacons being hacked, so our group knows it is possible. In order to counter this, we will need to possibly write a section of our code letting the operator know something out of the ordinary is not right. This will help our system to become more secure, and possibly one step ahead of the attacker. Another implementation to keep our beacons secure is to add a login and password so the administrator is the only person who can get into certain features of the beacon. An alternative mitigation can also include encrypting our code so if a hacker does penetrate our system it will take them some time to actually de-encrypt our code.

Communication is a high issue for not only the server, but for the project as a whole. If the wearable device loses communication with the server, it is due to a Wi-Fi issue, which will be very common due to the campus's Wi-Fi. To resolve this, we might need to send the mac address of our devices to IRT to enable a stronger connection between the wearable device and the server. If this does not work, we will need to have our server communicate to the wearable device using a Raspberry Pi, which has more security options. If the wearable device is not able to communicate to the server, then this can cause problems for the visually impaired. This may make the visually impaired user to get lost because they strayed off the course. This can also cause the visually impaired user to get injured.

Beacon

The beacon is an essential part of the project which also means that it can have a great amount of risk. We rely on the beacon for data that will be sent to the application and the wearable device. Without this information, the whole project will not work and can cause trouble to whoever is using the device. The beacon device is an off-the-shelf device that is already built, but it still comes with a few risks.

1) Interference

Interference is the biggest probability risk that the beacon has. The beacon communicates through Bluetooth technology, and more specifically, Bluetooth Smart/BLE. This Bluetooth protocol focuses on sending low energy signals. Bluetooth signals can be blocked or absorbed by walls, objects, people, and other signals operating in the same band as Bluetooth such as Wi-Fi and cordless phones. The beacons used will be placed on different buildings and different areas on campus. Interference will be an issue depending on the reliability of each device being used to pick up the data from the beacon and the signal coming from the beacon as well. Since the beacons are placed all throughout campus, there will be many people walking around which can affect the signals sent. There are also walls, buildings and other objects like trees that can cause the same problem. Interference can vary from beacon to beacon, so testing will be essential in where the beacons

are places. The plan is to place the beacons high; about 10 ft or more. If interference becomes a problem, the mitigation for this will be to reposition the beacons higher and or at a different location or to add more beacons in the area in order to add more access points to the same data for our other devices that need that data. Although interference is very likely, it doesn't seem to be a big problem at the moment.

2) *Communication*

Communication is a medium probability risk that the project may run into. Communication differs from interference in the way that we may not be able to get the data from the beacon at all instead of the data being only sometimes accessible. If the data is unable to be accessed by the devices the project is implementing, then the whole project will not work and an alternative method will need to be implemented. The mobile applications being developed must be able to pick up and interpret the Bluetooth Smart signal coming from the beacon. The beacon that the team currently possesses is compatible with the platforms of the mobile applications. That signal should be able to be attained by the applications. If not, then a new device/technology must be used or created as the beacon. On the other hand, the beacon is not certified to be compatible with the wearable device currently planned to be designed. There is a risk that it will not work or it may not be fully compatible. If the beacon does not work for the wearable device, a new device/technology will have to be implemented in addition to the current beacons.

3) *Stolen Beacon*

Another problem which has a low probability especially for the laboratory prototype is if the beacon gets stolen. Since the beacon is sending specific data related to the location of the beacon, a beacon that is stolen from that location will cause a location point to be without data. The beacons are planned to be placed in public areas that are populated with an abundance of people. The beacons will however be places high and out of reach. Stealing can still be a problem for those who are curious or really want to take the beacon. If it becomes an issue, the beacons must be secured by adding a security camera or by creating some type of lockable case enclosure. Another mitigation technique would be to create another device to watch that beacon and notify the project system that the beacon is missing so that it can be replaced immediately. The beacons cannot be easily be hidden because of the risk of adding interference.

E. Miscellaneous

In our design, there are many unforeseen risks that we might not take into account. Even if these miscellaneous risks are not greatly considered, we still believe that these issues need to be addressed and mitigated. We want to focus more on the most impacting miscellaneous risks that may possibly hinder our design.

1) *Device Compatibility*

As it has already been emphasized, communication is a huge aspect and we need compatible parts that will be able to communicate with other hardware in our design. What can happen during our design is that we may purchase incompatible parts. For example, a Bluetooth shield that acts as a peripheral device when we want the shield to be a central role device. Meaning, we want a Bluetooth shield that receives BLE signals from other devices and not transmit them.

Our only option of mitigation to this problem is to return the purchased part and order the correct one. Although this is the fastest and simplest solution, time will be taken away from us in our project. Time is very limited in our design and we cannot afford to lose time. However, the only way to speed up the shipping process is to pay extra. So, to avoid this situation, we would have to be confident and make sure that the parts we need for the project is correct and does what we expect it to do.

2) *Lacking of Communication between Group*

Communication between the team is a low probability risk and a medium impact to the project. The group relies on each other to be cooperative, helpful, and on the same page. Lack of communication can mean a few different things, but they all involve risk. One definition can mean that the group cannot communicate to each other through calling, texting, or other means. If at any time a team member has no way to communicate to the other team members and has valuable information that they have to relay, the project suffers due to that lack of communication. There is not much mitigation for this as if there really is no way for the team to communicate, and then the project may suffer. The odds are very low since we are in the 21st century and they are many ways to communicate in this age. Another way to interpret the lack of communication is if a team member is uncooperative and not doing their part of the project. They can cause frustrations within the group and cause another team member to have to pick up more tasks. This, in effect, will cause the project to suffer all because a team member was not responsible for letting the team know important information or not doing their part. The mitigation for this would be to kick the toxic member out of the group or make sure that each team member understands what they are responsible for.

3) *Financial Burden*

Financial burden is a big risk for our project since we do require multiple items for the wearable device. Our estimated cost for this project is close to \$1000.00. Our group will need to learn to spend wisely on personal items for this project until we are confident that we will be receiving funding. To ease our financial burden, we applied for a grant fund known as the ASI Campus Grant Program. This program is "particularly interested in projects that advance discovery and understanding while promoting teaching, research, and campus engagement". For this grant fund, our group followed the criteria required to enter this grant fund, which included a list of items required for our project, explanation of our project, and expected timeline. Our group will not know if and how much funding we will receive until mid-December. We will not be given the cash up front, but we will need to pay for each item as a team. We will receive a reimbursement towards the end of our project after we have written another report stating what items were purchased.

VIII. HARDWARE

A. Portable Device

The base of the hardware section of our project consists of the Raspberry Pi. It is fully capable of performing the necessary functions required to produce a workable prototype. The Raspberry Pi can be programmed through various programming languages such as C and Java. For our project we will actually be

using Python. Fortunately every member on our team has Raspberry Pi's; unfortunately we only have one Raspberry Pi 2, Model B's. Using the Raspberry Pi 2, Model B provides us with a faster processor and multiple cores as well as more USB ports providing us with enough ports to connect our devices for debugging and normal operations such as communicating with the server and beacons.

The model we are primarily working with is the Raspberry Pi 2, Model B. This model is actually faster and more powerful than the previous model. The Raspberry Pi 2, Model B consists of a 900MHz quad-core ARM Cortex-A7 CPU with 1GB of RAM, like the Pi 1, Model B+, the Raspberry Pi 2 consists of 4 USB ports, 40 GPIO pins, full HDMI port, combined 3.5mm audio jack and composite video, camera interface (CSI), display interface (DSI) Micro SD card slot, and a videoCore IV 3D graphics core [20].

Since the Raspberry Pi 2, Model B has an ARMv7 processor; it can run the full range of ARM GNU/Linux distributions, including Snappy Ubuntu Core, as well as Microsoft Windows 10. The Raspberry Pi 2 has an identical form factor to the previous (Pi 1) Model B+ and has complete compatibility with Raspberry Pi 1[20].



Fig. 11. Raspberry Pi 2 Model B [21].

What's nice about this model is that it has four USB ports, which allow us to have a keyboard, mouse, and two other adapters. The two subcomponents that we added to the Pi are the ASUS Bluetooth adapter and the Edimax Wi-Fi adapter. The Raspberry Pi actually requires some additional configuration to enable the usage of these subcomponents. The user will need to stay connected to the network in order to have access to the required data for routing. Initializing the connection can be done two ways, through the command line where we could actually change the wireless login information.

The other subcomponent is the ASUS Bluetooth adapter. One of the first steps for using the adapter is to make sure that the Pi can actually recognize the module. Our group chose the ASUS Bluetooth USB-BT400 adapter it uses Bluetooth Low Energy technology.

The fourth subcomponent is the Edimax Wi-Fi adapter, our group chose this specific Wi-Fi adapter because it was compatible with the Raspberry Pi, is compatible with CSUS wireless encryption, has a Green Power Saving mode so it does not waste a lot of battery, has a transmission data rate of 150Mbps and is portable[22].

The last component of the hardware device is the PiTFT Plus 2.8" screen, which outputs a video display of 320 x 240. The

purpose of the screen is to help make the hardware more user friendly for the visually impaired users by incorporating user interface functionality. With the four GPIO buttons included in the device, we were able to utilize its extra functionalities in our user interface.

The purpose of the Pi is to scan for Estimote beacons and be able to guide the user to their destination. Figure 11 shows the flow chart of how the portable device operates. We will need to program this device to actually have it route the visually impaired user.



Fig. 10. PiTFT Plus 2.8" Screen [23].

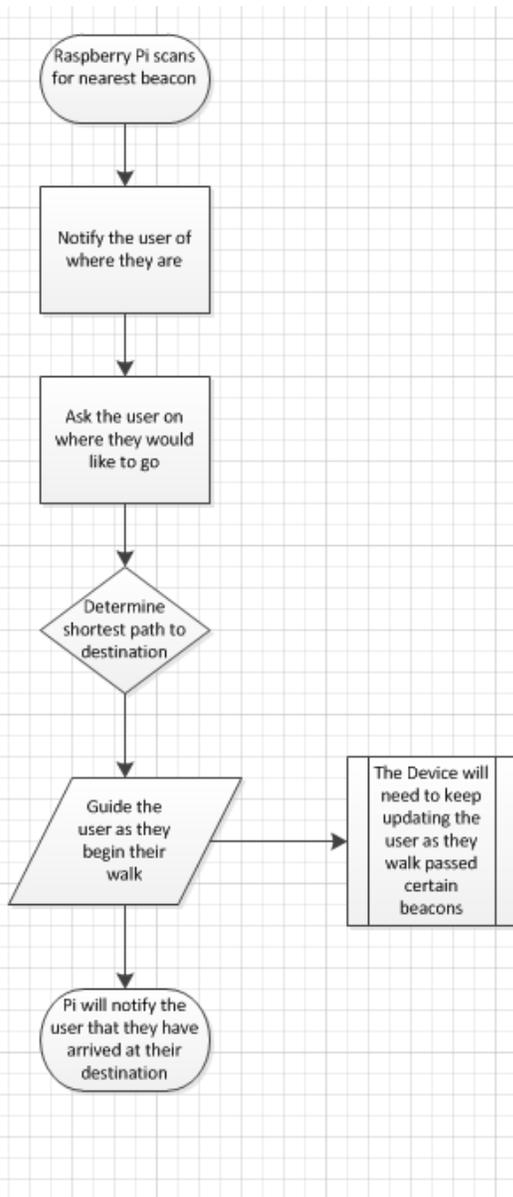


Fig. 12. Wearable Device Flowchart [24].

B. Software

1) Mobile Application

The software that is being implemented into our project is the most essential with respect to the application. Our project involves a great deal of software that will work in parallel with the hardware. Mainly, the software will be in the form of a mobile application that will continue to communicate with the hardware, which are the Estimote beacons placed around the CSUS campus. Overall, the software should correspond to the objective of the project, which is to guide disabled and non-disabled students through the CSUS campus.

A. Xcode

To design the mobile application for the project, we used the IDE – Xcode – to program our application. The application will be developed on the iOS platform; specifically, we will be making the application available on the iPhone. A large portion of the student body at CSUS has an iOS device, which gave us the incentive to start developing the application on the iOS platform. Xcode supports two types of programming version, Swift and Objective-C. Primarily, we will be using the Swift programming language because it is a simple and effective language to learn and is easy to understand. What makes Xcode a very reliable tool to use when developing an application is that we can incorporate Objective-C

code with Swift. Meaning, you can use both languages in the same programming file. Another aspect of Xcode is it has many features to make programming the application much simpler. For example, Xcode can create buttons, tables, and labels without actually programming the logic to them. With all these useful features, creating the iOS application will lessen the load need to design our project.

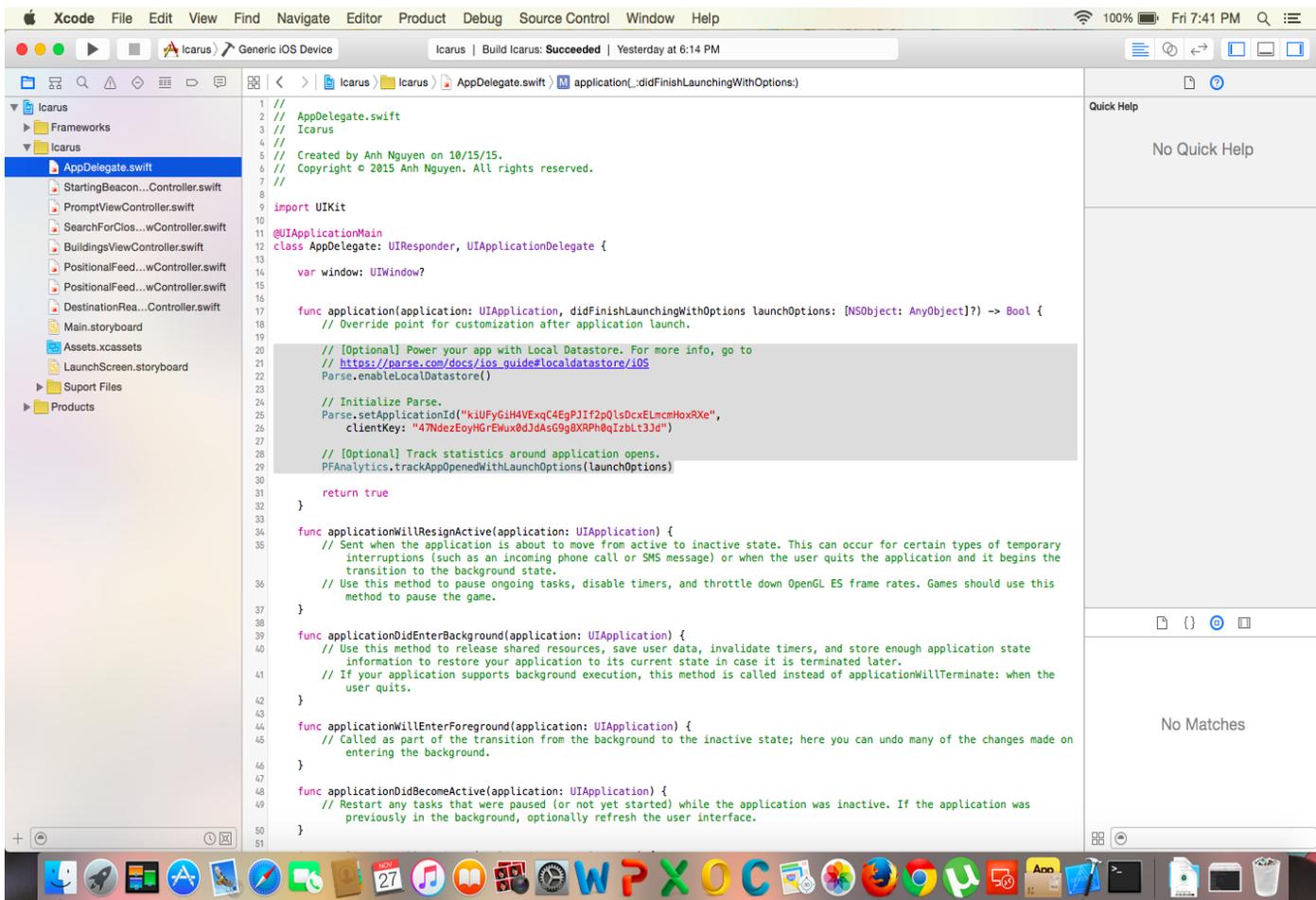


Fig. 13. Our team using Xcode to program our mobile application [25].

B. Application Design

Our focus, when designing the application, is to target non-disabled students that can utilize all the functionalities on a cellular device. The role for the application is to guide the non-disabled user to their destination as accurately as possible. The application will be working in parallel with the beacons and the server. The beacons will act as a guide to the guide the user to their destination, while the server will communicate with the application and relay information about the beacons. The flowchart in Figure 14 shows the overall layout of the application. To further demonstrate the functionality of the application, Figure 15 below shows the block diagram version of the layout of the application.

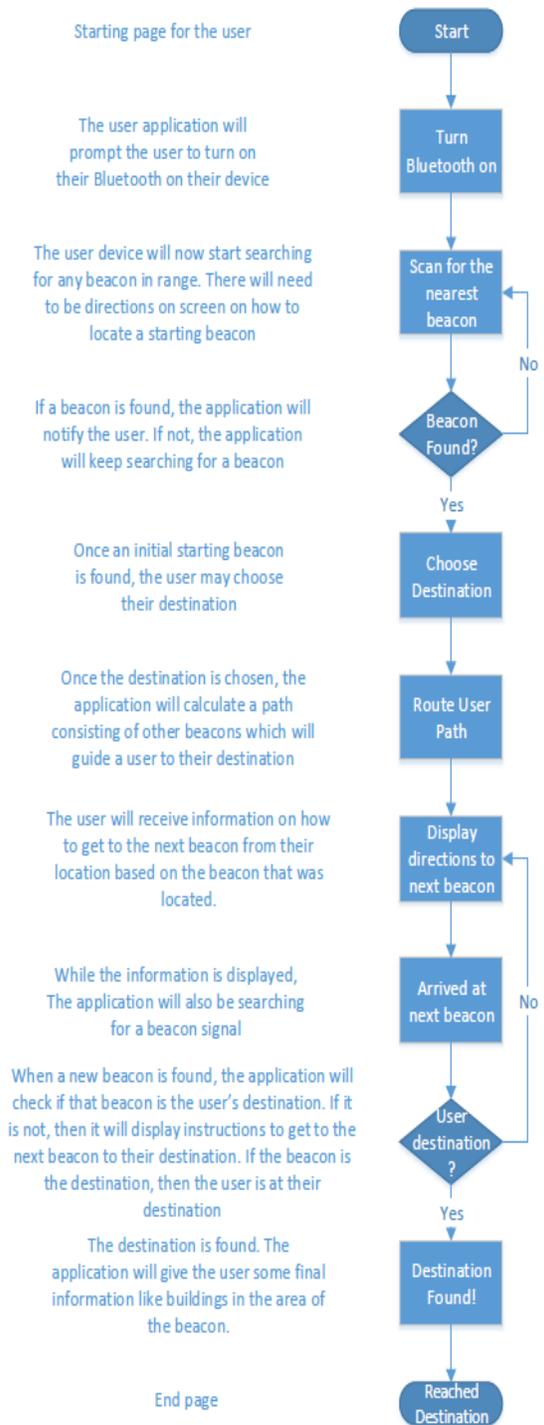


Fig. 14. Flowchart for our mobile application [26].

In the block diagram, there will be a starting window that will welcome the user to the application and will proceed to the next step when the user is ready. The next window of the application will notify the user to enable their Bluetooth function if the user has not done so. Our beacons utilizes Bluetooth Low Energy (BLE) signal, which is another form of Bluetooth, but consume less power. So, the application cannot be used if the Bluetooth function is not on. After the user enables their Bluetooth, they will need to search for the closest beacon in their area so that they can

destination. Essentially, that is the flow of how the application should be functioning and our team will continue to improve on the functionality of the application.

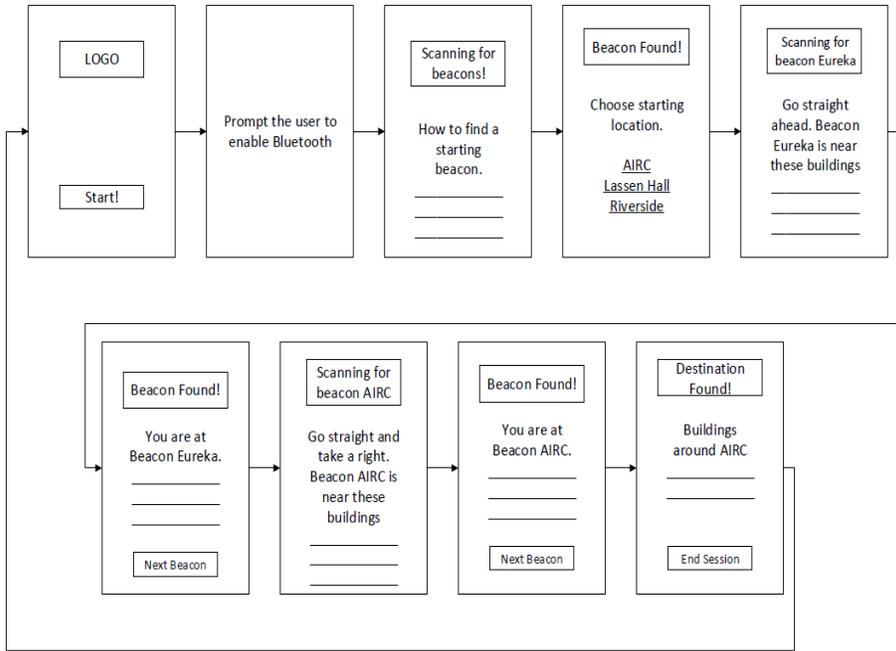


Fig. 15. Block diagram of the mobile application [27].

have a starting position. Our team assumes, for now, that the user is in the range of a beacon. When the user finds the closest beacon, the application will use that beacon as their starting point. The server will relay information about the beacon and send that to the application so that the application can use it throughout the process of guiding the user. Afterwards, the next window will prompt the user to choose a destination to go to. Again, the server will send back information regarding the destination the user chose. At this point of the process, the application will devise the shortest path from the starting point to the destination using a routing algorithm. The algorithm will be communicating with the server in retrieving the correct information to create the path for the user. Once the path has been created for the user, the application will start guiding the user to the destination using the beacons. The user will continue to navigate through the beacons until the user has reached their final destination. A series of windows will change depending on what the application should be doing at that moment. For instance, if it is looking for a beacon, a window will tell the user that it needs to scan for a beacon before continuing further with the navigating. Another example is if the user finds the correct beacon, the application will notify the user using a different window. Lastly, when the user reaches the destination, a window will appear, saying that the user has reached their destination. It will ask the user, again, to see if he/she wants to go to a new

C. Routing Algorithm

The application will use a routing algorithm to create a path so the user can follow. The algorithm is called Dijkstra's Algorithm, which is an algorithm that calculates the shortest path to all possible locations. What makes this algorithm very efficient is the fact that it can find the shortest path to all the destinations starting from any position. Since our beacons will be placed in certain parts of the CSUS campus, this algorithm will be effective. However, the most important part of the application is the route the user to the destination regardless if the path is faster than others. Knowing that the algorithm can calculate multiple paths gives us a wider range of routes to choose from. But, the algorithm will pick the

```

1: function Dijkstra(Graph, source):
2:   for each vertex v in Graph:           // Initialization
3:     dist[v] := infinity                 // initial distance from source to vertex v is set to infinite
4:     previous[v] := undefined           // Previous node in optimal path from source
5:   dist[source] := 0                     // Distance from source to source
6:   Q := the set of all nodes in Graph    // all nodes in the graph are unoptimized - thus are in Q
7:   while Q is not empty:                 // main loop
8:     u := node in Q with smallest dist[]
9:     remove u from Q
10:    for each neighbor v of u:           // where v has not yet been removed from Q.
11:      alt := dist[u] + dist_between(u, v)
12:      if alt < dist[v]                  // Relax (u,v)
13:        dist[v] := alt
14:        previous[v] := u
15:  return previous[]
  
```

Fig. 16. Pseudocode for the Dijkstra's Algorithm [28].

shortest path.

To show the functionality of the algorithm, below shows the pseudo code of the algorithm. The algorithm, again, is creating the shortest path to all the beacons. How it works is, the algorithm creates a routing table that contains the distances and nodes - beacons - from a graph. A graph is a map of where the nodes are. In the table, all the distances are initialized to infinity and the nodes undefined - null. This essentially means that there are no nodes that have been visited and all distances are not better than the other. The algorithm will then establish a source node, which is the starting point in our project. Then the algorithm will continue to execute as long there is a node that has not yet been visited. The algorithm will pick and node from the graph to start and the node will be considered visited. It will then check for any neighboring nodes to compare the distances from other nodes. The algorithm will calculate the distance from the neighboring node to the source and compare that to the distance value that has been calculated so far. If the current calculated distance is shorter than the one that has been calculated on the routing table, then replace that with the shortest distance calculated so far. Otherwise, do not update the routing table. This algorithm will continue to execute until all the nodes have been visited.

This is a straightforward algorithm and it is simple to implement. This algorithm has been used in teaching for many years and is still continued to be used today. The algorithm meets our needs in creating a path plan and it is certain that it will

calculated the shortest path from the starting point to the destination.

1) Server

As it has been mentioned, our application will be using a cloud backend database server called Parse. Parse is a third party server that can be used for developing your own server for many platforms. For our purposes, we are using Parse for our iOS application to store all of the data and information on the beacons; mainly, their name, major, minor, and distance values. Parse is a very simple server to use and is easy to set up. There is no programming required to set up this server, which lessens the work on our project.

In Figure 17, the role of the application, with respect to the server, is to retrieve data from the server and use that information to guide the user to their destination. At the same time, the server will respond to the application requests and send the proper information back to the application, assuming that the information being sent back is correct.

The advantage of using Parse is that it was created to handle backend transaction such as push notifications, sending data, and retrieving data. What makes this server particularly useful is that it was made to work with mobile platforms such as iOS and Android. It also works alongside with hardware such as Raspberry Pi and Arduino, which is also used in our project. Parse is a great starting in developing our project and our team will continue to use this tool for the remainder to the designing period.

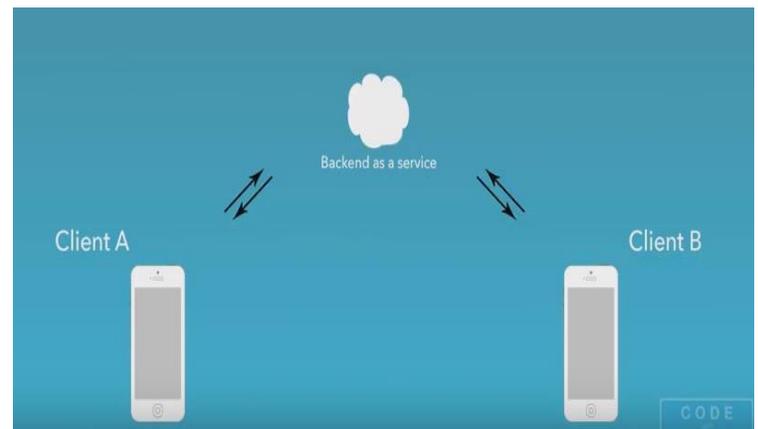


Fig. 17. Diagram showing how the server works with the application [29].

IX. MARKET REVIEW

Our team evaluated the success our project would have in the market. The first thing we considered was the target market and the consumers of our product. Our product would be marketed as a business to business product and would be aimed at providing accessibility to colleges. We can also incorporate other places to our market that would need accessibility for those who are visually impaired. The team then expanded on the idea to widen our target market by not just including those who have a disability, but to all people who have a hard time navigating in different areas. This allows for a bigger market and a broader range that our product can be used.

After analyzing the target market, we also looked at other factors that would impact the success of our product in the market. One of those factors is competition and similar products. There are currently a few similar products in our target market, but not very many. The similar products that we have found were mostly aimed at providing assistance to those who are disabled. Since we have broadened our market, we can use this as leverage to give more people interested in our product. With this market analysis, we can project how our product will act in the market and see if there is any potential in selling our product.

Our team now has a clearer idea of how assistive technology is progressing in the technological market. While observing the market, we saw the effectiveness of similar products and how it coincides with the current market for assistive technology. This, in turn, gave us a different view on how cost effective and reliable our product can be to possible consumers. From reviewing the applicable markets, our team has a better understanding of how economic viability plays a role in developing products. Seeing how assistive technology is still progressing, our product can contribute into promoting the awareness of assistive technology. As of now, the market is lacking a way of implementing a reliable solution that can provide the convenience desired by an individual. From observing the trend in this particular market we can see that there are signs of growth and the opportunity to encourage future development of dependable technology.

A. Target Market

The markets we are targeting are businesses and organizations who want to provide accessibility or convenience to an area with many points of interest. However, our initial target market has always been to focus on those who are visually impaired at CSUS, especially since our university contains the most visually impaired students out of all the CSU campuses in California. Overall, our market is narrowed down specifically to college campuses who lack assistive technology. Accessibility, in particular, has a very wide range of support and services that require specific attention, especially in the field of marketing. However, our engineering solution will be directed towards assistive technology that will provide support for the visually impaired. From what our team has gathered through research, commercialization of assistive technology is uncommon and rare, but the impact that assistive technology can provide for the market is tremendous. Assistive Technology Partners (ATP) explained that the United States market for assistive technologies is projected to grow from \$39.5 billion in 2010 to \$55 billion in 2016 [30]. Considering how limited the marketing is for this type of technology, this will simplify the workload needed to reach out to businesses and

organizations that provide assistance to the visually impaired and have a growing market.

With the growth of the population, it has the potential to fuel the market in assistive technology because one in five people are expected to be 65 or older in 2035 [30]. Studies from the Federal Interagency Forum on Aging Related Statistics estimate in 2008 that 17% of the age 65 or older populations have vision impairments [31]. This essentially means that aging adults are more likely to succumb to the prevalence of vision loss due to aging.

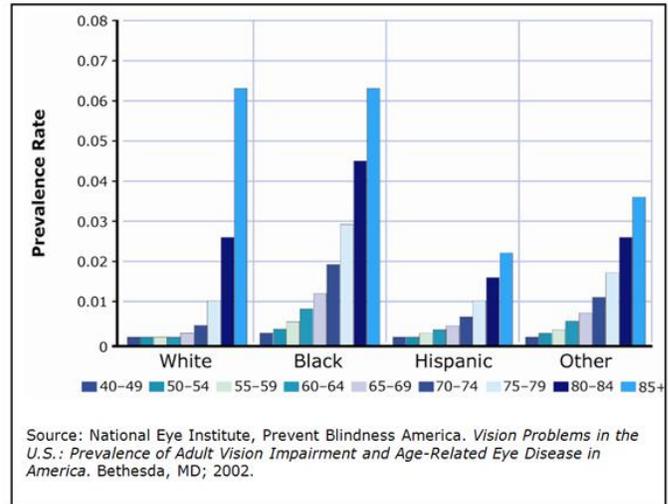


Fig. 18. Shows the population estimate of people who are visually impaired [31].

Centers for Disease Control and Prevention (CDC) states that only half of the estimated 61 million adults in the United States are classified as being at high risk for serious vision loss [32]. In addition, the World Health Organization estimated that in 2010, 285 million people are affected by visual impairment [32]. The fact is that visually impairment continues to be a problem in the population and is constantly increasing, giving us the notion that a

Global Estimates: 285 million people are affected by visual impairment*.

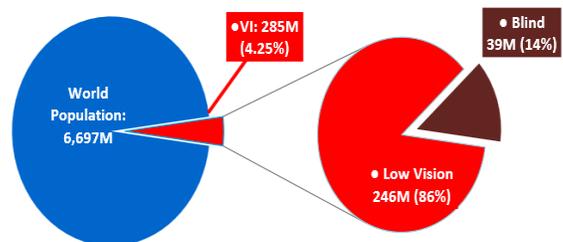


Fig. 19. Shows the prevalence rate of blindness in adults [32].

market for assistive technology has the potential to rapidly grow. Initially our team had intended on primarily focusing on the visually impaired and blind individual. After reaching out to local businesses and schools such as Arden Fair Mall, Regal Cinemas Natomas, Sacramento International Airport, Cosumnes River College, CSUS, and Raley’s Supermarket, we were able to become more familiar with the services that are available for visually impaired and blind individuals. We noticed that these businesses

do provide services to their guest or customers, but in the form of a personal guide like a chaperone. In particular, Regal Cinemas provide a feature for their guests called descriptive audio that gives the user a better understanding of what is happening within a film. We again noticed that there was a trend where these local businesses and schools lack the presence of assistive technology for the blind and visually impaired. There may be services offered for the visually impaired and blind, but there was nothing technologically assistive provided for them. We now live in an age where technology is constantly advancing, giving more opportunities to develop a solution for disabled individuals.

Over extensive research, we were able to conceptually understand that our design can be spread widely to larger areas other than CSUS. Essentially our product has the potential to expand and provide assistance to other areas that has support for disabled individuals. For instance, Disney World Magic Kingdom, located in Florida, accommodated approximately 19 million visitors in 2014 [33], averaging almost 53,000 guest per day [34]. Additionally, with the attendance of guess at the Magic Kingdom increasing, this makes the theme park susceptible to the possibility that a guest may be disabled [35].

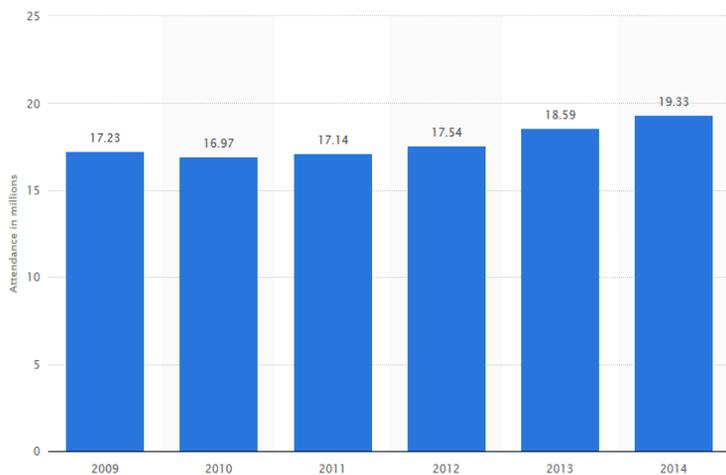


Fig. 20. Overall number of guests that attended Disney World Magic Kingdom from 2009 to 2014 [35].

This venue could possibly benefit from our product in helping their guests get to their destination since the park is approximately 107 acres, with over 100 attractions. This would be a great opportunity to promote accessibility because our product provides the necessary tools to provide accessibility and convenience to an individual. Seeing how the Magic Kingdom is large in stature compared to other theme parks, our assistive technology would give the guest a better experience of the theme park while eliminating the hassle of traversing the theme park. There are numerous scenarios where our design could assist every individual visiting the park in terms of navigating through confusing routes. With the service and availability of our product, we could step into the potential of helping individuals find specific attractions more efficiently. It presents the ability to improve business by enabling a better experience for guests by increasing their services of accessibility.

The possibility of visual impairment being more prominent in future populations offers the idea that our design can provide help

to the visually impaired, while contributing to the market for assistive technology. Our design does more than just contribute to a possible growing market in technology; this solution can become a great tool for people who have a visual impairment. The fact that assistive technology is still progressing, our design can make a major contribution in the technological world.

B. Similar Products

There is a low competitive market for our project, with few companies offering products relating to wayfinding. The numbers of successful and well known competitive companies is small and are still trying to grow and increase awareness for the need of this technology. Assisting those who require any means of aid by using today's technology is still a new trend.

1) Wayfindr

One main competitor is a company based in London called Wayfindr who started implementing their device to help those who are blind and visually impaired navigate a London train station. This company was formed through collaboration with the company ustwo and the Royal London Society for the Blind People. This is a project that is actually still in the works and has been funded by Google [36]. Wayfindr works almost exactly like our product. When finding a beacon signal, the user's device will beep and tell the user where they are and where they are headed. Our project differ slightly in which we are using beacons as destination points and guiding the user from beacon to beacon, eventually leading to their destination. Although Wayfindr is a nonprofit organization, Wayfindr would be a tough competitor to our product in which they are trying to provide.

2) Talking Signs

Another company that we have competition with is Talking Signs which is "A system of signage which can be read from a distance by a person who is blind is needed to provide a truly accessible environment. Such a system, the Talking Signs: is described here. Infrared transmitters are used to send sign contents to receivers carried by blind travelers, who can receive the sign information in the form of speech" [37]. One advantage that we have over Talking Signs is that our technology is much cheaper causing those who would like to purchase our equipment a greater incentive. Our technology is also more accurate since Talking Signs is based on GPS which is inaccurate by 2-3 m, these 2-3 m can mean a big difference especially for someone who is visually impaired. Our Bluetooth technology is much more accurate because we are not pinpointing the exact location of the user, the Bluetooth signal can be adjusted to the point where we are giving a general sense of where the user is located. Infrared technology can also be very hard to pick up, for example if the sun is shining on the infrared source it will be difficult if not possible for the user to pick up any information. Infrared is used heavily in the Talking Signs and that is how the user is receiving the information to navigate the user. Knowing this, many blind travelers can possibly lose their way and worst case, harm themselves. Talking Signs is another step in assistive technology that has the potential of improving the lives of many individuals, but it is not at the level of accessibility needed by the people.

3) Indoo.rs

Indoo.rs is a company that specializes in wayfinding using similar technology such as iBeacon and iOS. What makes our

product different from Indoo.rs is that they only centralize their product to work indoors to where our product can be used both indoors and outdoors. Our product is more effective at a geographical level because we are using our technology to guide people outdoors, where possible routes are unpredictable compared to being indoors. What makes them greatly competitive is they are achieving the same functionality as our design and using the same technology. However, Indoo.rs is currently selling their product for a standard package at \$499 per month while their professional package is priced at \$999 per month [38]. The prices for the product are at reasonable ranges, but our product can provide more service to the consumer. Again, our product can function indoors and outdoors, giving the consumer their money's worth. Having this extra service gives us a strong leverage on Indoo.rs because we are targeting a wider problem. We want to further increase a person's independency outside the public. Indoo.rs is heading in the right direction with assistive wayfinding, but our product is furthering its development and steadily improving assistive technology.

4) Projections

At the moment, we are implementing our project using only a few devices. The first device is a Raspberry Pi which includes a Wi-Fi dongle, a Bluetooth 4.0 dongle, and a 2.8" touchscreen. Our second device is an iPhone. The last device includes the beacons that we are placing around the campus. Theoretically, if we were to market the product, the pricing would be the cost of how many components the consumer would like to purchase for their business. The pricing would be broken down as follows: the cost of the portable devices, the cost of the software for the iPhone, and the cost of the beacons which will depend on how much area they would like to cover with the beacons. Additional fees can be for installation of the product and maintenance of product. Our portable device would be cheap to make, especially while using the Raspberry Pi. The only thing needed for the application is the cost of the application development kit which makes the app a very low cost product. The cost of the beacons will depend on our team producing the beacons or buying them from another vendor like Estimote which can range from \$15 to \$40 a beacon. This makes our product very cost effective and has great potential for making profit.

Taking into account the number of schools, theme parks, shopping centers, and other places our project can be used, shows that there is a big market for our product. If there is an increase of the need for accessibility and convenience for these places, then our product could trend and become a feature that all businesses will want. In a sense, our product would act like an alarm company in terms of selling components and providing a service. At the moment, our project is implemented on iOS devices. According to Statista, there was "44.53 million iPhone users in the United States" in 2012 [39]. This would allow our product to be accessible to a big population.

By providing new technology that will provide accessibility and convenience to different places, the project can become successful and become a standard to have in providing customers this type of service. This will benefit those who are visually impaired and make finding places easier for people. Promoting the concept of providing accessibility to these different places and placing importance on accessibility can make this a priority for businesses, which will place us in the forefront of this market.

X. FUTURE IMPROVEMENTS AND IMPLEMENTATION

Throughout the senior design period, we were able to achieve the goal guiding a user from one building to another using our engineering skill sets. However, since time was a major factor in our project, we were limited in incorporating features that could benefit our project. Hopefully, a future group can further improve upon our design and make it more efficient for future users.

A. Database migration

During our second phase of our design, we were notified by Parse that they will no longer be continuing their services and will migrate to a different database backend. If this project were to be further improved upon, the server will need to migrate to a different server or find an alternative third party backend to store all the beacon information. Another solution to this issue is to develop a new server that incorporates the same functionalities as the Parse server. However, by using a different server, you will have to use different source code to access the new database. The method of accessing the database is the same, but the code to actually access the database will be different depending on the server one will utilize.

B. Management on the Beacons

As of right now, the Estimote beacons are using a CR2477 battery to power the device. With appropriate enough settings, the beacon can last up to 4 to 5 years. Unfortunately as of now, we have no way of determining the battery life of the beacon without approaching the beacon with the Estimote application to verify the battery life. If this project continues to be further improved upon, a group can develop a management system that can determine the battery life of a beacon. This system will give the person, who is maintaining and managing the beacons, an easier time and it would lessen the hassle of having to approach each beacon to check the battery life. We would also like to be able to make sure our beacons functioning correctly and manage the beacons in different situations like extreme weather that may affect the beacons. Seeing if the beacons are working correctly and not tampered with is valuable information the project may need to be fully implemented in a campus. An alternative way of improving beacon management would be to design and implement our own beacons and developing a platform that will manage the system of beacons.

C. Suitable Replacement for Battery

As is was already mentioned, the Estimote beacons are using a CR2477 battery that powers the device for up to 4 to 5 years depending on the power distribution settings. A future group can develop an efficient solution where they can replace the CR2477 battery in the beacons. One solution that can replace the CR2477 battery is solar power. During the day, the beacons can be power using solar power when the beacons are actually being used while at night the beacons will no longer be powered on to be used. As long power is being saved on the beacons, any solution to battery power will greatly benefit the project.

D. Modifying the Hardware Case

We have a case enclosure that encase all of our hardware for the visually impaired – Raspberry Pi 2, battery pack, and touch screen. Currently, our devise is portable, but our case can be further

reduced, make it lighter and more portable. What a feature team can do to improve on the case is to make the dimensions small enough where the hardware can still fit and be portable. Also, the case is much heavier than it should be, therefore adding more weight for the user utilizing our hardware. If possible, making the case lighter would be a plus for future implementation.

E. Reducing Power for Portable Device

The battery for our hardware device lasts approximately 7 to 8 hours which is plenty of time for a user to use the device. The problem is that the device would have to be charged every day that a person uses it. An area of improvement would be to increase the battery life. To reduce the amount of battery consumption, we can further tweak the Raspberry Pi that we are using for the hardware device and make sure it is only using the resources it needs. We can also invest in a better battery pack that has more milliamp hour (mAh).

F. Espeak Function

While creating the audio functionality for the portable device, the team wanted to use a text-to-speech function that will allow users to easily understand the instruction prompts. The library we decided to use is Espeak which allowed us to use text to speech in our python code.

The Espeak library works, but is not as appealing to the person using it. While talking to Gene Lozano, Jr., a Disability Management Counselor at SSWD, he suggested out speech functionalities to sound as human as possible and that a female voice is preferred because it is easier to understand and listen to. The Espeak function in the portable device could sound better and easier for the user, however this is a function that even Google, Apple, and Microsoft are still trying to improve on. There are not very many open source text-to-speech options available for our hardware and some take more time to incorporate to our device. Ways that we can improve on our speech output would be to create our own .wav audio files to output our speech which will be as natural as we can get to the human voice or we can invest more time in searching for other text-to-speech options available. This would provide users a better experience.

XI. CONCLUSION

Conclusively, we were able to complete our senior design project and achieve the goal of assisting the visually impaired navigate through the CSUS campus. With the available technology that we are currently exposed to, we were able to make this project possible. We were able to design a portable device that allows a visually impaired student to navigate through the campus independently using the hardware device and features that we designed. Along with the hardware device, we designed an iOS application that will also accommodate the new and incoming students that have no familiarity of the CSUS campus layout. With the functionality of the Estimote beacons and Parse server, we were able to use their functionality, in unison with both the mobile

application and portable device, to guide the user through a series of beacons through preset instructions to their desired destination. With the Raspberry Pi 2's processing power, we were able to access its powerful features and we were able to enable Bluetooth communication between the Raspberry Pi and Estimote beacons, while at the same time communicating with the database using RESTful API. Similarly, the iOS application is able to communicate with the Estimote beacons using existing API libraries designed for iBeacon technology, making developing the application easier. At the same time, the Parse tutorial and documentation allowed us to make communication possible between the iOS application and the database.

In our senior design process, we needed to continuously modify and improve our project where it can be efficiently used without complications. When going through the senior design process, we were able to understand our project at a more technical and thoughtful level. We designed our project on the basis of the engineering concepts that we learned in our college career. We applied concepts such as creating a design idea, feature set, work breakdown structure, risk assessment, device test plan, and other concepts to develop the project in an organized way. We made sure, through rigorous testing, that our project is successful at guiding a student from one place to another. We were able to verify that our hardware can guide the user to their destination using Bluetooth signals from the beacons, which has a set of instructions particular to the beacon. With the addition of audio output, we were able to orally tell the user where to go versus reading a set of instructions on the hardware. We were able to use the Estimote beacons to our advantage by configuring the settings to accommodate a certain area of the CSUS campus to help further guide the user from one beacon another. The database made wayfinding possible with its feature to store informational data on the beacons, making it possible to differentiate beacons from one another. For new and incoming students, the mobile application will perform the same functionality as the portable device, but there will be readable text and audio output for them to read and listen to as they walk to their destination. Through the engineering concepts we developed during the senior design process, we were able to finalize our project and make our project deployable for future users.

It was a great milestone from when we were actually able to guide the user with our two platform devices while implementing and utilizing Bluetooth and WiFi. Although we accomplished our goal in assisting the user with our senior design project, we pondered on how we can take this project to the next level. That's why there's a lot to consider when moving forward with a senior design project. One of the main things we wanted to keep in mind is how can we improve upon our project with the limited time that we have in our course. From keeping in close contact with the SSWD we had the opportunity to obtain a good understanding on who we were trying to help. In order to really achieve our goal, we implemented various testing to really obtain viable data to really back up our final product. It was really nice how we were able to apply the concepts that we learned within our program such as the routing algorithm and responding to the common database. Within our effort of actually making an impact with our target users, our device definitely has the potential to make a difference. After actually producing a deployable prototype, we saw how we could expand upon this project such as how it could be applied to places such as theme parks and museums. We are hoping during our final

presentation in late May of 2016 that students and faculty will have the opportunity to see how our project promotes accessibility and convenience to a wide range of students and how new technology can be applied to further create more assistive technology needed in our world.

XII. REFERENCES

- [1] Calstate.edu, "Services to Students with Disabilities | Student Academic Support | CSU", 2016. [Online]. Available: <http://www.calstate.edu/sas/disabilities.shtml>. [Accessed: 30- Jan- 2016].
- [2] F. Andrew A. Dahl, "Blindness: Get Facts About Causes of Vision Loss", *MedicineNet*, 2016. [Online]. Available: <http://www.medicinenet.com/blindness/article.htm>. [Accessed: 30- Jan- 2016].
- [3] Who.int, "WHO | Visual impairment and blindness", 2016. [Online]. Available: <http://www.who.int/mediacentre/factsheets/fs282/en/>. [Accessed: 30- Jan- 2016].
- [4] Afb.org, "Technology Resources for People with Vision Loss - American Foundation for the Blind", 2016. [Online]. Available: <http://www.afb.org/info/living-with-vision-loss/using-technology/12>. [Accessed: 30- Jan- 2016].
- [5] Nfb.org, "Free Cane Program | National Federation of the Blind", 2016. [Online]. Available: <https://nfb.org/free-cane-program>. [Accessed: 30- Jan- 2016].
- [6] M. Peck, "RFID Tags Guide the Blind", *Spectrum.ieee.org*, 2016. [Online]. Available: <http://spectrum.ieee.org/biomedical/devices/rfid-tags-guide-the-blind>. [Accessed: 30- Jan- 2016].
- [7] Csols.com, 2016. [Online]. Available: http://www.csols.com/wordpress/wp-content/uploads/2012/12/14757828_s.jpg. [Accessed: 30- Jan- 2016].
- [8] Ustwo.com, 2014. [Online]. Available: <https://ustwo.com/blog/designing-wayfindr/>. [Accessed: 30- Jan- 2016].
- [9] 2016. [Online]. Available: http://delivery.acm.org/10.1145/2670000/2661380/p217-williams.pdf?ip=130.86.97.26&id=2661380&acc=ACTIVE%20SERVCE&key=F26C2ADAC1542D74%2EF8B29279A7E50DFA%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&CFID=578768480&CFTOKEN=93729307&__acm__=1454038780_80e6ee41a12192f4e4957ca391d3244f. [Accessed: 30- Jan- 2016].
- [10] 2016. [Online]. Available: http://www.eltis.org/sites/eltis/files/case-studies/documents/fin-noppa_1.pdf. [Accessed: 30- Jan- 2016].
- [11] 2015. [Online]. Available: <https://ustwo.com/blog/validating-wayfindr/>. [Accessed: 19-Sep-2015].
- [12] 2015. [Online]. Available: <http://www.ms.unimelb.edu.au/~moshe/620-261/dijkstra/dijkstra.html>. [Accessed: 19-Sep-2015].
- [13] 2015. [Online]. Available: <https://ustwo.com/blog/validating-wayfindr/>. [Accessed: 19-Sep-2015].
- [14] 2015. [Online]. Available: <http://www.geeksforgeeks.org/greedy-algorithms-set-6-dijkstras-shortest-path-algorithm/>. [Accessed: 19-Sep-2015].
- [15] 2015. [Online]. Available: <http://www.geeksforgeeks.org/greedy-algorithms-set-6-dijkstras-shortest-path-algorithm/>. [Accessed: 19-Sep-2015].
- [16] Developer.apple.com, "The Swift Programming Language (Swift 2): About Swift", 2015. [Online]. Available: https://developer.apple.com/library/prerelease/ios/documentation/Swift/Conceptual/Swift_Programming_Language/index.html. [Accessed: 19-Sep- 2015].
- [17] Python.org, "Welcome to Python.org", 2016. [Online]. Available: <https://www.python.org/doc/essays/blurbl/>. [Accessed: 31- Jan- 2016]. Available: Rlsb.org.uk, "Wayfindr | RLSB", 2016. [Online]. Available: <http://www.rlsb.org.uk/tech-hub/wayfindr>. [Accessed: 25- Feb- 2016].
- [18] Bluetooth.com, 'Fast Facts | Bluetooth Technology Website', 2015. [Online]. Available: <http://www.bluetooth.com/Pages/Fast-Facts.aspx>. [Accessed: 19- Sep- 2015].
- [19] Bing.com, 2015. [Online]. Available: <http://www.bing.com/th?id=JN.IZR8LSGhaid2bt6bfosVOQ&pid=15.1&P=0&w=300&h=300>. [Accessed: 19- Sep- 2015].
- [20] Raspberry Pi, 'Raspberry Pi 2 Model B', 2015. [Online]. Available: <https://www.raspberrypi.org/products/raspberry-pi-2-model-b/>. [Accessed: 28- Nov- 2015].
- [21] "raspberrypi 2 - Google Search", *Google.com*, 2016. [Online]. Available: https://www.google.com/search?q=raspberrypi+2&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjEppHvq7jMAhUPyGMKHT50AUkQU_ICigE&biw=1440&bih=730&dpr=1#imgrc=gGwJrS6MxEpiBM%3A. [Accessed: 01- May- 2016]. Edimax.com, 'EDIMAX Technology - Official Website - N150 - N150 Wi-Fi Nano USB Adapter, Ideal for Raspberry Pi', 2015. [Online]. Available: http://www.edimax.com/edimax/merchandise/merchandise_detail/data/dimax/global/wireless_adapters_n150/ew-7811un. [Accessed: 28- Nov- 2015].
- [22] Edimax.com, 'EDIMAX Technology - Official Website - N150 - N150 Wi-Fi Nano USB Adapter, Ideal for Raspberry Pi', 2015. [Online]. Available: http://www.edimax.com/edimax/merchandise/merchandise_detail/data/dimax/global/wireless_adapters_n150/ew-7811un. [Accessed: 28- Nov- 2015].
- [23] A. Industries, "PiTFT Plus 320x240 2.8 TFT + Capacitive Touchscreen - Assembled [Pi 2, Model A+ / B+] ID: 2423 - \$44.95 : Adafruit Industries, Unique & fun DIY electronics and kits", *Adafruit.com*, 2016. [Online]. Available: <https://www.adafruit.com/products/2423>. [Accessed: 02- May- 2016].
- [24] Team Icarus. Charts and Diagrams. 2015.
- [25] Team Icarus. Pictures. 2015.
- [26] Team Icarus. Charts and Diagrams. 2015.
- [27] Team Icarus. Charts and Diagrams. 2015.
- [28] H. Thomas Grossmann (Overall), "Dijkstra Algorithm: Short terms and Pseudocode", *Gitta.info*, 2016. [Online]. Available: http://www.gitta.info/Accessibiliti/en/html/Dijkstra_learningObject1.html. [Accessed: 04- May- 2016].
- [29] "CodeWithChris", *YouTube*, 2016. [Online]. Available: <https://www.youtube.com/user/CodeWithChris>. [Accessed: 04- May- 2016].
- [30] C. Casey, "Assistive technologies market growing rapidly - CU Denver Today", *CU Denver Today*, 2012. [Online]. Available: <http://cudenvertoday.org/assistive-technologies-market-growing-at-rapid-rate/>. [Accessed: 25- Feb- 2016].
- [31] Cdc.gov, "National Data | Data & Statistics | VHI | CDC", 2016. [Online]. Available: <http://www.cdc.gov/visionhealth/data/national.htm>. [Accessed: 22- Feb- 2016].
- [32] C. Katia Hetter, "World's top 25 amusement parks", *CNN*, 2016. [Online]. Available: <http://www.cnn.com/2015/06/03/travel/feat-most-popular-theme-parks-world-2014/>. [Accessed: 23- Feb- 2016].
- [33] C. Katia Hetter, "World's top 25 amusement parks", *CNN*, 2016. [Online]. Available: <http://www.cnn.com/2015/06/03/travel/feat-most-popular-theme-parks-world-2014/>. [Accessed: 23- Feb- 2016].
- [34] P. Reikofski, "How Many People Go To Disney World Every Day?", *Temporary Tourist*, 2015. [Online]. Available: <http://temporarytourist.com/how-many-people-go-to-disney-world-every-day/>. [Accessed: 25- Feb- 2016].
- [35] Statista, "Magic Kingdom Walt Disney World Florida attendance 2009-2014 | Statistic", 2016. [Online]. Available: <http://www.statista.com/statistics/232966/attendance-at-the-walt-disney-world-magic-kingdom-theme-park/>. [Accessed: 25- Feb- 2016].
- [36] Rlsb.org.uk, "Wayfindr | RLSB", 2016. [Online]. Available: <http://www.rlsb.org.uk/tech-hub/wayfindr>. [Accessed: 25- Feb- 2016].
- [37] J. Brabyn, W. Crandall and W. Gerrey, "Talking signs: a remote signage, solution for the blind, visually impaired and reading disabled", *Proceedings of the 15th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*.
- [38] Indoo.rs, "indoo.rs pricing", 2016. [Online]. Available: <http://indoo.rs/pricing/>. [Accessed: 25- Feb- 2016].
- [39] Statista, "Number of iPhone users in the US 2012-2015 | Statistic", 2016. [Online]. Available: <http://www.statista.com/statistics/232790/forecast-of-apple-users-in-the-us/>. [Accessed: 25- Feb- 2016].
- [40] Team Icarus. Charts and Diagrams. 2016.
- [41] Team Icarus. Pictures. 2016.
- [42] Team Icarus. Charts and Diagrams. 2016.
- [43] Team Icarus. Charts and Diagrams. 2016.
- [44] Team Icarus. Charts and Diagrams. 2016.
- [45] Team Icarus. Charts and Diagrams. 2016.
- [46] Team Icarus. Charts and Diagrams. 2016.

- [47] Team Icarus. Charts and Diagrams. 2016.
- [48] *Sketchappsources.com*, 2016. [Online]. Available: <http://www.sketchappsources.com/resources/source-image/estimote-ibeacons-devinmancuso.png>. [Accessed: 26- Mar- 2016].
- [49] "The Hitchhikers Guide to iBeacon Hardware: A Comprehensive Report by Aislelabs (2015) - Aislelabs", *Aislelabs*, 2016. [Online]. Available: <http://www.aislelabs.com/reports/beam-guide/>. [Accessed: 26- Mar- 2016].
- [50] "The Hitchhikers Guide to iBeacon Hardware: A Comprehensive Report by Aislelabs (2015) - Aislelabs", *Aislelabs*, 2016. [Online]. Available: <http://www.aislelabs.com/reports/beam-guide/>. [Accessed: 26- Mar- 2016].
- [51] Team Icarus. Pictures. 2016
- [52] Team Icarus. Pictures. 2016.
- [53] Team Icarus. Charts and Diagrams. 2016
- [54] Team Icarus. Charts and Diagrams. 2016.
- [55] Team Icarus. Charts and Diagrams. 2016.

GLOSSARY

- 1) **Android** – Is a mobile operating system (OS) based on the Linux kernel and currently developed by Google.
- 2) **Bluetooth** – Is a wireless technology standard for exchanging data over short distances (using short-wavelength Ultra High Frequency (UHF) radio waves in the Industrial, Scientific, and Medical (ISM) band from 2.4 to 2.485 GHz).
- 3) **Braille** – a tactile writing system used by people who are blind and low vision.
- 4) **Braille Embosser** - Is an impact printer that renders text as tactile braille cells.
- 5) **C** – Is a general-purpose, imperative computer programming language, supporting structured programming, lexical variable scope and recursion, while a static type system prevents many unintended operations.
- 6) **Cloud** – A database that typically runs on a cloud computing platform.
- 7) **Computer bug** – An error, flaw, failure, or fault in a computer program or system that causes it to produce an incorrect or unexpected result, or to behave in unintended ways.
- 8) **Computer crash** – When a computer program, such as a software application or an operating system, stops functioning properly.
- 9) **Database** – Is an organized collection of data. It is the collection of schemes, tables, queries, reports, views, and other objects
- 10) **Debugging** – The process of finding and resolving bugs or defects that prevent correct operation of computer software or a system.
- 11) **Dijkstra's Algorithm** – Created by Edsger W. Dijkstra, it is an algorithm for find the shortest paths between nodes in a graph.
- 12) **Disease Control and Prevention** – Is the leading national public health institute of the United States.
- 13) **Estimote** – Small wireless sensors that can be attached to any location or object. They broadcast tiny radio signals, which a smartphone can receive and interpret, unlocking micro-location and contextual awareness.
- 14) **Global Positioning System (GPS)** – Is a space-based navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.
- 15) **iBeacon** – Is a protocol standardized by Apple and introduced at the Apply Worldwide Developers Conference in 2013. They use Bluetooth low energy proximity sensing to transmit a Universally Unique Identifier (UUID) picked up by a compatible application or operating system (OS).
- 16) **Integrated Development Environment (IDE)** – Is a software application that provides comprehensive facilities to computer programmers for software development.
- 17) **iOS** – Is a mobile operating system created and developed by Apple and distributed exclusively for Apple hardware.
- 18) **Host** – A server dedicated to hosting a service or services for users.
- 19) **Java** – Is a general-purpose computer programming language that is concurrent, class-based, object-oriented, and specifically designed to have as few implementation dependencies as possible.
- 20) **Nodes** – A basic unit used in computer science. Nodes are devices or data points on a larger network. Devices such as a personal computer, cell phone, or printer are nodes. When defining nodes on the internet, a node is anything that has an IP address. Nodes are individual parts of a larger data structure, such as linked lists and tree data structures. Nodes contain data and also may link to other nodes. Links between nodes are often implemented by pointers.
- 21) **Objective-C** – Is a general-purpose object-oriented programming language that adds Smalltalk-style messaging to the C Programming Language.
- 22) **Received Signal Strength Indicator** – Is a measurement of the power present in a received radio signal.
- 23) **Server** – is both a running instance of some software that is capable of accepting requests from clients, and the computer that executes such software.
- 24) **Swift** – Is a multi-paradigm, compiled programming language created by Apple for iOS, OS X, and watchOS development.
- 25) **User Interface (UI)** – Is everything designed into an information device with which a human being may interact -including display screen, keyboard, mouse, light pen, the appearance of a desktop, illuminated characters, help messages - and how an application program or a Web site invites interaction and responds to it.
- 26) **WiFi** - Is a local area wireless computer networking technology that allows electronic devices to a network, mainly using the 2.4 gigahertz (GHz) ultra-high frequency (UHF) and 5 GHz super high frequency (SHF) industrial, scientific, and medical (ISM) radio bands.
- 27) **Xcode** – A program compiler developed by Apple that allows programmers to create computer or mobile based application.

APPENDIX A. USER MANUAL

Project Icarus offers two different devices for users. The mobile application offers wayfinding help for anyone who needs it while the hardware device is suited towards those who are visually impaired and need more detailed guidance.

*A. Mobile Application**1) Downloading the Application*

The application is still in development phase and not yet on the market. To get the application, the user must contact Team Icarus for more information. The application will have to be installed to an iOS device using Xcode. The program compiles the application and then installs it straight into the device.

2) Running the Application

Once the application is installed on the device, the user may now run it. Upon entering the application, the user will be greeted with a starting screen prompting the user to use the app from a button. The user will need to enable a Wi-Fi connection or mobile internet connection and enable Bluetooth capabilities on their mobile phones. Once the application has an internet connection and has Bluetooth on, the user can begin searching for beacons by pressing the continue button. The mobile application will then begin to search for a starting beacon. Once a starting beacon is found, the user will be prompted to choose a destination among the predetermined paths available. The application will then guide the user to their destination by listing sets of instructions on how to get from each beacon to the next beacon. When each beacon is reached the application will update with new instructions to get to the next beacon. The user will be notified that they have reached their destination once they receive the destination beacon signal.

3) Audio

Audio assisted instructions are automatically incorporated with the application. The audio instructions follow exactly what is stated on the screen and are not needed, but add convenience.

4) Settings

There are currently no settings for the application at the moment.

*B. Hardware Device**1) Putting on the Hardware Device*

The deployable prototype for the hardware device currently features a belt/strap design. The user must first adjust the belt to their preference and move the hardware device harness to the side of the non-dominant hand. Then the user can then continue to attach the shoulder strap to secure the belt around the body. Once the belt is secured, the hardware device can be attached to the hardware harness.

2) Running the Hardware Device

The hardware device must first be powered by attaching the power cable from the battery to the hardware device. The device will then boot up with the on screen application. Once the application is booted on the device, the user may now use it. Upon entering the application, the user will be greeted with a starting screen prompting the user to continue by pressing a button. A WiFi connection will be needed to run the application. The hardware device will then begin to search for a starting beacon. Once a starting beacon is found, the user will be prompted to choose a destination among the predetermined paths available. The application will then guide the user to their destination by listing sets of instructions on how to get from each beacon to the next beacon. When each beacon is reached the application will update with new instructions to get to the next beacon. The user will be notified that they have reached their destination once they receive the destination beacon signal.

3) Audio

Audio assisted instructions are automatically incorporated with the application. The audio instructions follow exactly what is stated on the screen.

4) Settings

There are currently no settings for the application at the moment.

APPENDIX B. HARDWARE

C. Portable Device

Once we've established the necessary components required to work the first phase of the senior design, it is important to now look forward for the work required for the next semester. Our team not only plans on improving on the prototype but we also plan on adding to the project. During the spring semester we plan on actually testing primarily on the outside rather than in the hallways of Riverside. This will ensure that our project operates correctly in the desired environment.

One of the areas that we will be looking into is voice recognition. This was a plan that our group discussed that should be a feature for the hardware for the visually impaired. We plan on having buttons most likely for on and off mode. But the general form of user communication to the device is through voice.

Since we will be testing outside we thought it would be great idea to begin data collecting in the second semester. The data that we plan on collecting is how the device behaves in certain areas of the campus; we also wanted to observe how the Raspberry Pi operates with students walking around. One of the things that we want to account for is line of sight and interference. We want to catch these issues early on and that way we can mitigate the problem and ensure that the user gets to their desired destination. We can track the signal strength values and from these values we can observe how the signals are being received from the Estimote beacons to the Bluetooth adapter of the Raspberry Pi. We will also have to test the Raspberry Pi's Wi-Fi capability outside ensuring that we will be able to get internet access outside the buildings.

During data testing, we also have the opportunity to implement one of our countermeasures for the user, which is to notify them that they are leaving the range of which they require them to have access to the network. This will require us grabbing data from the WiFi adapter that we are using to access the data from the Parse server. We saw that there is a way to grab characteristic data from the Edimax adapter. The notification should let the user know that they are leaving the region of normal operation. Our device requires a network connection to operate properly. Without the connection, they have no routing directions. We may also place excess beacons around the boundary that a user should not be going to and if the beacon is found, then there will be a notification to let the user know that they are leaving the operating area.

This topic actually goes into the next issue of having another countermeasure. Although we want to be expecting the best case scenario, this is not the case when testing. We still want to enable the user to have routing information if there is no network communication. We will be looking on giving the Raspberry Pi additional memory that way it can carry backup routing data. The way this would work is if the Raspberry Pi reaches several attempts to connect to the network, then it

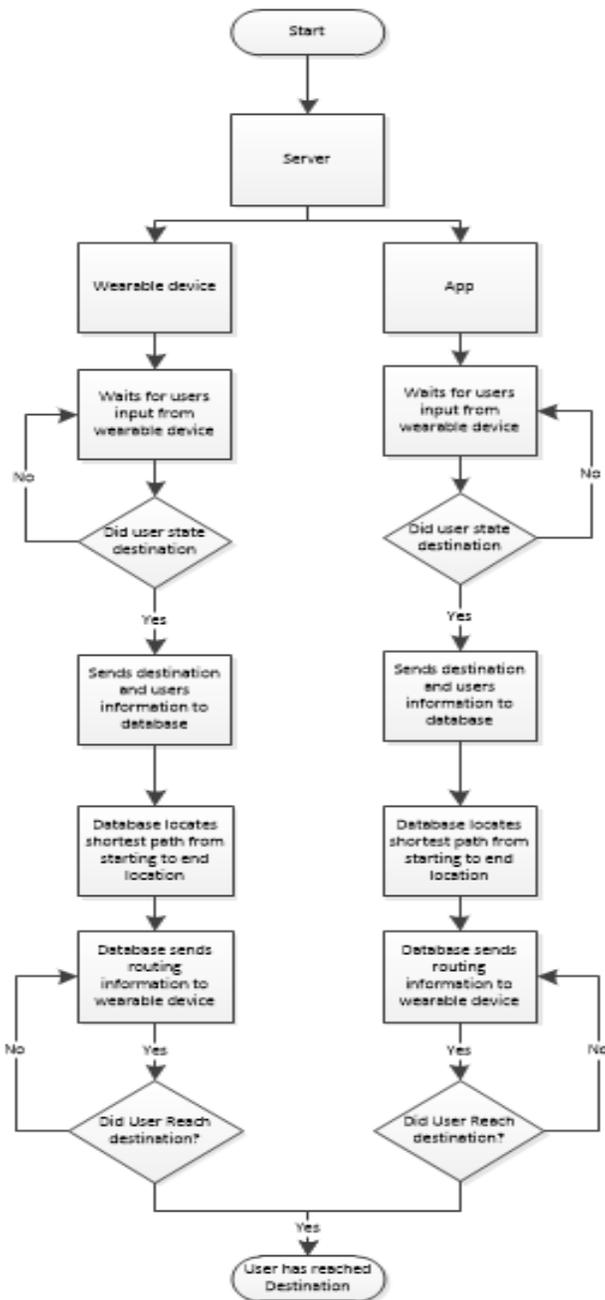


Fig. 21. Wearable Device Flowchart [40].

will switch to “backup mode” where it will begin to access data from the backup routing data. This was actually part of our mitigation concepts that was introduced during our risk assessment section. Having this feature enables a safe and efficient device provided for the user.

The Raspberry Pi that we are currently working with is encased in a plastic case that is fairly compact. During the next semester we will be looking on designing on how we will make the device wearable. We will be considering areas such as where the primary component will be placed with respect to the user. We were planning on having the device placed in the front area of the user. A possible implementation is connecting the wearable to the user through a strap. We will be considering size of the component.

When testing the Raspberry Pi we normally have it plugged through a mini USB cable to the wall. The user will need to be mobile, so we will be looking at what kind of external power supply that the Raspberry Pi can use. We do not want the battery pack to be too big, but we also want to provide long lasting service.

The method of testing our program through the Raspberry Pi is to actually tell it to compile the Python code through command line. What we would like to happen is to have the Raspberry Pi automatically start running our program when turned on. We will need to determine how to actually tell the Pi to actually do this on startup. This will essentially be the finishing touches to our hardware section.

Another aspect of the hardware is to have the Raspberry Pi have specific modes of operation. This would be our way of reducing power consumption. We would need to determine how to force the Pi to operate in an idle state and operate in a fully on state. When the Raspberry Pi is turned on, it is using all of its modules. We could possibly get into the mainframe and tell the Raspberry Pi to shut off unnecessary modules to relieve the power consumption. Very much like when a computer is not being used for period of time, it moves to its idle state.

The primary tests that we applied to the portable device area are the time response. This test consists of recording the time it takes for the hardware to actually recognize the beacon signals. This will give us a better understanding of when the instructions will execute as the user is traversing the campus. We designed the portable device to actually output instructions upon signal recognition. When the portable device comes in contact with a transmission range, the device should relay a set of instructions that will guide them to the next beacon.

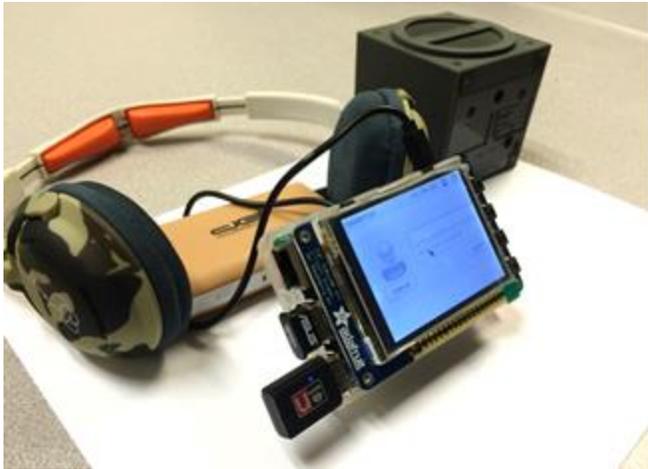


Fig. 22. Preliminary Physical Design of Portable Device [41].

1) Project Tuning

The opportunity to begin testing actually played a very big role in project tuning. We were under the impression that we had our portable device operating efficiently that was not the case when actually testing.

One of the unique instances that occurred while testing is that while scanning for the beacons, we actually saw that we were picking up all Bluetooth devices within the vicinity of the portable device. Although we wanted to be able to recognize Bluetooth signals, we only wanted to handle the signals that we wanted. The signals that we wanted are being transmitted from the estimate beacons. We were actually picking up devices such as Bluetooth headphones, wireless mouse, and other devices transmitting Bluetooth devices. This was very problematic since it caused our software to behave irregularly, caused the device to even crash at times. In order to remedy this problem, we had to actually filter out the unwanted signals. To do that we actually had to insert another for loop within our initial scan function. This would in turn, force the portable device to only handle minor values that are transmitted from

Estimate beacons. We initially placed a filter that had a 10 interval scan process. This actually fixed the problem, but we did encounter a unique trade off with the filter.

The next issue was that with the 10 interval process is that we now began observing long scan processes. Below are testing data that accumulate over 15 seconds to actually acquire the Bluetooth signals from the beacons. Although we were actually able to filter out the bad signals we were now forcing the portable device to take longer to handle the required signals

This is now the instance where we actually had to start tuning our device to take shorter times to actually pick up the wanted minor values from the beacons. Instead of now using a 10 interval scan process, we now changed it to three. In the next section you will actually see the difference in response time with respect to the scan interval process changes.

2) Final Test Results

Now that we were able to actually filter out the unwanted signals and changed the scan interval, we can see how it dramatically changed the response time of the portable device in the next set of data below.

One of the decisions that we made as a team as a result of the final test results was that even though we have full control of the transmitting range of all the beacons, the best possible result would be to set them to have a transmitting power of 50 m. The reason why we chose this range was because from the results we were able to achieve a reasonable response time for recognition, not only that but there was consistency between the samples of data, that is one thing that we want to have in our project which is stability of the signal recognition. We also concluded that 30 m was a little too close and that 70 m was too far for a proper distance to actually execute an instruction to the user.

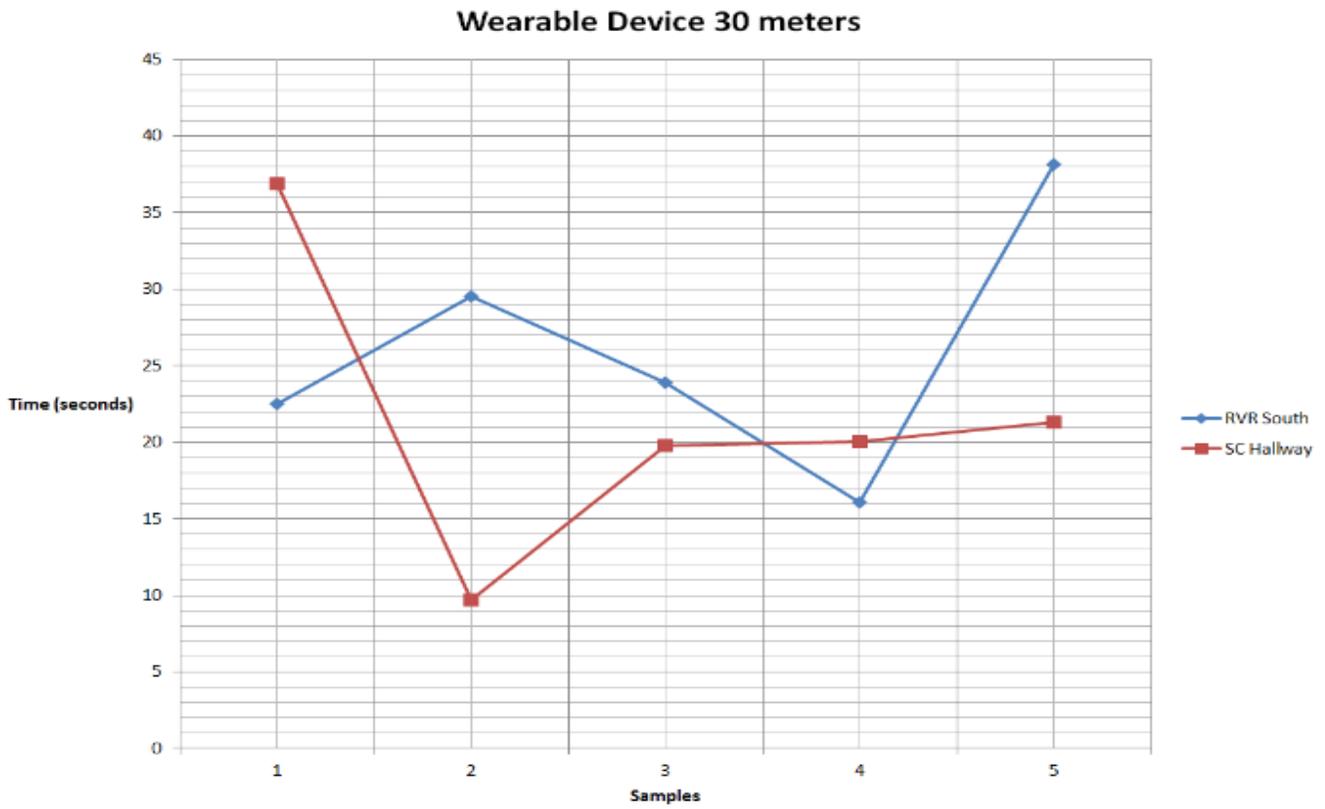


Fig. 23. Long interval scan at 30 m [42].

Figure 23 shows the long intervals of the hardware device at 30 m, which shows the amount of samples taken with respect to time. In Figure 24, the line graph represents the same response times recorded in Figure 23, but at a different region of 50 m.

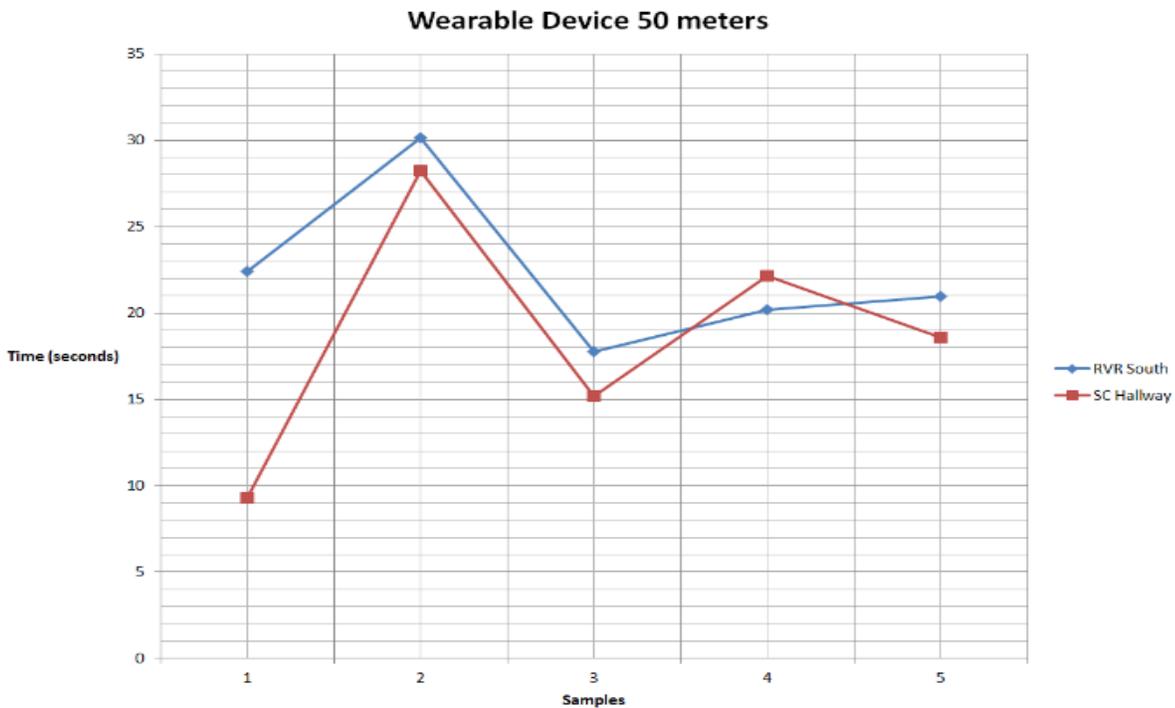


Fig. 24. Long interval scan at 50 m [43].

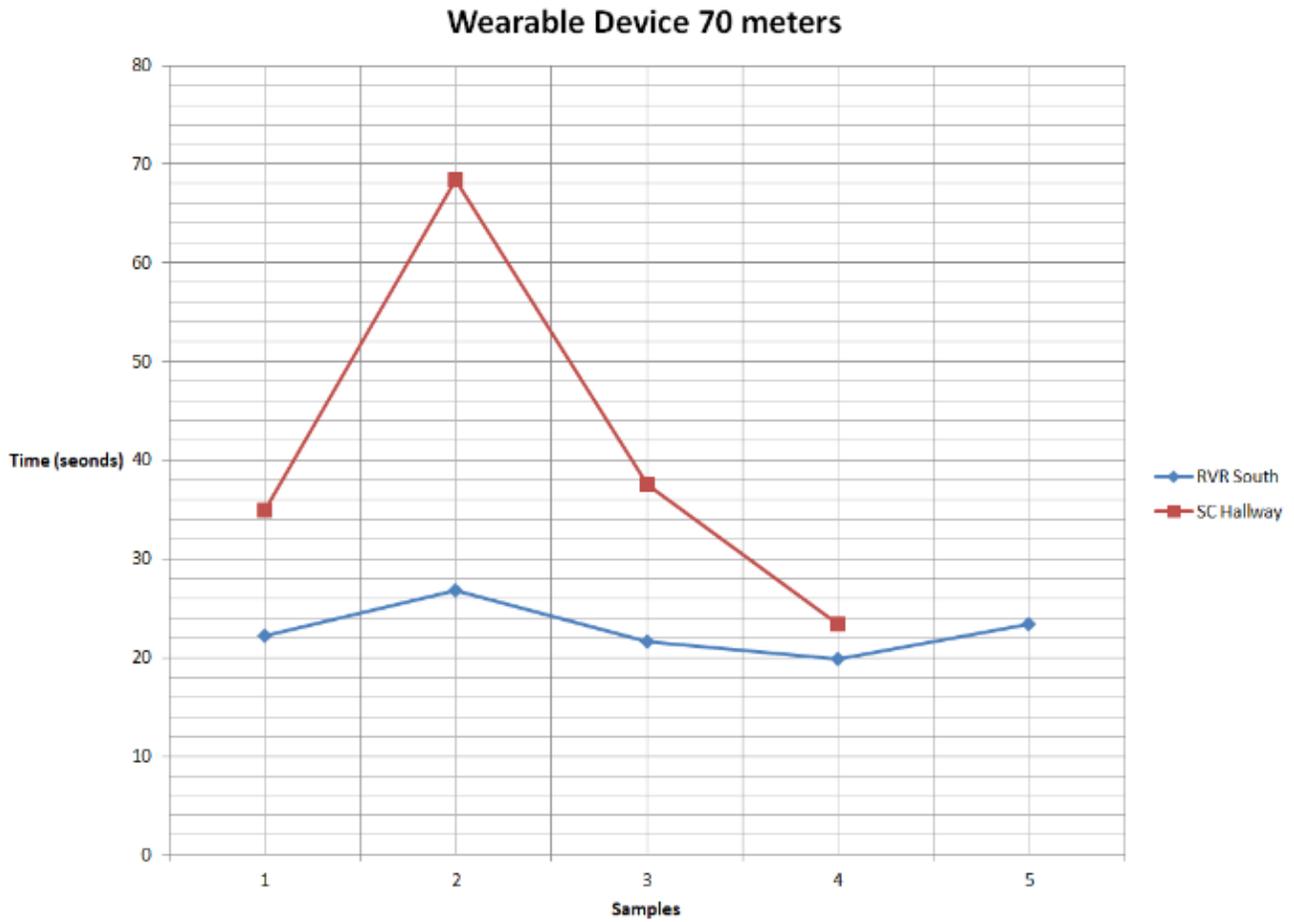


Fig. 25. Long interval scan at 70 m [44].

Similarly to Figure 23 and 24, it displays the response times at different intervals, but at 70 m.

In Figure 26, the line graph represents the same 30 m response time, but the difference is that the intervals are shorter with respect to time.

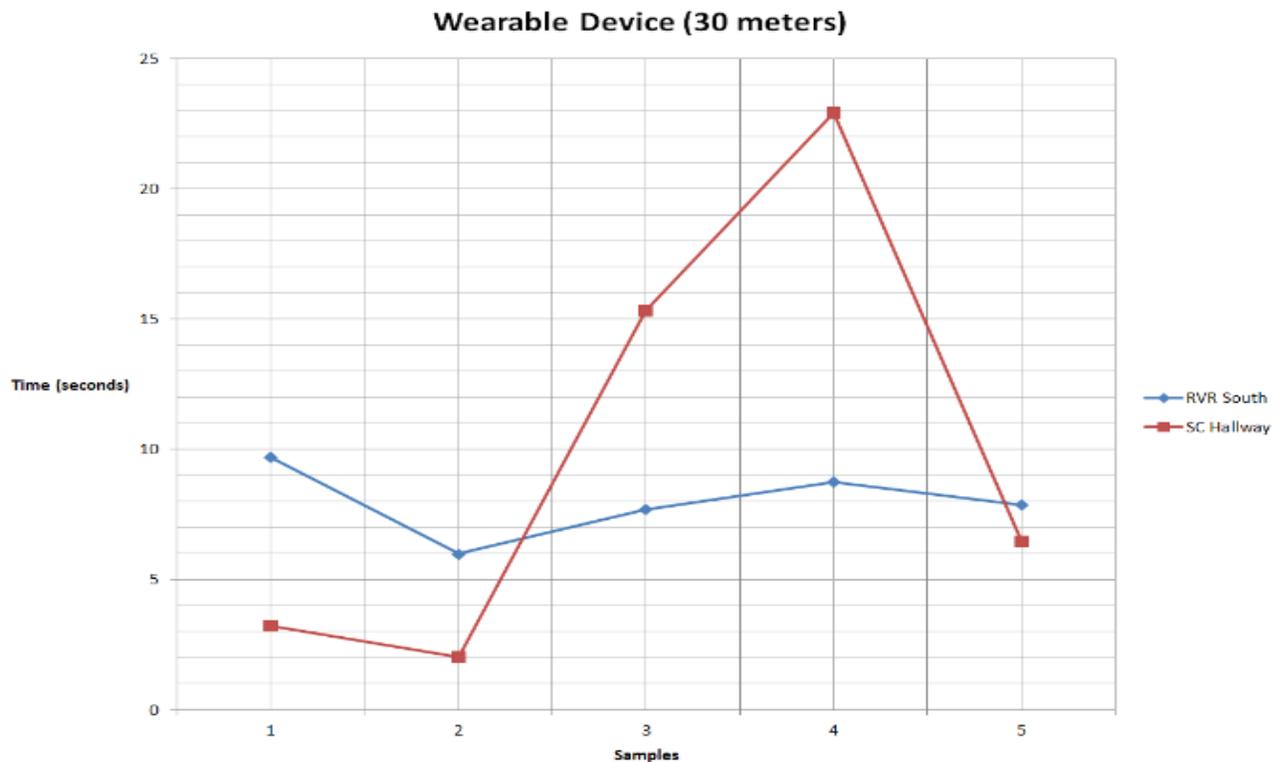


Fig. 26. Short interval scan at 40 m [45].

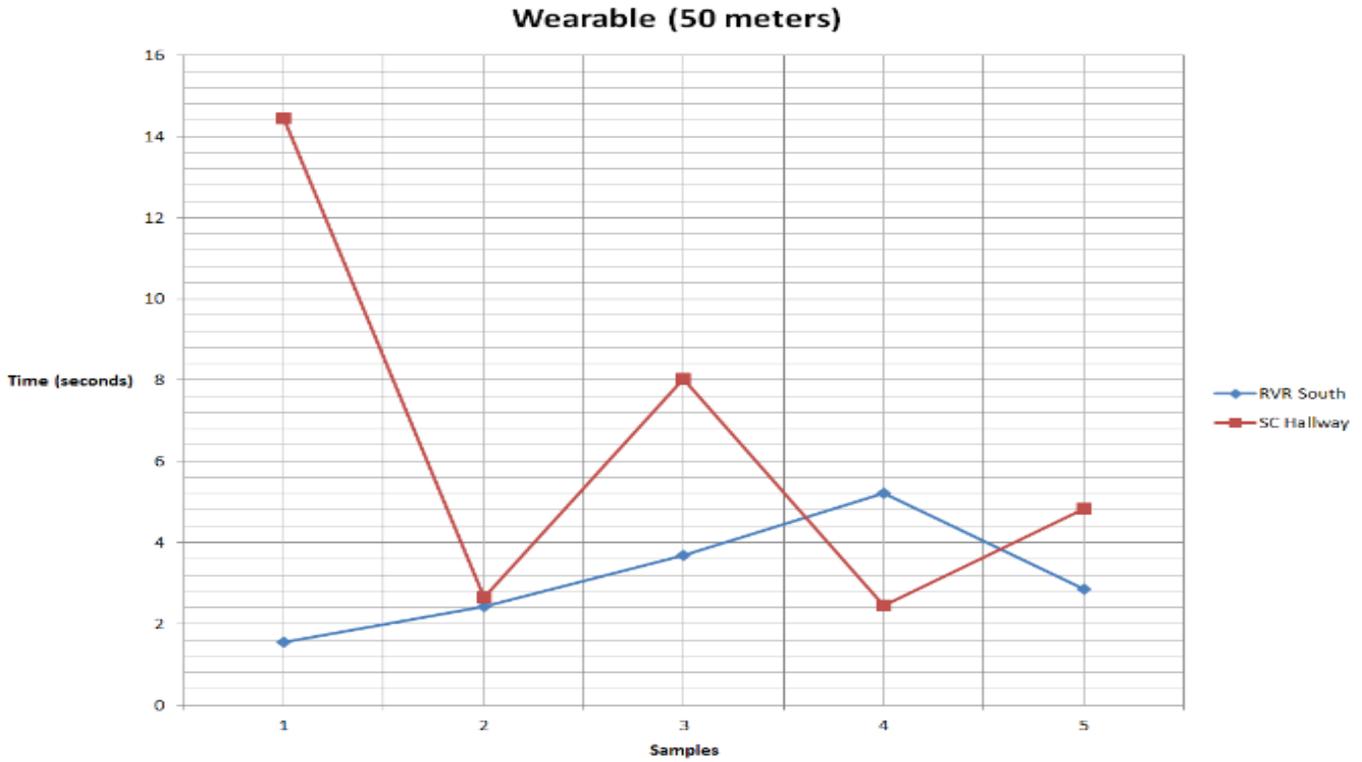


Fig. 27. Short interval scan at 50 m [46].

Again in Figure 27, it shows the response times at 50 m, but at short intervals. Figure 28 show the short intervals of the response times at 70 m.

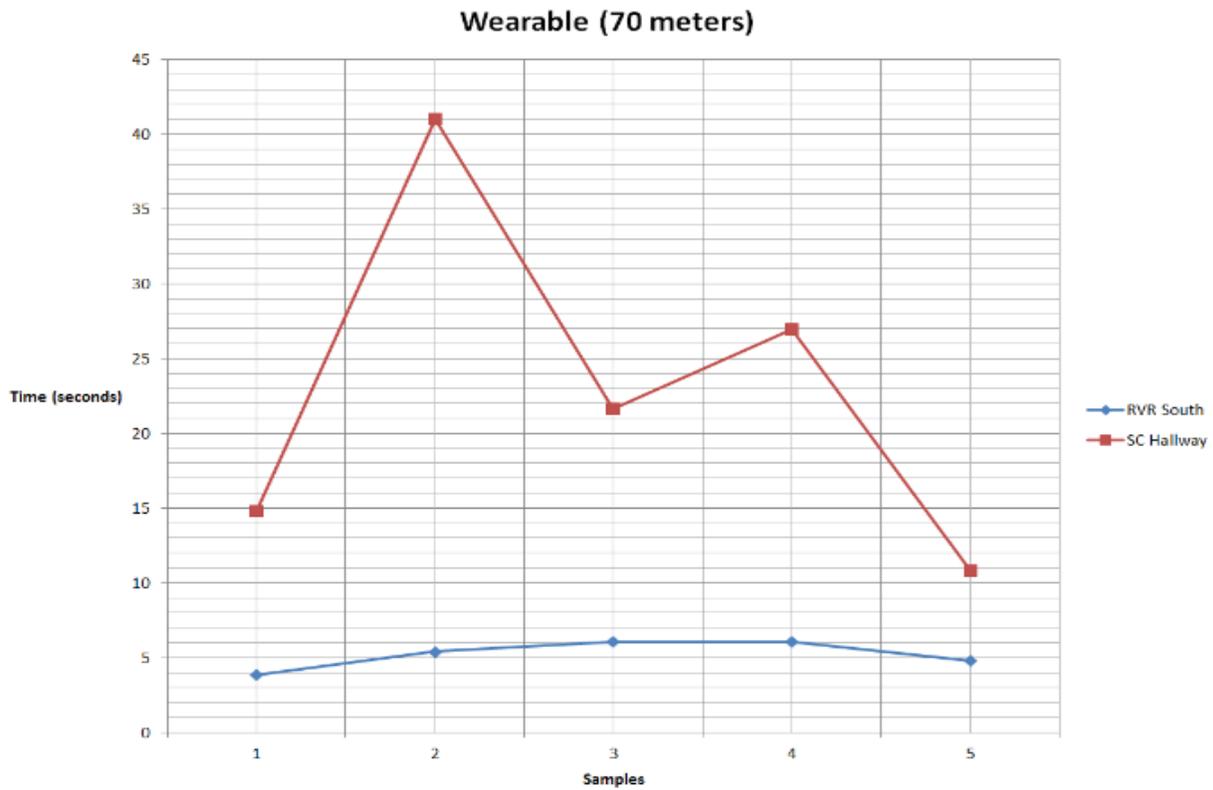


Fig. 28. Short interval scans at 70 m [47].

D. Beacons

The beacon fulfills the regional beacon awareness feature of the project which allows us to associate a beacon with a certain area. Beacons emit a BLE signal that advertises data. This data consists of a UUID, major and minor value, and RSSI. This data can be used to differentiate the beacons and help determine what area a user is in depending on where we have selectively placed the beacon. Our mobile application and hardware device scans for specific “starting beacons”. Once they are found, a user can select a “destination beacon” and will then be guided to each beacon along the path to their destination with predetermined instructions. When a user gets to each beacon, the user will be notified and will be guided to the next beacon until they reach their destination.

Without the beacons, our devices have no way of knowing where a user is and cannot guide a user as they navigate place to place. The beacons are what essentially give a user interaction to the environment with the device and allows for a type of real time guidance.

1) Features/Components

The purpose of the region beacon awareness feature is to allow the devices we will be implementing a way to have spatial intelligence.



Fig. 29. Estimote Beacons [48].

but differ in the way they output information to the user – one is intended to be used by those with visual impairments while the other can be used by anyone. When a device finds a “starting beacon” by detecting the BLE signal from a beacon we have configured to be a “starting beacon”, the user will be able to select a “destination beacon” and be guided to that beacon. Guidance is accomplished by guiding a user to several other beacons along a predetermined path and instructions that the device gives a user. The device will be searching for each beacon along the path and will further instruct a user once each beacon is reached until a user reaches their destination. Both the hardware device and mobile application make decisions based on the user input and the beacon signals they detect.

2) Implemented Solutions

The solution for creating the region beacon awareness was to use the iBeacon technology. There were several types of beacons available in the market, but the beacon the team decided on were the Estimote beacons. Beacons can be built by using hardware such as a Raspberry Pi and a Bluetooth dongle, but the project requires many of these beacons and the team does not have enough time to build all the beacons. There are also many other beacons to purchase, but the Estimote was the best fit for the project in terms of battery life, range, durability, and functionality.

Estimote beacons are made by Estimote and use iBeacon technology to emit BLE signal advertisements. Each signal carries out data that include UUID, major and minor value (additional identifier values), and RSSI. This data can be configured according to our needs to define a region. The Estimote beacon also has settings that can change the interval of advertisements, the range of the signal, and turn on and off other features of the beacon. Estimote beacons are small in size and have an adhesive backing that is designed so that they can be placed on walls or objects. Each beacon is weather proof and benefits us since we will be placing the beacons outside.

3) Testing Results

The role of the beacons is to output a signal that both the mobile application and portable device can receive to identify and discriminate between the beacons. The beacon will represent a region that the mobile application and portable device will detect.

To test this feature, we wanted to test the accuracy of the range settings the beacon had and how fast our devices can detect the beacon signal. We first set a beacon outside and had markers for 30 m away, 50 m away, and 70 m away from the beacon. We would then set the beacon range to 30m, 50m, and 70m. We would then be around 10m to 15m away from the marker that corresponds with the settings we

To provide the feature, we used iBeacon technology which both the mobile application and hardware device can detect. iBeacon technology uses BLE also known as Bluetooth Smart to transmit data. The Bluetooth signal uses low power and transmits at a different frequency than regular Bluetooth. iBeacon is made by Apple and they have libraries already made in order to develop applications for iOS using this technology. The hardware device we are implementing uses a Raspberry Pi along with a Wi-Fi and Bluetooth 4.0 dongle. The Raspberry Pi is able to pick up BLE signals including the beacons we are using.

The beacons serve as a specific landmark for a region. Both the hardware device and the mobile application function in a similar way,



Fig. 30. Different types of iBeacon beacons [49].

have configured and walk towards the marker. The distance from the beacon is what we recorded. Below shows the results gathered when testing this feature.

Beacon Signal Test

From the above results, it seems the beacon range is not as accurate as we expected. For instance, when we set the beacons to 30m, we would receive the beacon signal more than 5m away from what was expected. The 50m setting gave us the most consistent results in which we will probably favor these settings when using the beacons for the project. Although the beacon range is not exactly 50m, we have enough data to make adjustments and speculate where a user would receive a beacon signal.

4) Integration with other Features

As mentioned earlier, the beacons will be used to identify a region that a user will interact with using the mobile application or the hardware device. The software will make decisions based on what beacon each device picks up and what the user is inputting.

The hardware device picks up the BLE signal by using a Bluetooth 4.0 dongle and using a specific library that will return the data of all the BLE signals that are picked up. We have adjusted this code recently to scan a certain amount of times and only return BLE signals that we specify. Each beacon can be configured to transmit UUIDs that we can set ourselves.

The mobile application also picks up the beacon signal using a Bluetooth 4.0 receiver built into the phone. We are currently only creating an application for iOS devices, and the only iOS devices that have Bluetooth 4.0 receivers are the iPhone 5 and newer models. Since iBeacon technology is a protocol made by Apple, they have provided libraries to allow application development using iBeacon.

We did try to create another mobile application that would run on Android, but there was only the need for one application to fulfill the feature set and we do not have the time to implement both. Since iBeacon technology is not native to the Android platform, specific libraries are needed. There is not much information on how to use the libraries and a lot of testing would be needed. We were able to use some of the Android application that was developed to learn more about how the Estimote beacons function and the type of scanning we wanted to use to look for beacons. We took this information and applied it to the iOS application.

Beacon Response Test

Table XII

Table of beacon testing results

Beacon Signal (Feet)							
Distance	Beacon	1	2	3	4	5	AVG
30 meters (~100 ft.)	RVR South	100 ft	39.48 ft	39.56 ft	105.6 ft	90 ft	74.93
50 meters (~160 ft.)	RVR South	172 ft	191 ft	190 ft	192.6 ft	194.8 ft	188.08
70 meters (~225 ft.)	RVR South	238 ft	229 ft	238 ft	234 ft	227 ft	233.20

APPENDIX C. SOFTWARE

E. Mobile Application

To reiterate, the objective or societal problem for our system is to design a series of devices that will assist the visually impaired and incoming students in navigating through the CSUS campus with independency. My task for the project was to create a user interface using a mobile application to perform the necessary task to guide a user to their destination. However, the target for the application is towards incoming students who are not familiar with the CSUS campus. Seeing how majority of the students at CSUS have a smartphone, we narrowed down our solution in creating a mobile application, specifically an iOS application for the iPhone.

What the iOS application needs to do for the user is to guide the user, using preset beacon locations, as a guide to instruct the user to their destination. Using the Estimote beacons as a guide, the beacons will output a Bluetooth Low Energy (BLE) signal that the application will receive in distinguishing the other beacons in possession.

The signal will contain unique values such as Universal Unique Identifier (UUID), major and minor, and Received Signal Strength Indication (RSSI) to indicate which beacon it is. Using these values in the BLE signal, the application will access the database to match the information so it can accurately differentiate the beacon. Once the beacon has been identified, depending on the beacon the application will send back instructions to navigate the user to the beacons in the set path until the user has reached their destination. An aspect that is relevant to the application is the ability to calculate a path for the user. The user will need to find a starting beacon to start the navigation of the user. After the starting beacon is discovered, the application will calculate the shortest path to the destination for the user, which will lessen the need for the user to decide a path to follow.

To test this functionality, we performed tests to assure that the application will function the way it should. Our test involved testing all the feature sets, which included accessing the database and guiding the user to each beacon until the destination is reached. What we tested for the application is the response time when approaching a beacon. We wanted to see if the application can receive the beacon at a reasonable time. If the application was able to receive the application at a reasonable time, then it was successful in passing our test case. Otherwise, we needed to adjust our application where it can receive the signals at a reasonable time. Conclusively, the application was able to receive a signal at a very substantial rate. The application will be able to receive the signal at about 3 s as long as the application is within a beacon transmission region.

As far as being integrated with the system as a whole, the application needs to function with the other features of the project. The application needs to access the database to retrieve the information needed to identify a specific beacon signal it received. Along with the beacons, the mobile application needs the signals to accurately match the information that was stored in our database to ensure that the beacon we received is the correct beacon. If each feature does not function together, then the application or the whole project would fail to work. Each aspect is important in making the application work.

1) Features/Components

The mobile application is one of the primary aspects of the feature set of the project. What this feature essentially does for the project is to provide assistance for incoming students who are not familiar with the CSUS campus. Primarily, the application will access the common database to retrieve beacon information so it can be utilize in guiding the user to their destination. The application will use a routing algorithm, Dijkstra's Algorithm, to create the shortest path from the starting beacon to all the other destinations on the CSUS campus. The application will also guide a user from a starting beacon transmission region to an end beacon transmission region by providing a predetermined path and giving sets of instructions to prompt a user to reach each preset beacon region until a user arrives to the beacon region selected. The user will arrive to the destination once receiving the transmission signal of the end region beacon. Lastly, the application will only work in the proposed area and only along the main pedestrian pathways of the selected area.

In relationship to the system as a whole, the objective of the project is to guide the visually impaired or incoming student to their destination without the assistance of others. However, our primary target for our application is towards incoming students who are not familiar with the campus layout. Our team was able to incorporate the idea of assisting incoming students by relaying instructions to the user as they traverse through the campus through our mobile application. The routing algorithm provides a calculated path for the user so the user would not have to device a path plan to navigate to the campus. The path is the shortest and direct path to all destinations throughout the campus. The application provides the needed assistance through easy-to-use instructions that is simple enough for the user to read and guide themselves to their destination, which is the goal of the project. As long as the application is able to guide the user through the preset beacons, then the application fulfilled its feature set and met the expectations of the user.

2) Implemented Solution

We wanted to incorporate a solution where an incoming student, who has access to a smartphone, can utilize the features that are involved in our project. This led us to the solution of designing an iOS mobile application for the iPhone.



Fig. 31. Left: iPhone that uses the application for incoming students. Right: Hardware used for visually impaired students [51].

Since our project utilizes iBeacon technology made by Apple, this was a simple solution to come by. Apple has developed APIs that can work in parallel with iBeacon technology and iPhone. We are using Estimote beacons that outputs a BLE signal that has distinguishing values that the iPhone can receive from the signal. The application will retrieve the UUID, major and minor, and RSSI values. For our purposes for this project, we only need to use the minor value of the beacon signal to distinguish the difference between other beacons. The beacons are covering a specific area of the CSUS campus and we only need the minor value to identify which beacon the application received. The beacons are used to assist the user by relaying information to the application where the device will decode the signal and send instruction sets to the user so he/she can use it to guide themselves through the campus. With this minor value, the application will use that to match the minor value it received from the database and use that beacon information to give specific instructions to reach that beacon. Overall, the application will access the database, use the minor value to find the beacon with matching value, and relay the information back to the user so they can guide themselves to their destination.

3) Testing Results

After performing the needed testing for the mobile application, we achieved results that were helpful in improving our project. Through various amounts of testing, our team was able to understand our project at a more technical level. We wanted to test our feature set and reassure that our mobile application has met the requirements specified in our feature set “punch list”. The goal for testing the application was to make sure that the application can fulfill its functionality as stated in the feature set “punch list” through our test methods to dictate to us whether the application has passed or failed testing.

One of the most important tests that we performed on the application is the response time for the application. When we tested the application response time this correlates to the other features of the application. By testing the application’s response time, we were able to verify that it was able to access the database, receive transmission region signals from the beacons, and use the signal information to guide the user to their destination. With this in mind, the goal of the test was to see how responsive the application is when receiving the signal. As long as the mobile application can receive a beacon signal, it should be able to perform the other functionalities specified in the feature set “punch list”. In respect to passing or failing, if the application responds to the signal at an appropriate time, then it would have successfully passed the test. Otherwise, we will need to examine the problem and figure out why the application is slowly responsive to the signal. To test the response time, we wanted to test the application when the beacon signal is at 30 m, 50 m, and 70 m. Below shows the results of the response time of the mobile application.

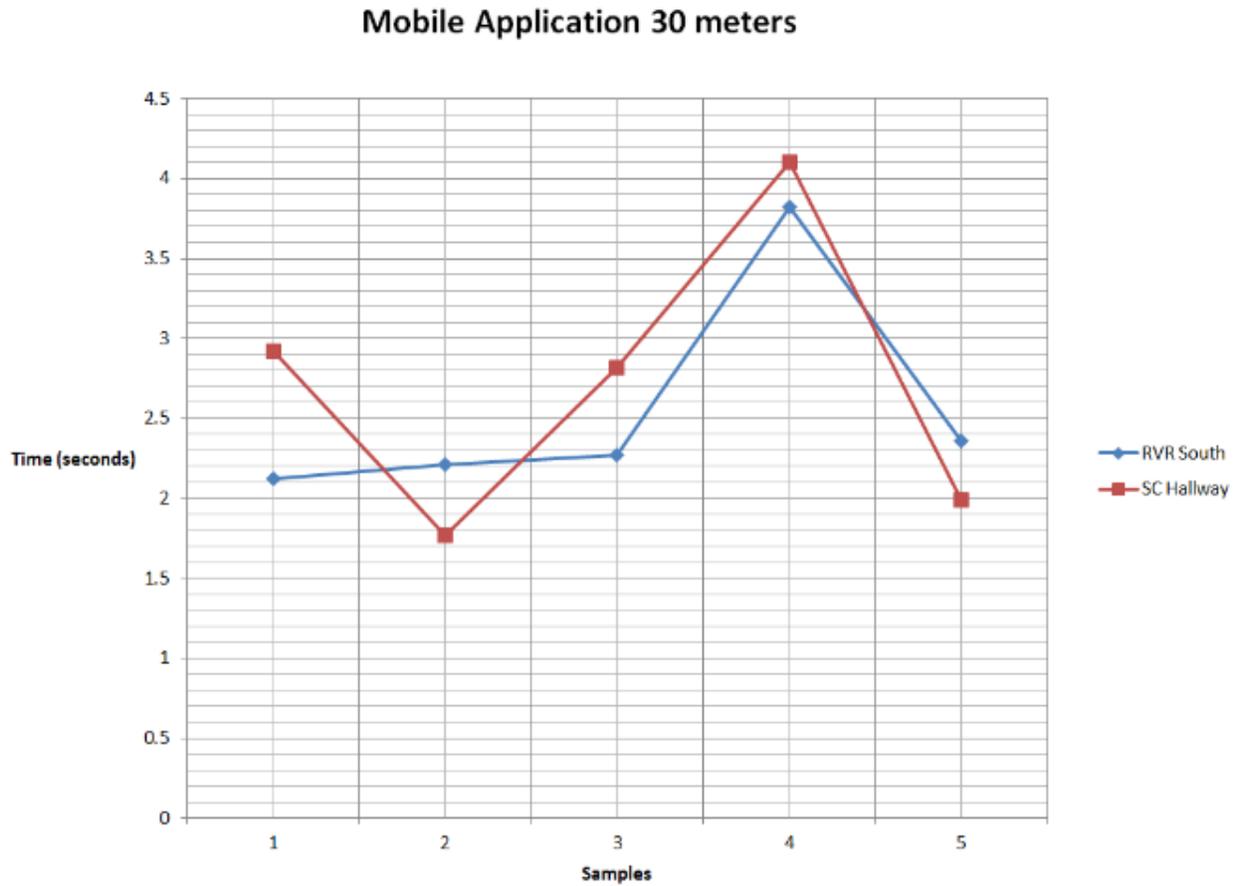


Fig. 32. Line graph of Mobile Application for 30 m [53].

Figure 32 shows the line graph representation of the response time of the mobile application at 30 m. The response time were taken at samples with respect to time. In Figure 33, it shows a line graph similar to Figure 32, but with respect to 50 m.

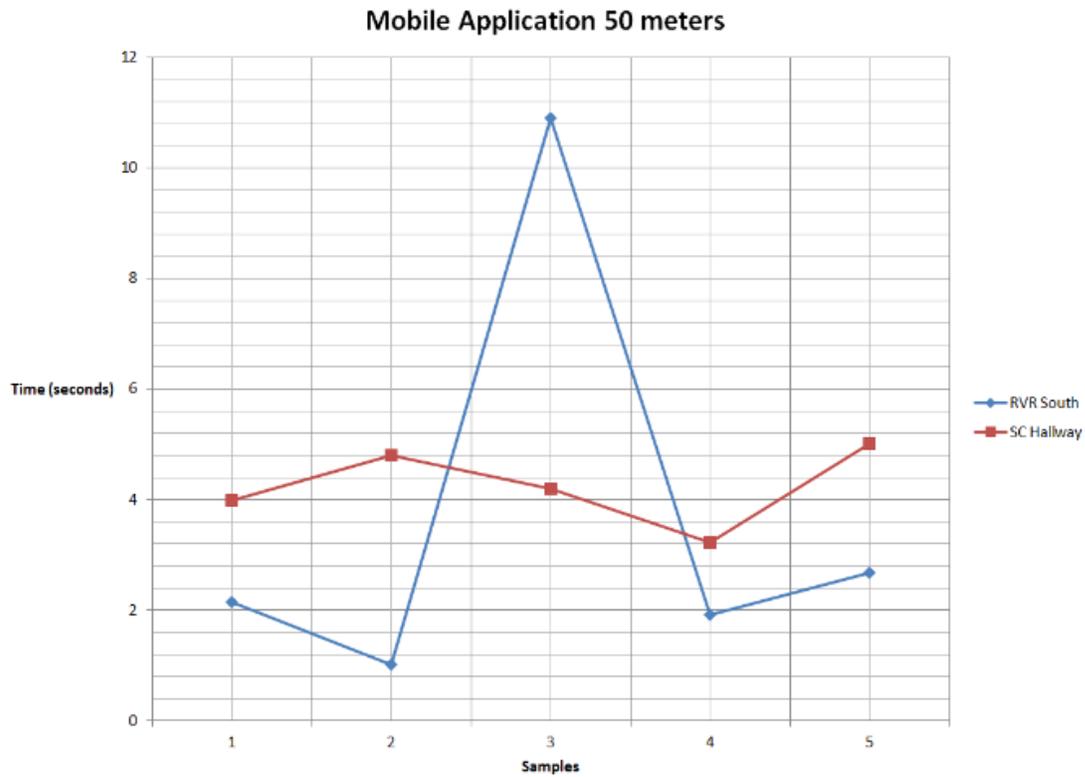


Fig. 33. Line graph of Mobile Application for 50 m [54].

The line graph shown in Figure 34 shows the response times at 70 m.

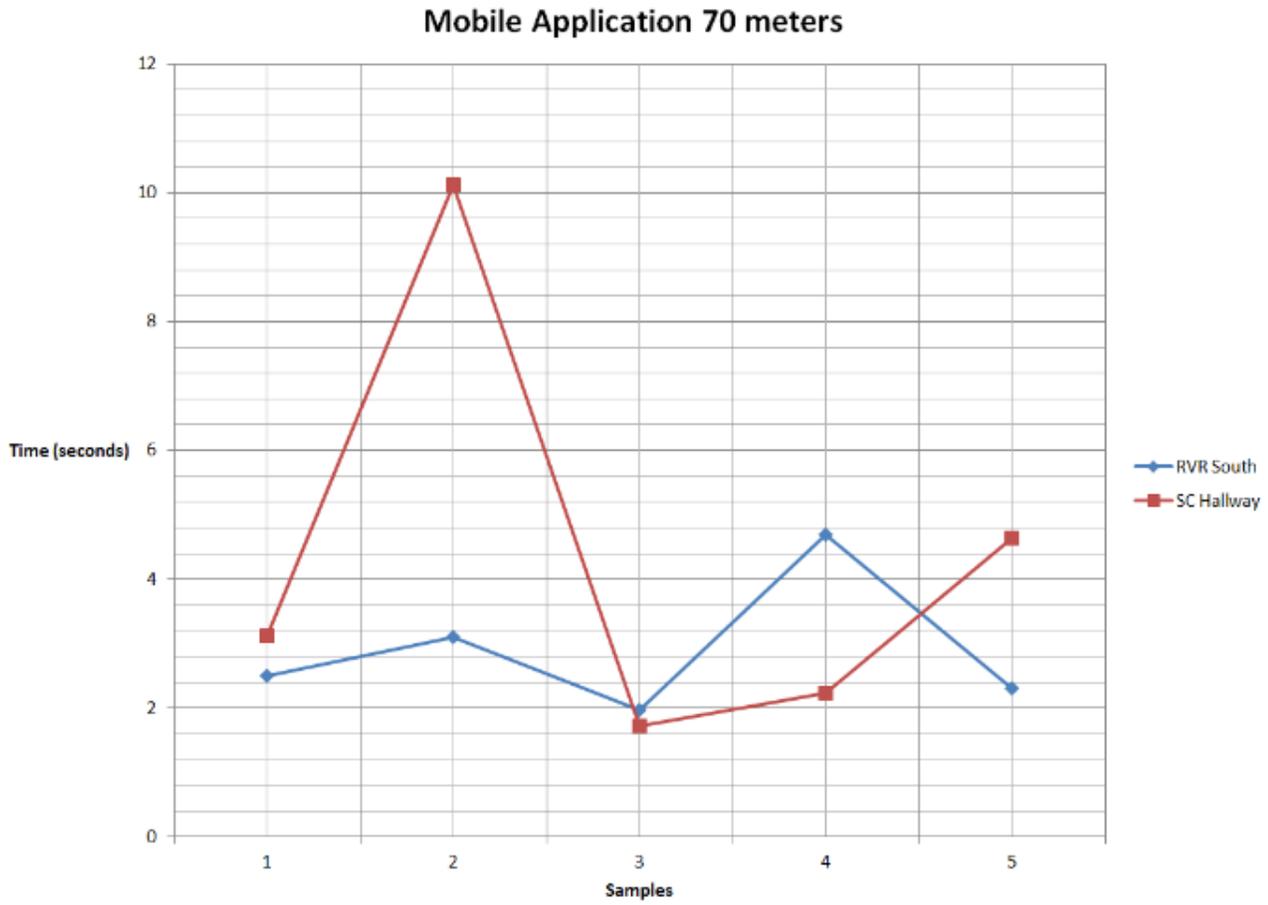


Fig. 34. Line graph of Mobile Application for 70 m [55].

According to the test results, it is conclusive that the mobile application has a fast response time, which is beneficial when receiving beacon signals as one walks through the CSUS campus. With the results gathered, it seems that the mobile application averages at a response time of 3.42 s, which is relatively fast. At 50 m, our application had very consistent results of about 2 s or 4 s, which is the consistency we wanted in our mobile application. What we noticed in our project is that sometimes our beacons would go to “sleep”. Meaning, that our Estimote beacons goes to a powered down state where the signal is not being outputted from the beacon. This also validates that the application was able to distinguish other beacons through the minor value it receives from the signal using the database we created. With each beacon we had, the application was able to relay instructions to the user so that he/she can guide themselves to their destination. As it can be seen, the mobile application has passed its testing plan and can be further improved upon until it is fully function to be used by the user.

4) Integration with other features

When being integrated with the other features of the project, the mobile application functions along with the database and the beacons. With respect to the database, the mobile application communicates with the database to receive information on a particular beacon. Essentially, when a user approaches a beacon and receives a signal from it, the application will go to the database and will identify which beacon the user has approached. Once the beacon was identified, the application will continue the rest of its functionality to guide the user to their destination. In terms of the beacon, the application is using them as a guide for the user to direct themselves to the destination. The application will receive the distinguishing information that the beacon signal outputs. With the information from the beacons, the application will decode the information and use that to relay the proper instructions to the user depending on the beacon signal the application has received. This functionality will occur for all beacons utilized in this project. Each beacon will have a specified instructions set that application will be giving to the user as they guide themselves through the CSUS campus.

APPENDIX D. MECHANICAL DRAWINGS AND SUPPORT DOCUMENTATION

*There are not mechanical drawings and support documentation associated with this project.

APPENDIX E. VENDOR CONTACTS

Contacts: SSWD (Services to Students with Disabilities)

On behalf of Project Icarus from the College of Engineering and Computer Science we would like to express our appreciation to the Services to Students with Disabilities (SSWD) for the input in helping us with our senior design project to help students with disabilities. The department's knowledge with working with disabled students assisted us in designing our project design. We would also like to thank you for meeting with our group to help increase our awareness and understanding of how the CSUS visually impaired students get around campus. If it wasn't for the SSWD office we would not have been as successful as we were for this project. With their contribution we hope to make an impact on the CSUS campus.

The generous support of individuals like you makes it possible for Senior Design Projects and other forms of organizations that require funding to exist and to make California State University, Sacramento (CSUS) a great place to study and educate ourselves.

Contacts: UEI (University Enterprise Inc.)

On behalf of Project Icarus from the College of Engineering and Computer Science we would like to thank you for your contribution of \$700. Your financial support helps us continue in our mission and to assist those in our community. The generous support of individuals like you makes it possible for Senior Design Projects and other forms of organizations that require funding to exist and to make California State University, Sacramento (CSUS) a great place to study and educate ourselves.

APPENDIX F. RESUMES

Anh Duy Nguyen

OBJECTIVE: To obtain a career opportunity in the engineering field.

EDUCATION

California State University, Sacramento

Graduation Date: May 2016

Degree Objective: Bachelor of Science in Computer Engineering

PROFESSIONAL SKILLS

- **Programming Languages:** Java, C, Assembly (x86 and MIPS), Verilog, VHDL, Python, TCL and TK, Swift
- **Operating Systems:** Microsoft Windows (XP/Vista/ 7/ 8/ 10), Mac OS X, Linux/Unix (CentOS, Kali Linux, Raspbian)
- **Software Tools:** Quartus Altera II, Multisim, Microsoft Office, Microsoft Visio, Xilinx ISE Design Suite, Xcode, JGrasp, Cadence PSpice, Wireshark, VCS Synopsis, Cadence Virtuoso, Eclipse, Google Docs, GNU Debugger (GDB), VMWare, PuTTY
- **Hardware Tools:** Oscilloscope, Function Generator, Logic Analyzer, Digital Multimeter
- **Hardware:** Altera Amani GTX CPLD, Raspberry Pi B+ (ARM1176JZF-S), Xilinx Spartan 3E FPGA
- **Bilingual:** Fluent in English; Understand and speak Vietnamese.

PROJECTS OR PROJECTS IN PROGRESS*

- **Automated Book Scanner:** A final group project designed to turn pages of a book automatically, scan the book and convert the scanned book to a readable format.
- ***Eastern Ways Martial Arts Mobile Application:** An iOS mobile application programmed in Swift that allows for easier communication between Martial Arts instructors and students. The mobile application will replace the old fashion phone call and paper work and utilize email and messaging for faster and sufficient communication.
- ***Project Icarus:** An electronic self-navigating device that assists disabled students in traversing the college campus without having an actual person assists the disabled student. The device will be operated using microcontrollers, wireless sensors, and a mobile application to provide simple interactive use for the disabled student.
- **Building Computers:** Building computers that utilizes new and used computer components. The process of building the computers involves troubleshooting and configuration.

WORK EXPERIENCE**California Department of Public Health; Student Assistant**

(December 2014 – May 2016)

Information Technology Services Division / Application Development Support Branch (ITSD / ADSB) tasked with developing the applications used in the department, which accommodates the needs of the consumer of California. Position provides the opportunity to offer IT services to the department when needed.

Intel Ultimate Engineering Experience, Sacramento State (IUEE); Intern

(June – July 2013)

A six week program held by Intel and California State University, Sacramento (CSUS) that engages innovative participants to learn. It allows inexperienced participants to develop new programming and circuit skills. Worked in teams to design business propositions for future clientele and learn from the experiences of Intel employees and interns.

HONORS AND AWARDS

CSUS – Dean's Honor List: Spring 2012, Fall 2013, Spring 2014, Fall 2014, Spring 2015

Eastern Ways Martial Arts – Outstanding Student of the Year 2014/2015

EXTRACURRICULAR ACTIVITIES

- MESA Engineering Program (MEP); Member
- Institute of Electrical and Electronics Engineers (IEEE), CSUS; Member
- Tau Beta Pi; Member
- Society of Hispanic Professional Engineers (SHPE); Member
- Eastern Ways Martial Arts Kung Fu and Tai Chi; Kung Fu Martial Artist
- Vietnamese Eucharistic Youth Movement; Youth Group Leader

RELEVANT COURSES COMPLETED OR IN PROGRESS*

- **Computer Science:** Program Concept and Method, Discrete Structures, Computer Architecture, System Program Unix, Data Structure and Algorithm Analysis, Operating System Principles, Computer System Attack and Countermeasure
- **Computer Engineering:** Circuit Analysis, Advanced Logic Design, Computer Interfacing, Network Analysis, Signals and Systems, Computer Hardware Design, Electronics I, Computer Network + Internet, Advanced Computer Organization, *Senior Design Project, Probability and Random Signals, *CMOS and VLSI, *Operating System Pragmatic

Rohit Pandit

OBJECTIVE: A position in Computer Engineering.

EDUCATION:

In progress: **BS, Computer Engineering**, CSU Sacramento; May 2016

RELATED COURSES:

Operating System Pragmatic*	Senior Design Project I	Electronics I	Unix System Management
Problem & Random Signal*	Robotics	Operating System Principles	Network Analysis
Senior Design Project II*	Computer Network + Internet	Signals and Systems	Advanced C++ Programming
Advanced Computer Organization	Data Structures and Algorithm Dev.	Advanced Logic Design	Assembly Language
Computer Hardware Design	CMOS and VLSI	Computer Interfacing	<i>* In progress as of Spring 2016</i>

KNOWLEDGE AND SKILLS

Computer Languages: C/C++, Java, Verilog, VHDL, X86 Assembly, MIPS, Unix, Python, HTML/CSS, SQL, Latex

Hardware/Software: Skilled at troubleshooting and solving hardware and software problems. Able to learn and work with new technologies easily. Skilled in setup, maintenance, documentation and training of hardware and software.

Computer Skills: MultiSim, VMWare, Pspice, Cadence18, Eclipse, Altera Quartus, Putty, FPGA, Synopsys, Matlab, SharePoint
Leadership/Management: Developed strong leadership skills while serving multiple officer positions for Competitive Robotics- responsible for maintaining records and documentation; setting up events, procuring funds, materials, food, and space.

Coached recreational soccer teams in Sutter, CA from 2007 through 2009.

Languages: English; Intermediate language skills in Hindi, Punjabi, and Spanish

PROJECT EXPERIENCE:

Senior Design: Project goal is to help students navigate the CSUS campus through a portable device. This portable device is aimed for visually impaired and incoming students. Design will aim to reduce dependency for students that require individual assistance.

Robotic Arm: Coded a robotic arm designed to scan and find Lincoln Logs on a given plane, pick up the logs in the middle, and build a house in a prescribed location. The project required learning C++, running calculations on three-dimensional mid-points, working with teams and delegating responsibilities, and improvising parts from other gadgets. The team of six completed the project over the course of six months.

Datapath: With a 2 person team used a given set of instructions to build a datapath and wrote code-implementing solution as quickly as possible. The project was broken into 2 phases: In phase one the team designed the datapath, and in phase two the team coded each component of the datapath.

CMOS Design for Flash ADC & Dual-Slope ADC: Built a Flash ADC with a 2 person team. Learned Cadence software in order to create the gate, layout, and schematic views.

TV Remote Controlled RC Car: Reverse engineered a radio controlled car with a team of 3. The project was designed to enable the car via an original Comcast remote control.

Arena Mover Robot: Worked on the electrical, controls, sensors, and app to control a robot with a team of 5. This robot is intended to help carry up to 800LBs for any and all CSUS clubs & affiliations.

DIY Microscope: Built a do-it-yourself microscope out of materials that were scavaged around the house. This microscope is intended for phones to view objects at a close range.

WORK EXPERIENCE:

Housing and Technology Services SA	Housing and Residential Life, CSUS	Feb 2014- Present
Responsible for trouble shooting hardware and software problems. Responsible for managing software network portals. Entrusted with security and administration privileges. Set up a tracking system for completing tasks and keeping supervisors informed.		

Cashier & HW/SW Tech	Sutter Mini Mart	Jan 2007- Present
Intern – Housing and Technology Services	Housing and Residential Life, CSUS	May 2015-Aug 2015
Front Desk Student Assistant	Housing and Residential Life, CSUS	Nov 2013- Feb 2014

ACTIVITIES AND ACCOMPLISHMENTS:

Chair for Engineering and Computer Science Exposition- Engineering Joint Council Present Present

Vice Chair- Hornet Pride Leadership Challenge Present Present

SpaceX-Hyperloop Pod Competition Present Present

Active Member of :MEP, SHPE, EOP, IEEE Present Present

Project Manager, Adviser, Event Coordinator, Treasurer, Secretary- Competitive Robotics Aug 2013-May 2015

Working 17 hours per week, while carrying 17 units, and being active in all the above organizations.

Matthew Caesar Gorospe

OBJECTIVE: To obtain a challenging position in a high quality engineering environment where my resourceful experience and academic skills will add value to organizational operations.

EDUCATION:

California State University, Sacramento

Degree Objective: Bachelor of Science in Electrical Engineering

Planned Graduation: Spring 2016

RELEVANT COURSES COMPLETED OR IN PROGRESS*:

- **Electrical Engineering Courses:** Electronics I, Electronics II, Intro to Logic Design, Intro to Circuit Analysis, Applied Electromagnetics, Electromagnetic Conversion, Advanced Logic Design, Introduction to Microprocessor, Network Analysis & Lab, Signals and Systems, Computer Hardware Design, Electronics I, *Senior Design Project I and II, Modern Communication Systems, Digital and Wireless Communications, Advanced Hardware Design, Probability and Random Signals, *CMOS and VLSI, *Physical Electronics
- , Computation Methods and Application, Introduction to C Programming, *Digital Control Systems, Introduction to Feedback Systems

PROFESSIONAL SKILLS:

- **Programming languages:** C, Verilog, VHDL, Python, Visual Basic
- **Operating Systems:** Microsoft Windows (XP/Vista/ 7/ 8/ 10), Mac OSX, Linux/Unix
- **Software:** Quartus, Multisim, Microsoft Office, Xilinx, LTspice, PSpice, Microsoft Visual Studio, Microsoft Visio, MATLAB, Cadence Virtuoso, ADS (Advanced Design System)
- **Tools:** Amani GTX CPLD, Oscilloscope, Diligent Analog Discovery, Arduino UNO, Spartan 3E FPGA, Raspberry Pi, Logic Analyzer, Intel Edison
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PROJECTS OR PROJECTS IN PROGRESS*:

- **Water temperature and level regulating system:** Our team's objective was to create a system that regulated water temperature and water level by using microcontrollers and several other electrical components.
- ***Project Icarus:** An electronic self-navigating device that assists disabled students in traversing the college campus without having an actual person assists the disabled student. The device will be operated using microcontrollers, wireless sensors, and a mobile application to provide simple interactive use for the disabled student.
- **Other class projects**
 - **Antenna Patch**
 - **Design Communication System through Simulink**
 - **PLD project**
 - **Research Paper on 3D Memory**
 - **CPE 151**

COMMUNICATION/ORGANIZATION:

- Punctual, motivated, innovative, and reliable. Strong ability to quickly adjust and adapt to unexpected situations.
- Remarkable communication skills through written reports and interactions with team members during lab and peers at the work place.

WORK EXPERIENCE:

Regal Cinemas Entertainment Group, October 11, 2010 – Still currently employed

Responsibilities include:

- customer service
- food preparation
- ticket selling
- auditorium cleaning
- theatre checking

EXTRACURRICULAR ACTIVITIES

- Institute of Electrical and Electronics Engineers (IEEE), CSUS; Member
- Volunteer basketball coach at Natomas Charter Middle School 2009
- Volunteer at Sacramento Public library 2009-2010