Towards Building iBeacon-based

Smart Indoor Environments for

Visually Impaired Users

by

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ABSTRACT

Improving accessibility to public buildings by people with special needs has been an important societal commitment that is mandated by federal laws. In the information age, accessibility can mean more than simply providing physical accommodations like ramps for wheel-chairs. Better yet, accessibility will be fundamentally improved, if a user can be made aware of important location-specific information like functions of offices near the user within a building. A smart environment may help a new person quickly get acquainted about the environment. Such features can be more critical for cases of making an indoor environment more accessible to people with visual impairment. With the intention to promote the integration of visually impaired people in society, this thesis efforts on methodologies for building smart and accessible indoor office environments with the help of Apple's Bluetooth Low Energy (BLE) technology called iBeacon to provide location awareness and enable easy access to information about the environment to people with visual impairment. This thesis presents work done on developing an iterative based approach in improving the configuration of given number of iBeacons to gain optimal signal coverage in a given office space environment and enabling smart features such as tagging points of interest and push notifications. This work aims to exploit the idea to look at visual impairment beyond the level of disability and cash it at as an opportunity to bring about a change of style of living. This work develops a methodology by introducing an end-to-end systems that uses intelligent server side and visually-impaired-friendly client side interfaces to give a prototype of an assistive technology to help them do basic activities like getting familiarized about an office environment without the need for asking for assistance.

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CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

Improving accessibility to public buildings by people with special needs has been an important societal commitment that is mandated by federal laws[1]. In the information age, accessibility can mean more than simply providing physical accommodations like ramps for wheel-chairs. For example, a building can be truly accessible to people with visual impairment if localization within the building is provided to a user somehow. Better yet, accessibility will be fundamentally improved, if a user can be made aware of important location-specific information like functions of offices near the user within a building. Such a broadened sense of accessibility is critically related to indoor localization.

GPS-based devices, in general, do not provide high-precision localization in an indoor setting, and thus researchers are trying to discover alternate ways to gather accurate location-based information for indoor environments. Significant amount of work is being done in the field of indoor navigation and positioning using Apple's BLE technology based device called iBeacon[2].

There have been previous works to help users in the aspect of navigation by using a small volume based devices which are of low cost and have easy integration with bluetooth technology based mobile devices [3][4]. One of the notable bluetooth based technology is Apple's implementation of BLE technology called iBeacon. Work has been done to help navigate patients to their ward [5] or give an interactive historical experience to visitors of a museum [6].

Although localization and navigation of people with visual impairments are described in [7] [8] [9] these works do not consider in providing high localization accuracy tailor-made to a specific environment.

1.2 PROBLEM STATEMENT

The novelty of the proposed approach therefore lies in the fact that it addresses the question on how to practically prepare the environment for maximum signal coverage and how it can be expanded to more complex requirements such as access and gain information about a given indoor environment to visually impaired users.

We work with iBeacon technology by using small cost-effective coin sized devices called Estimote Beacons(iBeacon). This may be used to estimate the proximity of another bluetooth-enabled device.

With multiple iBeacons deployed in an environment, we may able to achieve localization of a user carrying a bluetooth-enabled device.

For a given environment, with the above technology, we may be able to make an environment more accessible by providing a user with

localization information. Further, additional location-specific information can be provided to a user. This idea has been proposed to make, for example, a market smarter so that functions like pushing relevant advertisements may be supported when a user walks by an aisle [10]. In practice, if a finite number of iBeacons need to be deployed for an environment, there may be optimal positioning of the iBeacons (for achieving best localization) that cannot be purely determined by the geometry of the environment, since there are other factors like interference of walls or other radio wave-emitting devices.

In this thesis report, we develop an approach for iteratively discovering such an optimal configuration of a given number of iBeacons for more accurate localization.
The main objective of the proposed system is to enhance smart functions like pushing notifications, tagging a point of interest, providing location-specific information to everyone, especially users with visual impairment.

As iPhones are popular among visually impaired people[11] and eliminate the cost of acquisition and learning to use a new device, we design an iOS-based app to assist a user in positioning the iBeacons for making an environment accessible.

1.3 RELATED WORK

1.3.1 USE OF SIGNAL BASED TECHNOLOGY:

Indoor positioning techniques are evaluated based on their performance in scalability, precision and complexity [12]. As applications in the field of indoor navigation, monitoring and advertising started to gain momentum, several technologies ventured into the field of indoor positioning [13] shows the use of WLAN, Bluetooth or radio frequency identification technology to perform the task of indoor positioning, [14] talks about the use of radio waves to locate and track users' coordinates using signal strength information collected by multiple receivers.

There were other signal strength based works to perform the task of localization as discussed in [15][16][17][18][19] With the progress of time and technology and easy connectivity to the Internet in shopping malls, office building, hospitals via WiFi, it was practical to use WiFi-based access points to get the tracking of a mobile-based user in the WiFi range as shown in [20][21]. However, these technologies couldn't not give accurate reading in an indoor-based locality.

1.3.2 USING NEW BLE TECHNOLOGY:

As time and technology evolved, the popularity of the indoor positioning system was determined by the accuracy of position, longer range of transmission, lower cost of installation. Then came along bluetooth technology based devices with their area based signal range and its small volume, low cost, easy integration with mobile devices. One of the notable bluetooth based technology is Apple's implementation of BLE technology called iBeacon. Work has been done to help navigate patients to their ward or give an interactive historical experience to visitors of a museum. These work done focus on the navigation of the user within a given premise but do not talk about improving accessibility or making the environment smarter. In this paper we mainly focus on the methodology for building a well accessible environment and draw attention to the design ways that make it smart.

1.4 CONTRIBUTIONS

1.4.1 SMART AND ACCESSIBLE INDOOR ENVIRONMENT:

In this work, I propose a methodology built towards making a given office environment smart and easily accessible by visually impaired users. This task is achieved by designing and developing an end-to-end system. We use the latest technology used for indoor location using small yet smart iBeacons which can transmit and receive BLE signal for a wide range. We program these iBeacons in a way that environmental constraints such as signal interference and distortion are reduced to a great extent. This is achieved using our methodology which finds an optimal placement for above said iBeacons. This methodology is promisingly effective as the default apps or software out there use more than required number of Ibeacons to convert a given area. This methodology intelligently reduces the number of beacons and more importantly strategically gives a placement position so its net effect is not hampered by environmental constraints. To test and deploy such an approach, we build an iOS based app to give the IBeacon placement and a server side which runs our said approach. Many smart features are incorporated into the working of the methodology like tagging points of interest, which make a contribution to the office space or mark an important place. Accessibility is achieved as the IBeacons can access maximum signal strength when placed in places where signal strength might be hampered.

1.4.2 ITERATIVE APPROACH OF FINDING IBEACON PLACEMENT:

This is one of the key contributions of the work as it demonstrates that the default mid point based suggested placement of iBeacons can be changed to make it more effective. Our methodology uses the same number of iBeacons and suggests an optimal position of iBeacons so that we can maximize the signal strength of the network of beacons so as to improve accuracy of the generated user positions. This is an iterative process and this work shows the hurdles in achieving such an arrangement of iBeacons and shows the work done to work towards their configuration in the best way possible.

The rest of the document is organized as follows.

Chapter II explains the design and methodology of the optimal placement of beacon task. All features and factors influencing the process are explained here. Chapter III describes the interface and human-computer interaction aspects. This chapter tals more about server side application and client-side user interface. Chapter IV throws some insight into experiments and performance of the thesis. I finally conclude in Chapter V.

CHAPTER 2

DESIGN AND METHODOLOGY

The objective of design is to develop an end-to-end methodology of building smart and accessible indoor environment. This section describes the components used in research, the hardware and software tools required, the methodology worked to achieve the result and the conditions under which the tests were done.

2.1 BUILDING UPTO THE METHODOLOGY

2.1.1 WHAT ARE iBEACONS?:

iBeacon provide proximity awareness. This means smart devices with Bluetooth ® 4.0, and support for BLE, can determine the proximity to an iBeacon by receiving the broadcast. This is done by the device operating system or dedicated libraries. Given a location, the first step is to configure it. This is done by placing selected beacons in the given environment as directed by the estimote app. Estimote based set of tools for building precise, blue-dot location service indoors, it uses Estimote Indoor Location SDK. SDK provides location accuracy and this information can be cached to estimate how a location varies depending on location size, shape, and crowd density.

2.1.2 ENVIRONMENTAL FACTORS:

The aim is to recalculate the positions of the beacons from their default locations as the suggested map is in an ideal environment where signal fluctuations are averaged out or evenly considered. External factors such as carpeted floors, cubicles, printers and WiFi routers, metallic cabinets, wooden furniture, cables, servers, computers, mirrors, glass walls and people moving within the location space highly influence the signal propagation thus leading to the fluctuation of RSSI. This hampers in localization of the given space. The user location reported may be error prone due to external factors that affect the signal coverage. Thus, iBeacon technology defines four proximity zones for estimating distance to a beacon: immediate (very close to the beacon), near (about 1-3 m from the beacon), far (further away or the signal is fluctuating too much to make a better estimate), unknown (proximity cannot be determined)[22]. The idea is to recalculate the positions where we maximize signal strength.

2.1.3 TWO MAP APPRAOCH:

To discover the optimal configuration it is important to start off with a good initial configuration, i.e., the default configuration obtained from estimote SDK. To achieve that, we first assume an ideal model of the world, i.e., an obstacle-free environment. However, the estimation of location accuracy will largely vary in the real world environment due to aforementioned external factors as discussed above. Thus we need to iteratively refine the positions of the beacons. We compare the location accuracies in an ideal and practical environment and iteratively suggest new positions for the beacons to cover optimal signal coverage in the practical environment.

2.2 USAGE OF TWO MAP APPROACH:

2.2.1 BEACONS IN IDEAL ENVIROENMENT:

Ideal environment refers to an environment where RSSI does not fluctuate. By considering so, the distance of an object from the beacons corresponds to the location accuracy of that object's position. Several localization techniques such as trilateration, multilateration, proximity technique and other localizations algorithms [23] [24] are used to give an estimate of the position of interest. These methods work on the concept of estimating distinct location coordinates of the object by knowing the position coordinates of the signal emitting sources and the distances of the object from these sources.

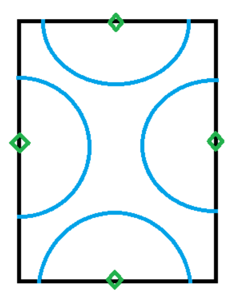

Figure 1: Beacons in an ideal environment

2.2.2 BEACONS IN PRACTICAL ENVIRONMENT:

Given a location of m by n meters, our goal is to estimate location accuracy at each point. We construct a mesh of size m by n and the positions of the beacons B_1, B_2, B_3, .., B_n are known and are positioned one per wall. We assume that the number and the position of the beacons are known and there is no signal interference among the beacons. The Euclidean distance between each point in the environment and the considered number of beacons is calculated. Based on the four proximity zones of beacons, each point along with its the measured distances to each beacon yield a possible location accuracy. This results in dividing the map into definitive groups based on the probable level of accuracy. These definitive groups are excellent, good, medium and low are used to chart an ideal environment based heat map.

2.3 IMPLEMENTING METHODLOGY:

2.3.1 GENERATING HEATMAPS:

A mesh-based heat map is charted based on location accuracy by the data points obtained. Each color palette denoted the range of location accuracy recorded at that instance of the grid. Heat map generated from the user movement is compared to the ideal heat map obtained from the previous section. Ideally, the practical map and the ideal map should be similar unless there is a presence of significant signal distorting agents. A distortion is said to occur if there is a decrease in reported location accuracy in the practical heat map. Areas where the practical heat map performs worse, i.e., shows a lower range on the accuracy scale, denote possibility of distortion in the environment. All such distortions are identified.

2.3.2 SUGGESTING BEACON MOVEMENT:

The idea is to reduce areas showing distortions and suggest beacon placement where information passage is maximized. Arranging beacons to give excellent/good location accuracy zones achieve this. The parameters for beacon movement depend on its proximity to the closest beacon, number, extent and priority of each distortion. Hence, a look-up table is generated based on this derived information. Also, signal coverage at original position of beacon and the suggestive new position is constantly compared to make sure the original beacon signal is not being jeopardized due to the new suggestion. An optimum position is suggested so a significant amount of original area is still under coverage and a good amount of distorted region is bought under coverage.

2.3.3 ITERATIVE PROCESS:

The suggestion of the new beacon estimated position is given in the form of new coordinates and the direction from its original placement. Based on the new coordinates of the beacon suggestion from the previous step, the position of beacons are updated. The entire process of indoor movement is repeated again. There could be unseen parameters that would have changed after the first iteration. Hence, we go for another iteration with the new beacon positions. The motive is to iteratively find the optimal beacon placement which is the result of the suggestion derived by comparing re-calculated ideal heat map with the latest user movement based (practical) heat map. When the new suggested beacon position is fairly far away than the original position, the user is asked to move the beacon in small increments in the direction of the suggestion by keeping the suggestive distance as the maximum threshold in order to not jeopardize the existing signal coverage area. The optimal signal coverage is a trade off between maximizing location accuracy and minimizing the distorted regions. The method tries to achieve this in 2-3 iterations.

2.4 SOFTWARE COMPONENTS:

The software side of this project involves the user interface of the methodology. We have designed and developed an iOS based app. The app has two main functions to deliver and is used by people with vision and visually impaired people. The main features of the app are:

2.4.1 CALIBRATION:

A interactive and simple way to suggest optimal positions of the ibeacons by involving user movement. It is a high contrast color based UI which presents three options to the user: Start, Stop, and build. This task is carried out by people with normal vision. The default pre-configured location map from the cloud is loaded onto the phone. This map is a rectangular shaped map which shows the featured beacons, orientation of the user, x and y coordinates of the user, accuracy with the position is estimated. By default, the bottom left corner of the map is assigned as the origin. On selecting “Start”, the user walks around the location and his/her every point is reflected on the map with the meta data such as accuracy, position mentioned below. All this information is saved and sent to the server. On completing a walk-around the location, the user can select the “Stop” option to stop the recording, saving and sending of metadata about the user. The third option is “Map”. This option switches the screen to show the beacon suggestion based on the accuracies of that iteration.

The Map leads to a screen that shows two maps: one ideal and one practical, the ideal map shows how the algorithm is trying to match possible defined accuracies based on the signal strength and location proximity. The practical map shows the accuracies given real world user information collected.

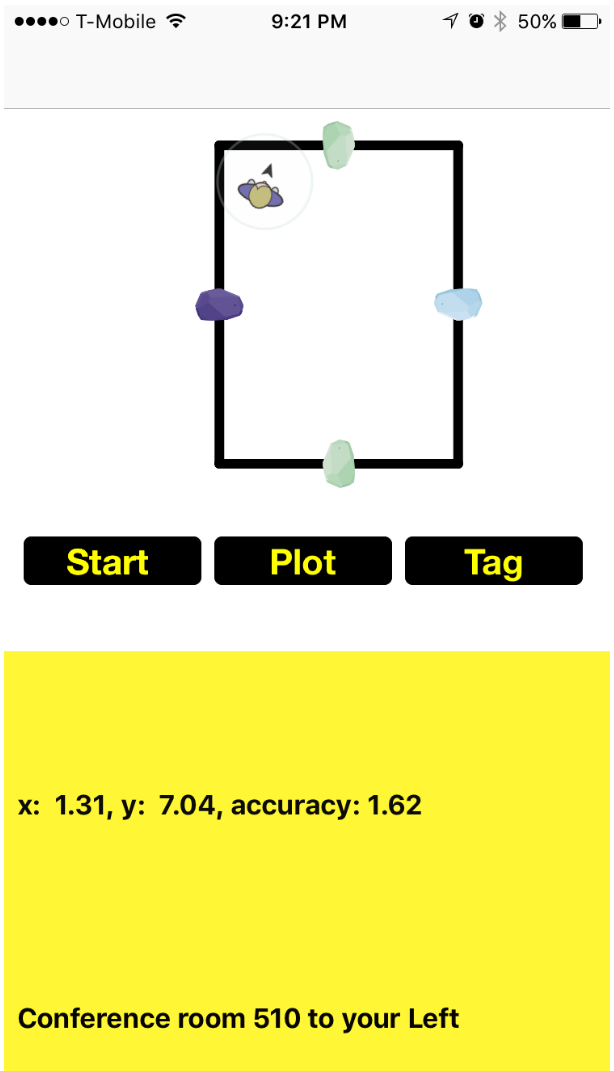

Figure 2: Home Page

2.4.2 SMART FEATURES:

This feature is for the visually impaired user. Features to facilities the flow on easy access to information and spreading location awareness are vital for designing a smart environment. These smart features can be useful for making an indoor environment more accessible to people with visual impairment.

2.4.2.1. TAGGING:

The point of interest can be tagged by giving the coordinates and name of the tagged point. An example of such feature is as shown in figure below. Whenever a tagged point of interest appears while walk through the indoor space, information about the location can be provided to the user.

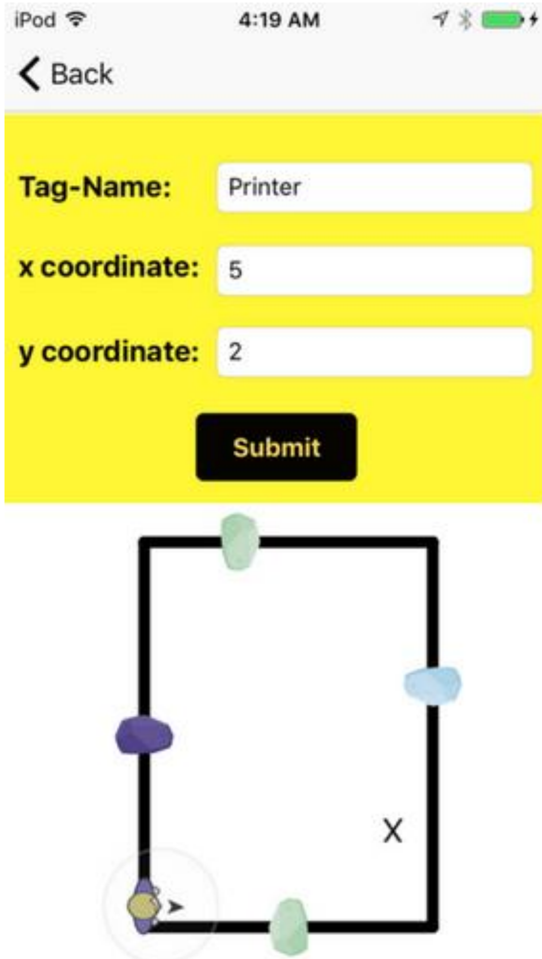

Figure 3: Tagging a point of interest

2.4.2.2 PUSH NOTIFICATION:

Irrespective of the app running in foreground or background, a push notification can be released to give information about the location the user is at. This experience facilitates a sense of familiarity and location awareness.

2.4.2.3. SCREEN READER:

If the app is open and the homepage is being viewed, notifications on screen are displayed in clear large and contrasting text. However, in an event where it is unclear, the user may use the screen reader option to read on the notification text and get updates at every step.

2.4.3 SERVER SIDE:

Mobile phones have limited resources such as power, bandwidth constraints, data storage and computation. To reduce the computation on the iOS phone, the calculations and running of code to find the beacon placement suggestion is not done directly on the phone. For the purpose of the project, we hosted a live server to run in the backend of the app. The client(app) communicates with the server using JSON over HTTP. All the metadata about the beacons such as estimote map, location coordinates, accuracy information is constantly sent to the server while the app is running in the foreground by the user. The usefulness of the server can be seen when it runs a python based code for real-time beacon suggestion based on the data sent over from the app. It needs to accept requests from clients, talk to the database, and give back a response to the clients. Since the data is sent and processed in real-time, there is no database to this server, it runs as a mere application server. The server needs minimal maintenance and can be activated by any admin/tester.

The server also provide web services and displays web pages. The server is built on Flask micro-framework. It provides core-Components such as URL routing, request and response objects and templates. More about the server and its functionality is explained in chapter 3.

2.4.4 FLOW CHART OF METHODOLOGY:

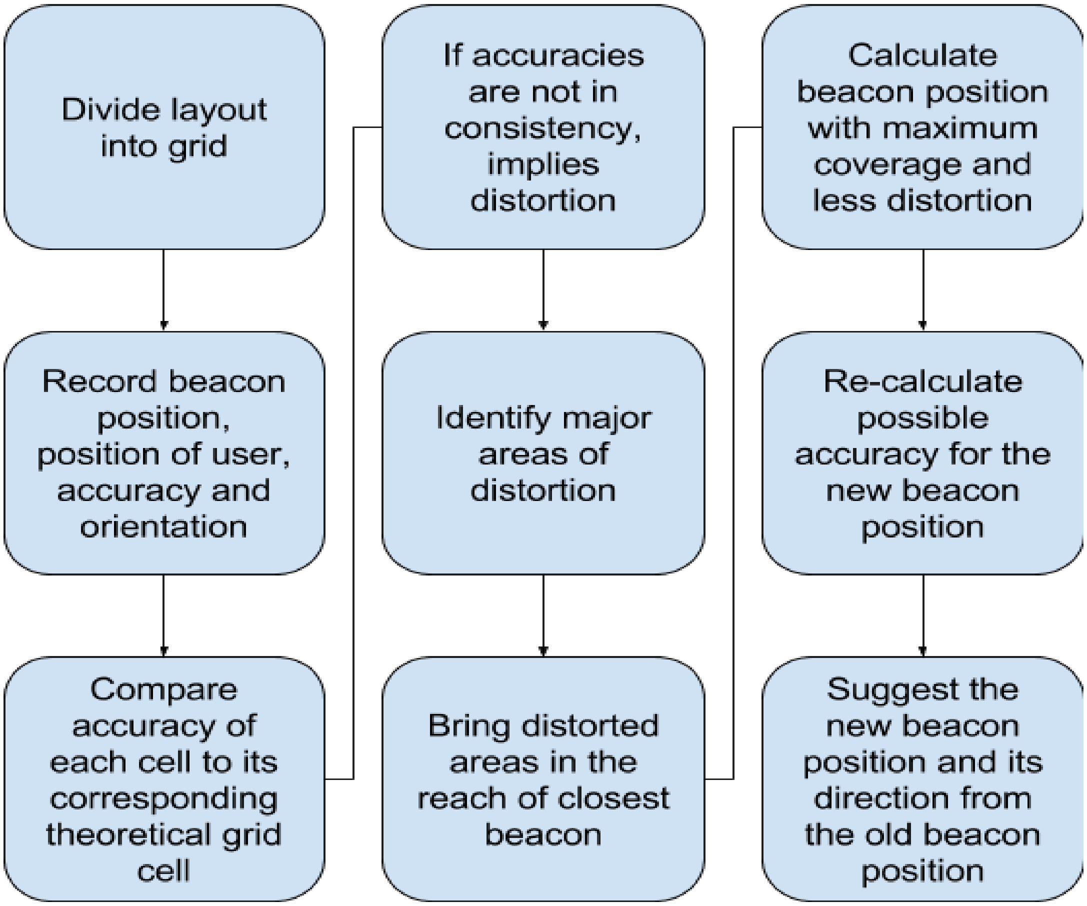

Figure 4: Flow chart of methodology

INTERFACE AND HCI FACTORS

This chapter discusses the user interface and user experience section of the work. The ubiquity, popularity and portability of smart phones among users provides as an easy access to information. The methodology to find suggestive optimum placement to iBeacons is implemented and wrapped with other HCI based factors to provide a sustained operation.

This was structured and integrated with an end-to-end server side and mobile interface based client side to support it.

3.1 SYSTEM ADMINISTRATION

3.1.1 USE OF THE SERVER:

We have a set of sighted users who have used this app to do the installation and optimal configuration of beacons. The server has a blue print map of the floor plan of the office. The section of the office space where the user is walking is asked as an input from the sighted user during configuration.

A user seeking information about the indoor office location holds the smart phone at shoulder level and walks around. Every movement of his/her is streamed and sent as a request to our server. The server receives the location updates of the user. The user's local coordinates are synchronized with the global coordinates of the entire floor map. This sync makes the server aware of where the user is present at every step. As soon as user's position is updated to the server, the user will get a notification about his proximity to tagged location points. For instance, the user gets a notification on the home screen stating that he/she is approaching the printer or conference room. The notifications are not limited to location based information. The server hosts a web page where the activities and events happening in office can be updated. Hence, the notification will be tailor made to say more about the venue. For instance, the user will be notified saying that he/she is approaching a conference room where a seminar on robotics is happening from 11am-12pm.

3.1.2 SERVER AS A BACKEND:

Based on the functionality and server application, especially its size and architecture, the backend server can be divided into two parts: computing server and web page. The iOS application connects to the server-side application which is basically a software program running on a remote server.

We use a python framework called Flask to run the backend. Since Flask supports RESTful API, data from the iOS app can be sent and received. The swift based app sends information about location position (x and y coordinates, accuracy and orientation of position) is encapsulated in JSON format utilizing built in encryption and login interfaces over HTTPS. The incoming HTTP request is to invoke the python code which finds the optimal beacon placement.

3.1.3. INTERACTIVE WEBSITE

A custom code based web application based on HTTP acts as a web page on the server on local host. This page provides information about the building, its location and the floor plan, the types of office space. The most important piece of information is the user interactive based entry where one can update the interest points and enter events and activities happening in each interest point.

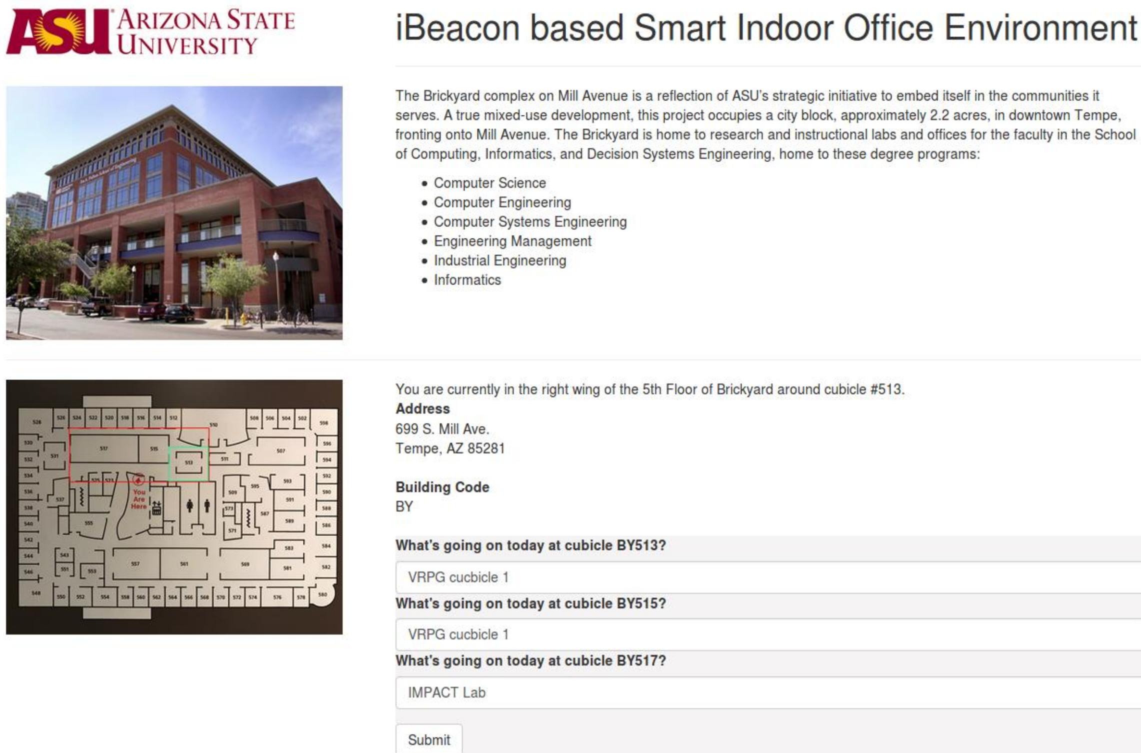

Figure 5: Web server homepage

3.2. TYPE OF SYSTEM ADMINISTRATORS

When the app is run on an iOS based phone, the server needs to be manually restarted by running a command through the terminal. The request and response of objects and information starts at the server. The interactive web pages is a simple web based application. Point being, the server admin can be done by anyone without any prerequisite knowledge about app development. Non-tech savvy individuals can handle this job by using minimum effort.

3.3. FLOOR PLAN MAP

We present a prototype to provide an overall understanding of how a local beacon map fits into the global coordinate system of a large scaled office map. The first hurdle in building such a mapping to provide description of the office plan is the availability of a usable floor plan. As we ran our experiments in Brickyard building of Arizona State University, access to floor plans of office space was a hurdle. We acquired office plans from common ASU pages. It was Nevertheless, the resolution of the image, scaling and dimensions in meter scale were not accurate. We pre processed the image of the fifth floor of Brickyard building by selecting a small section covering two lab areas in the east wing of the building. The small section was converted to meter-based grid format. At the time of installation, this grid is projected on the screen of the app and the user is asked to pick his two diagonals end of local map in the global grid system. This, furthermore, enables the server to understand the position and orientation of the user. The red box is the default floor map registered is the user doesn't notify where he/she is at.

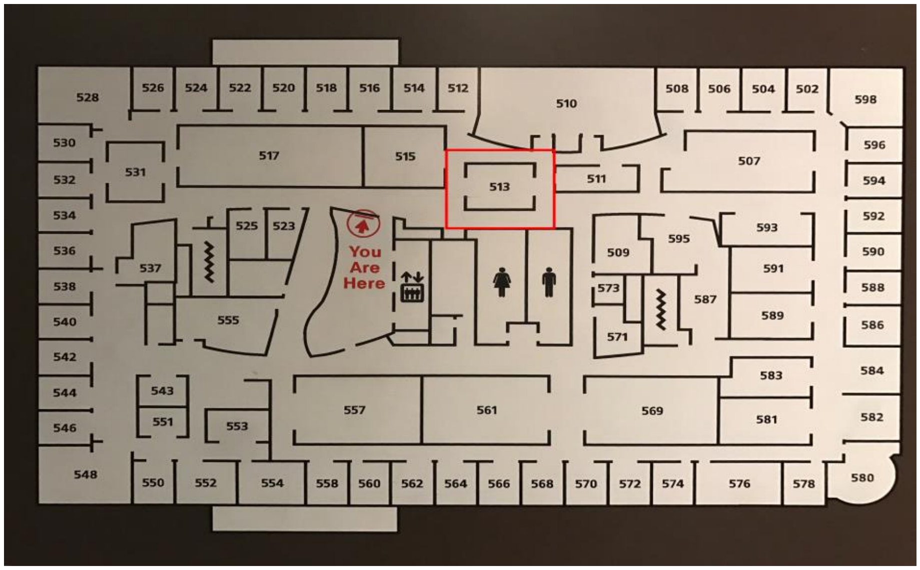

Figure 6: Floor plan of office space

3.4 CLIENT SIDE APPLICATION

This section of thesis work talks about the client app side of the system. The client app is designed keeping in mind the features, contents and functions of the making the office environment smart and accessible by the user. The mobile user Interface (UI) design requirements are significantly emphasized in the client side as it end product is tailor made for visually impaired users. Special considerations in UI design are ensured giving priority to usability, readability and consistency. Particular care and thought has been put into the layout of information, commands, content in the app, composition and colors without jeopardizing style consistent. Along with these requirements, the app is designed to be very intuitive to use for installation and location awareness.

The iOS app developed is two segments. Sighted users do the first segment and the second segment is the final product which designed for visually impaired users.

3.4.1 TYPES OF USE AND ITS USERS:

3.4.1.1 INSTALLATION OF BEACONS:

We use four estimote location beacons which can be attached to static points inside a given space. Before deploying the beacons to our specific use, we have to configure them on the developer cloud on estimote where we use Estimote app to

The installation of beacons is a manual task where four location beacons are set on static points inside a given space. Sighted users do by the setting up and installation of the iBeacons. We selected a small 6mx8m section of a large office space unit office. Each Location Proximity iBeacon is set to maximum Broadcasting Power (+4 dBm) and affixed one per wall at the centre of each wall of a rectangular shaped office space. “Start” option on the interface provides the estimated location coordinates and estimated location accuracy at every step the user takes. At every point, approximate measurements of the location are displayed ie, x,y coordinates, orientation and accuracy of that point. The accuracy means the accuracy of the proximity value, measured in meters from the beacon as given in the table below.

Accuracy	Proximity value
Very High	+/- 1.00m
High	+/- 1.62m
Medium	+/- 2.62m
Low	4.24m
Very Low	>5m
Unknown	Unknown

Table 1: Accuracy values of iBeacons based on their proximity

4.3.2 USER HANDLING:

The user is asked to hold the bluetooth-enabled mobile at chest-level and walk around the location. The user is at liberty to walk anywhere inside the space based on the arrangement of furniture or cubicle walls or any other physical obstruction. Every user trace results in an iteration. Due to human traffic and other external environmental factors, the readings vary slightly every time the testing is performed.

3.4.1.2 REARRANGEMENT OF BEACONS:

Once the location positions and accuracies at each point are sent to the server, the user is able to tap on “Plot” option to envision and see the display of detailed heat maps showing the effect and extent of location accuracy in ideal and practical scenarios. Based on the distortions present in the environment, at every iteration, the suggestion of the new iBeacon estimated position is given in the form of new coordinates and the direction from its original placement. This suggestion is displayed at the bottom of the screen. Based on this suggestion, the user is supposed to physically change the position of the beacon and perform another iteration of walking around the space. This task is also done by sighted users.

3.4.1.3 BUILDING A SMART ENVIRONMENT:

Additional features like tagging a point of interest or selecting a given small 6mx8m section from the entire floor plan are some personalized options to give us more insight about the location. The option "Tag" enables the user to tag a particular point of interest like the projector switch, printer. These coordinates are local to the small cross-sectional grid. On submitting, they are registered and saved into the global coordinate system. When the user clicks the option "Stop", he/she can select the small section where the local map can be traced in the main blueprint of the floor map. The user can view the main floor map and the scaled grid represented by criss-cross blue dots, the user is asked to enter the points where the small 6m by 8m local map overlaps on the main grid. This request is submitted to the server. Sighted users do this task.

3.4.1.4 END USER PRODUCT:

When deployed, the visually impaired user has an interface consists of only one screen, the launch page. Without any external help, he/she can receive maximum information about the office room. This can include position of the user in the given map, important tagged points such as coffee table, printer, exit door, cubicle number, direction of movement, orientation on the user in the map. Another feature of the iBeacon set up is that the user can get notifications about any tagged point, for instance, if the visually impaired user passes by the conference room, the iBeacon based app lets him/her know about the event currently happening in the hall. The app has contrasting colours, big clear lettering and is easy-to-use. The interface is pretty intuitive and requires minimum effort to use it.

3.4.2 HUMAN FACTORS:

The aim of our user design is to provide visually impaired users an understanding between the main motive and the application functions to provide a clear simple solution to the task of location awareness. There are a lot of features that have been taken into consideration.

3.4.2.1 USER:

The user group that we are targeting is visually impaired users. As iPhones are popular among visually impaired people ~\cite{paladugu2013supporting} and eliminate the cost of acquisition and learning to use a new device, we design an iOS-based app to assist a user in positioning the iBeacons for making an environment accessible. Users have to be able to understand and read the command icons. The app features large text and a simplified, high-contrast graphical user interface with large on-screen buttons. These facilities a clear distinction between the labels and buttons on the screen. This aids in pin-pointing in projecting sharp images/information to the user. The end product for the visually impaired user is just one screen. This screen is basic and simple and projects the location awareness based information in large clear text. To avoid any unwanted clicks, the icons in this page are reduced to minimum. The buttons on screen are larger and rounded with color contrast highlights.

3.4.2.1 USER:

The development of the app is done in Xcode based on programming language of Swift. The easy integration with Indoor Location toolkit of estimote was the prime reason for developing user interface in Swift. Xcode gives an easy platform to do any updates or run services in the background. Xcode has a smoother integration with Flask server which runs the main python code without any additional software tools or interfaces.

3.4.2.3 ENERGY EFFICIENT:

Activities such as calculation and storage are staggeringly reduced as the methodology of iBeacon placement suggestion is calculated by the server and the information related to the environment such as location name and dimensions, iBeacon positions, interactive push notifications, tagged areas of interests are saved in the server database. Thus, bluetooth enabled mobile device can connect to the server and access the location enabling multiple devices to access the location and the computation in the devices is reduced thereby saving battery-life.

3.4.2.4 SIMPLICITY:

We decided to strike a balance between attending to design considerations and dealing with the specific requirements of the app. We have limited the number of pages of the app to minimum to avoid unnecessary functionality or to clutter the interaction. The user interface is simple, more natural, and typically something a user can get familiar with in few trails. Installation and set-up is done in three pages, building of smart environment in two and end user functionality in one. We did not add features like add pinch to zoom functionality to not complicate things.

3.4.3 KEY ELEMENTS FOR SOCIAL INTERACTIONS:

This section describes the social aspect of the task developed in our thesis work. As we are dealing with office space environment, certain key things are important.

3.4.3.1 INFORMATION:

Apart from the tagged interest points, what other information is necessary. Such as doorways, elevator switch, names of the colleagues when user passes in front of their room, stairways. There should be a possible way that they can choose the basic information that provides immediate access to the office around them.

3.4.3.2 USER CONFIDENCE:

When a new user or visually impaired user uses this app to get acquainted with an office space. It is difficult for anyone to view yourself in a social situation, which is new and unfamiliar. Being aware of new colleagues' names in orientation doesn't help as one may not remember all the names. This may lead to social awkwardness. However, passing by their rooms while the app tells you who they belong to helps you to recollect their name and gives you more confidence as you can now remember who they are greet them if they pass by. This feature makes up for the less availability of tactile exploration in public locations.

3.4.3.3 SOCIAL BONDS:

The office is a place to get work done, but it is also a place to create relationships. Lack of eye contact or any disability shouldn’t impose in any way and which is why it should be a place that they are comfortable, happy, and healthy.

CHAPTER 4

EXPERIMENTS AND EVALUATION

4.1 DESCRIPTION:

This section of thesis work asserts emphasis on the experiments and evaluation part. We show some of our experiment runs and consider the viewpoints of developer, user and software and hardware performance. We will first describe the how the internal graphs are generated which are furthermore used in determining the result.

4.2 CODE-RUNS AT SERVER SIDE:

4.2.1 ACCURACY PLOTS:

Placed in an unknown office environment, our first task is to know more about the environment. This is important because we are dealing with bluetooth low energy and obstacles in path are important to be taken care of. Environment could include objects present in and around the area such as computers, servers, plants, printers, desks, chairs, trash cans, or big and path-determining objects like cubicle walls, ac vents, windows, doors, heavy insulation and even human bodies caused by body mass absorption. As discussed in chapter 3 sub section installation of beacons, we ask the user to hold the GPS and Bluetooth enabled mobile device and walk around the office space where beacons are affixed on the walls. We select three office spaces of varied dimensions and test how the signal strength and accuracies differ.

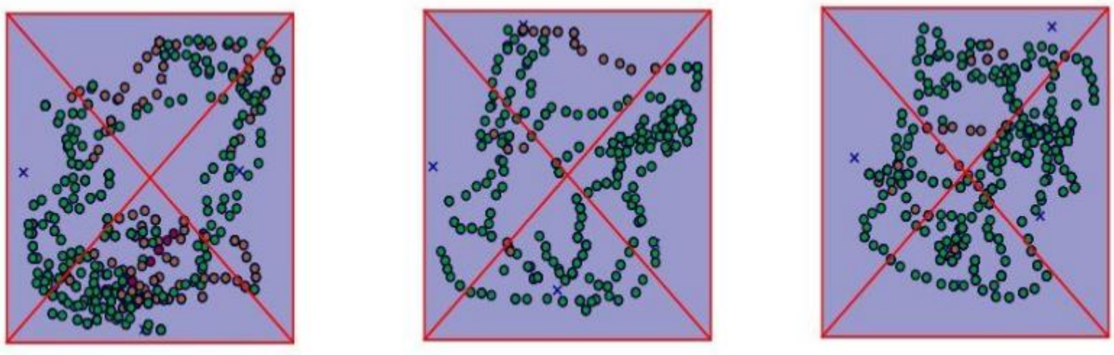

Figure 7: Accuracy plots of user-movement generated graphs

Above are three iterations of a 8mx6m floor plan of a section of office space. They vary in the placement of the beacon. These graphs are how the server perceives the configured office space. ‘x’ indicate the beacon positions

Accuracy Level	Color
Best	Green
Medium	Orange
Bad	Red
Unknown	Grey

Table 2: Color coded accuracy levels in server map

We notice that the accuracy plots of a location vary as the RSSI values of beacons fluctuates quite a bit. Hence, we use the proximity zones to see how well the signal is faring. These zones are near, immediate and far represented as green, orange and red. This is purely RSSI and proximity based.

4.2.2 METRICS:

Based on the zones, each rectangular floor plan is divided into four triangles to capture the signal strength varying around the beacon. Dividing by triangles gives us more scope to cover area around each beacon and the respective corners of each wall it is present on.

We used a metric to come up with a ranking which leads to decide which position and direction to move the beacon. The obtained user-movement generated map is divided into four zones. The density of the good/medium/bad points are measured in every zone to give its confidence ratios:

Good ratio = Number of good points/Total number of points

Medium ratio = Number of medium points/Total number of points

Bad ratio = Number of bad points/Total number of points

Every iteration is subject to acquire a confidence ratio. Based on the obtained information, a metric is formed. This metric gives us an analysis and displays the following suggestions for every iteration:

1) Zone with the best coverage

2) Zone with the worst coverage

Each iteration has an array of values indicating its density ratio, average ratio, how evenly spread out it is, ratio in association with the length of wall After three iterations, the method suggests the best iteration of all based on the following criteria:

1. Calculates the weighted confidence of each wall: worse the accuracy, higher the weight assigned to it.

2. Based on 1) it assigns a pre-ranking to each iteration. Checks the following cases before giving a final rank to the three iterations:

a. Case: If confidence ratios are almost similar for given iterations, pick the one which has green points more evenly spread out

b. Case: If the iteration with a better rank has few bad points, the second best Iteration is selected based on how many points are closer to the average value, provided the second-best iteration has a good confidence votes on all walls.

c. Case: In case of similar ratios for confidence of walls, the longer wall having the same ratio as the shorter wall will be picked.

4.2.3 PROXIMITY ZONES:

Looking up the table of (x,y) coordinates and their corresponding accuracy values, each beacon has a proximity sensing zone. The zone is a three concentric semi circles around each beacon location. The three levels are: good zone, medium zone and bad zone. The radii of each of these three semi-circles are internally calculated:

GOOD Zone : Encloses all points of HIGH and VERY HIGH accuracy values.

MEDIUM Zone: Encloses all points of MEDIUM accuracy values.

BAD Zone: Encloses all points of LOW and VERY LOW accuracy values.

Although the zones radii differ on every new testing, it is coded in a way that each zone covers atleast 80% of the above said accuracy value points designated to it.

4.3 ITERATIVE SEQUENCES

Figures 8,9,10 show the three iterations: 1,2,3. We can see that the ideal and practical heat maps for every iteration are compared based on level of accuracy as indicated by definitive color coded levels, i.e., excellent, good, medium and poor. At every iteration, the suggestion of the new iBeacon estimated position is given in the form of new coordinates and the direction from its original placement. Iteration 1 Figure 8 shows there is a possible distortion in the top left corner, hence the methodology suggests the direction of movement and new iBeacon placement coordinates of the closest iBeacon to bring the given environment into optimal signal coverage. This suggestion is displayed at the bottom of the screen. The optimal signal coverage is a trade off between maximizing location accuracy and minimizing the distorted regions without jeopardizing the existing signal coverage area.

Based on the new coordinates of the iBeacon suggestion from the previous step, the position of iBeacons are updated. The entire process of indoor movement is repeated again as shown in Iterations 2 and 3 Figure 9, Figure 10. There could be unseen parameters that would have changed after the first iteration. Hence, we go for another iteration with the new iBeacon positions. The motive is to iteratively find the optimal iBeacon placement which is the result of the suggestion derived by comparing re-calculated ideal heat map with the latest user movement based (practical) heat map. The method tries to achieve this in 2-3 iterations and finalize the best of 3 iterations.

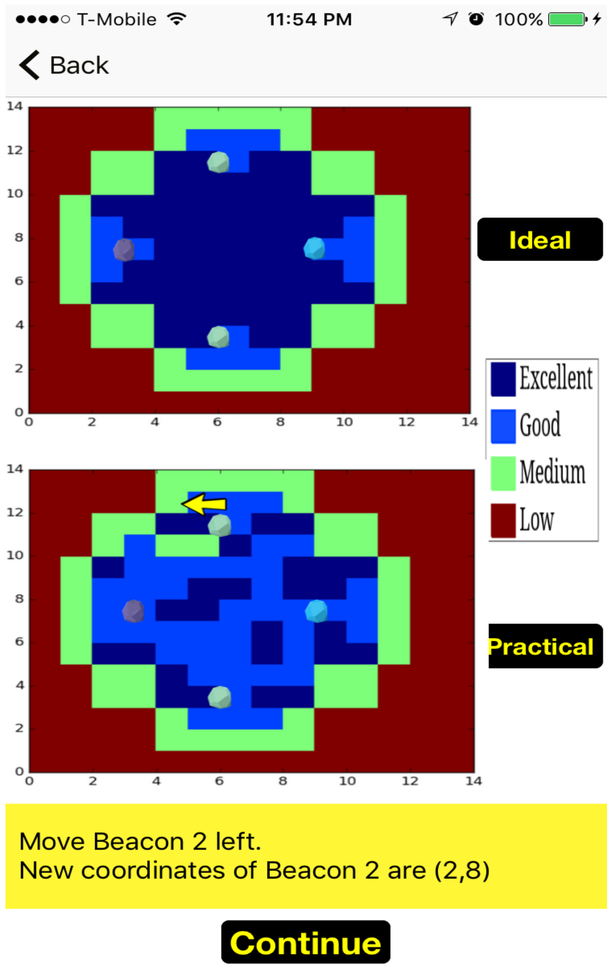

Figure 8: Iteration 1

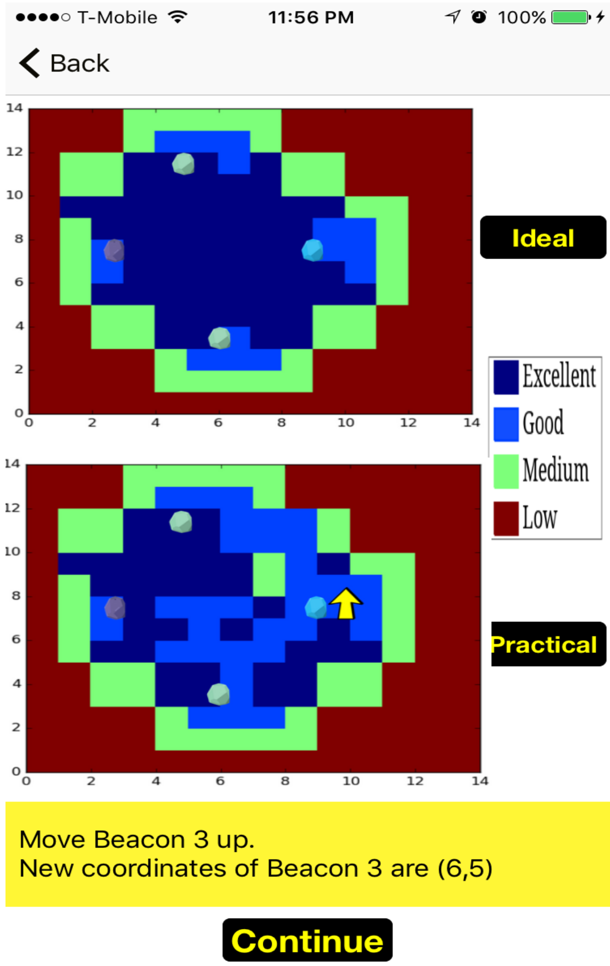

Figure 9: Iteration 2

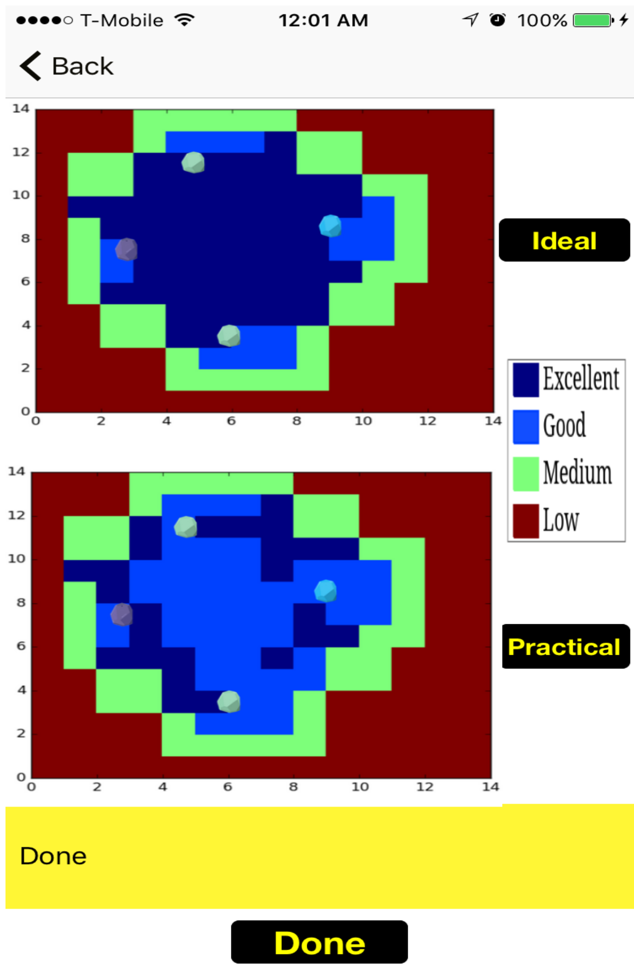

Figure 10: Iteration 3

4.3 EXPERIMENT ANALYSIS FROM USER POINT OF VIEW:

4.3.1 DEVICE ITERACTION:

The experiment consists of hardware such as ibeacons and iOS device. Testing was done to see of robust the hardware performs on repeated use, low battery life and improper orientation of the devices. We noticed that batter life of iBeacons greatly affects the experiment results and hence we always fine tune the ibeacons to maximum broadcast for the experiment and reduce to almost 0 when not in use.

4.3.2 USER HANDLING:

There are various ways where human bodies can absorb bluetooth signal and this hampers in recording location accuracy values. The possible suggestions would be to increase the height of placement of iBeacons so that there is considerable less interference in iBeacons' line-of-sight. During our experiment testing, we tried asking different built users to try and test the app. The height of the users with respect to the beacon height caused a few variations.

4.3.2 NOISY ENVIRONMENT:

The method is tested in an office space environment. Although a rough assessment of distortion level can be predicted based on the stationary machinery and furniture in the office but the level of human traffic may vary time-to-time. We tried to maintain consistency and picked a certain time of the day to run the experiments when unnecessary distortions due to lunchtime traffic, student body traffic, Friday evening traffic were avoided.

4.3.2 TIME FRAME OF EXPERIMENT:

The installation and configuration is a task, which required few minutes of time. On a average, it took the user ten minutes to complete iterations. The end-user experiment designed for visually impaired users is not time bound and can be used as long as the app is running.

CHAPTER 5

CONCLUSION

Looking at visual impairment beyond the level of disability can be looked at as an opportunity to bring about a change of style of living. This gives us an opportunity to help visually impaired people lead an independent life where their social challenged are not limited. Designing a methodology to help them do basic activities like getting familiarized about an office environment without the need for asking for assistance is what this work wants to achieve. The beauty of making an environment easy accessible is that it helps people from all walks of life. In order to improve the quality of life for visual impaired people, in this work we focused on iBeacon technology to make an office room more accessible and help visually impaired people gain maximum information about the environment. The next step in our work is to conduct surveys by asking different age based visually impaired participants and see how they would respond to the smart environment and collect feedback to improve the experience. Another possible future work is to enable the server to automatically identify the need for re-calibration. This can be a practical need if the environment has changed due to factors like moved or newly-introduced furniture. Such a task may be done in many ways, and we outline one possibility below. After calibration, the 6m by 8m beacon grid is deployed with new and different global coordinates, each iOS app used by any user will be able to send its accuracy levels along with every position update to the sever. This enables the server to discern if the signal strength is good enough to keep the given beacon arrangement. If the server determines that the beacon arrangement is no longer optimal (e.g., too many spots within the covered area have only weak signals), it will notify the administrator asking for re-calibration. We want to improve the scalability of the map considered by expanding to a larger office space, the experience can be enhanced using voice-activated features to give such visually impaired users a walk-through interactive experience by enabling access to the local environment.

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