Towards Building iBeacon-based Smart Indoor Environments for Visually Impaired Users

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Abstract

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 paper reports 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. We present our preliminary work 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.

Author Keywords

Bluetooth Technology, iBeacon, Indoor Localization, Proximity, Bluetooth Low Energy

ACM Classification Keywords

H.5.2 [User Interfaces]: Methodology

Introduction

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 [6] [14]. 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 [13] or give an interactive historical experience to visitors of a museum [8]. Although localization and navigation of people with visual impairments are described in [7] [5], these works do not consider in providing high localization accuracy tailor-made to a specific environment. 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 paper, 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

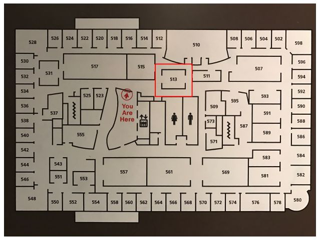

Figure 1: Floor Plan of Office Space

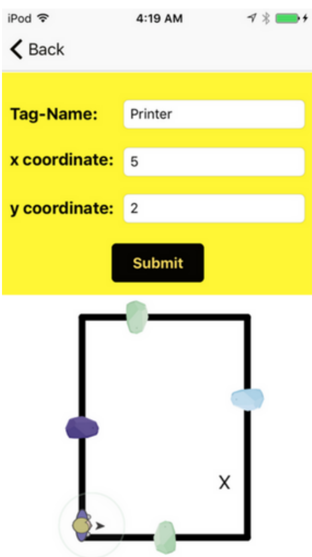

Figure 2: Tagging of a place of interest

user in positioning the iBeacons for making an environment accessible.

Such a technology would be very useful for making the environment most accessible to people with visual impairment as they can familiarize with the environment without depending on anybody. The current stage our focus is on algorithmic aspects of the proposed framework and the experiments have been focused on testing the easiness of use of the app and effectiveness of the methodology in helping the configuration of the iBeacons and providing an interactive based experience of getting to know information about the environment.

Supporting iBeacon Configuration

Effect of Received Signal Strength(RSSI): The information obtained from a smart environment depends on the coverage of the signal across the office space. iBeacons use BLE technology which works on the principle of Received Signal Strength (RSSI). In an ideal obstacle-free environment, the signal strength of the bluetooth devices remains constant and strong. The distance of the object's estimated position from its real position is termed as location accuracy. Several localization techniques such as trilateration, multilateration, proximity technique and other localizations algorithms [9] [12] 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.

Ideal and Real world: In an ideal/theoretical scenario, we can estimate 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 using the above mentioned methods. Although the range of an iBeacon is 70 m, its full effect can we witnessed in the proximity of 4m. This is due to the real world environmental 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. This hampers the estimation of obtaining location coordinates and location accuracy. In order to get a better understanding of the relative distance between different iBeacons, iBeacon technology defines four proximity zones for estimating distance to a iBeacon: immediate (very close to the iBeacon), near (about 1-3 m from the iBeacon), far (further away or the signal is fluctuating too much to make a better estimate), unknown (proximity cannot be determined) [4].

Generating Heat maps: This sub section describes the core of our methodology. We obtain user generated location points and their corresponding proximity zones (explained in detail in “Testing the Environment" section). A mesh-based heat map is charted based on location accuracy by the data points obtained. Each colour palette denotes the range of location accuracy recorded at that instance of the grid. Ideal heat map is charted purely on distance between the signal source and user location coordinates. Heat map generated from the user movement(practical heat map) is compared to the ideal heat map. Location accuracies at every point are compared. 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.

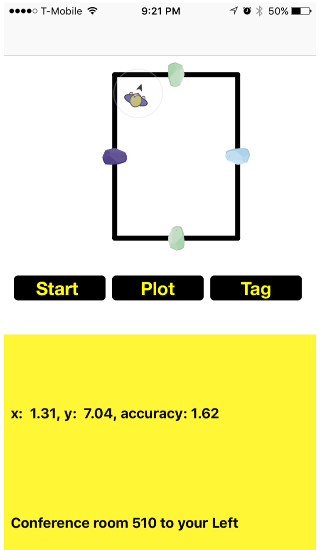

Figure 3: Launch Page

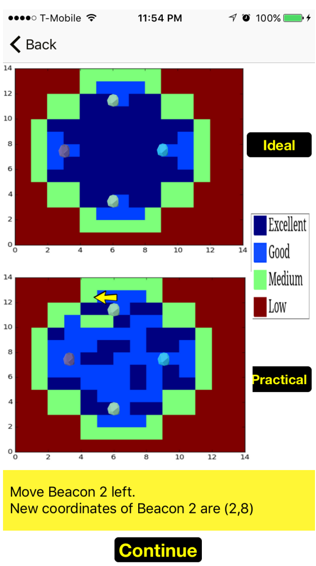

Figure 4: Iteration 1

Iterative based iBeacon Movement Suggestion:

The idea is to reduce areas showing distortions and suggest iBeacon placement where information passage is maximized. This is achieved by arranging iBeacons to give excellent/good location accuracy zones. The parameters for iBeacon movement depend on its proximity to the closest iBeacon, 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 iBeacon and the suggestive new position is constantly compared to make sure the original iBeacon 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. This process is done 2-3 times to get an accessible location map which emulates the ideal heat map or has maximum amount of excellent/good accuracy zones.

Enabling Smart Features

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.

1. **Tagging:** The point of interest can be tagged by giving the coordinates and name of the tagged point. A example of such feature is as shown in Figure 2. Whenever a tagged point of interest appears while walk through the indoor space, information about the location can be provided to the user.

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.

Testing the Environment

Installation of iBeacons : This section covers how the environment is set up to make it smart and accessible by the visually impaired people. The setting up and installation of the iBeacons has to be done by people with normal vision. We conduct experiments in a small 6mx8m section of a large office space unit office as shown in Figure 1. 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. 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. Since finding the best configuration for iBeacon positioning technique is an iterative process, we use a swift-based iOS app equipped with Estimote Indoor Location SDK [3] to map user position in the considered office space. This SDK assigns an origin to the bottom left corner of the 6mx8m grid. Due to human traffic and other external environmental factors, the readings vary slightly every time the testing is performed. We performed the experiment over 50 times and used our lab mates as test subjects.

Interface : As shown in Figure 3, “Start” option on the interface provides the estimated location coordinates and estimated location accuracy at every step the user takes. The location accuracy is the value that estimates the proximity zone of the iBeacon. This value tends to fluctuate based on the obstacles in the environment. The location coordinates and accuracy are recorded at every point. Every user trace results in an iteration. “Plot” option envisions and displays

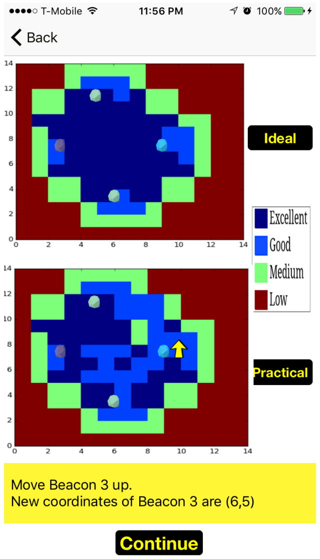

Figure 5: Iteration 2

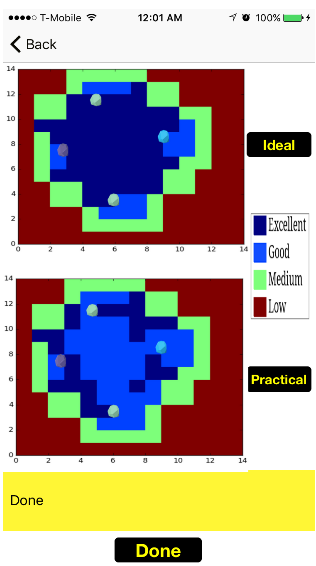

Figure 6: Iteration 3

detailed heat maps showing the effect and extent of location accuracy in ideal and practical scenarios.

Iterative Suggestions : Figures 4, 5, 6 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 colour 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 4 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 5, Figure 6. 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.

Interface for Visually Impaired User : When deployed, the visually impaired user has an interface consists of only one screen, Figure 3. 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.

Across Borders

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 assistive technology to help them do basic activities like getting familiarized about an office environment without the need for asking for assistance is what this paper 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. 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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