HospiX: The Hospital Exploring Application for Smart Devices

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***Abstract*-** Hospitals are indispensable part of our lives when it comes to providing best medical facilities to people suffering from various diseases, disorders or syndromes. Usually, it is a place that in a vast area with lots of buildings and places such as laboratories, wards, pharmacies, etc. In such situation, patients, visitor and even the working staff might find it difficult to find the necessary place they need to be at a particular time. The newest members who join the hospital staff might take a while to be familiarized with the hospital area including all the places in it. When it comes to the Outdoor Patient Department (OPD) patients, they also might have to go several rooms to meet their doctors, or to get X-rays, lab reports, and buy medicine. Having direction boards helps, but it is not always productive. Sometimes people might find it difficult to read when they are not properly maintained by time. To the people who visit their family, friends and relatives who are hospitalized, it is really hard if they do not know where to find the ward they have been admitted on. On the other hand, they might get to know that there are special goods (E.g.: food items, clothing and medical items) to brought from the outside, so before even visiting the patient they have to go back and bring them. These kinds of situations are very common in both government and private hospitals in Sri Lanka. So it is necessary for the hospitals to provide those parties with a mobile navigation system which helps them to find their way inside the hospital area. It is a mobile navigation system, and it includes a patient health monitoring procedure as well. At the prior study, a number of available technologies were studied and evaluated to choose the most effective and cost effective use for developing the system as well as its use and maintenance. The system use Bluetooth BLE for its implementation process with the aid of iBeacons. Therefore, the HospiX mobile application has been able to answer all the issues mentioned above by helping both hospital staff, visitors and OPD patients who comes to the hospital.

***Index Terms*-** Hospital, Navigation, Patient Health Monitoring, OPD, Android Application, iBeacons, Bluetooth

I. Introduction

In most developing countries, provision of basic preventive, primitive and curative services is a major concern of the Government. With growing population and advancement in the medical technology and increasing expectation of the people especially for quality curative care, it has now become imperative to provide quality health care services through the established institutions [1]. In that case, the use of mobile technology can be used to improve their quality of service from various manners. Not only for the supplement of the high quality medical treatments, can it be used to make a useful application which all the doctors, hospital staff members and patient's guardians can benefit. "HospiX: The Hospital Exploring Application for Smart Devices" is one of those upcoming mobile applications that has the ability of providing such constructive services.

As mentioned previously, hospital is a place with many places, such as pharmacies, wards, clinics, laboratories and etc. It is also a really busy place because, it handles matters of life and death all the time. So the responsibility of the doctors and the hospital staff members is really high, so being at a place at the correct time is really important. In a vast area like that, sometimes it could be hard to find particular locations of a hospital even for a usual person who works at the hospital. For a person who visit the hospital for the first time, it is much harder. The HospiX application will be a mobile application that runs in android platform that provides location finding and getting direction services at the hospital premises, using the newest technology, Bluetooth LE (iBeacons).

Unlike Global Positioning System (GPS) iBeacons has the capability of tracking the micro locations even in a limited geographical area in a very accurate manner. Since it works in long distance, it makes it more beneficial. With the aid of this device, HospiX will be able to locate the places in the hospital using a smart device.

HospiX will come as a combination of a mobile application and an android application which are merged together, where the mobile application is capable of accessing the online database of the desktop application using an application program interface (API). Since the desktop application records all the details of the patients including the test results, and treatment details, the authenticated users can view them according to their authorization level. As an example, the doctors can view the assigned patient's blood test results and come to a conclusion about the sickness he or she is suffering, or the current condition of him/her without even visiting the patient. This saves the time of the doctor, which can be allocated to a patient in a much critical condition.

The recommendations that is being made by the doctors for a particular patient can be received as push notifications by the guardian of that patient. This is important for them because they will get an idea about how the contribution should happen from their aspect.

This project consists of designing and implementing an Android application for exploring the hospital. The authors have several objectives as follows.

A. General objectives

- Develop a hospital exploring application that can be used by any person with a very simple knowledge of using a mobile application.
- Develop highly user friendly application.
- Release the application without any errors.
- Provide the application to the market for free of charge.

B. Specific objectives

- To implement an accurate navigation system than GPS.
- To develop a successful real time notification system.
- To store patient details in a proper manner.
- To process data efficiently.

The rest of this paper is organized as follows. Section 2 has provided the existing related work. Section 3 describes the methodology of this paper. The results and discussion is mentioned in Section 4, and the conclusion of the HospiX project has described in Section 5.

II. Literature Review

Giles L. and Barton D. et al (2011), has discussed about an electronic patient tracking system for use in a hospital, particularly a hospital emergency room facility [2]. A plurality of patient tracking modules are provided, each of which includes a multi-character display for indicating patient name and patient complaint as well as an indicator of attending physician and nurse. Illuminated color coded switches are used to indicate the placement of orders for work to be done. The system provides automatic timeouts if the order is not completed as evidenced by subsequent operation of the switch, within a predetermined period of time and changes the lamp status to an alarm condition, such as flashing with a particular cadence.

Harmon, A. et al (2011) has discussed about a patient tracking system that receives the first location of the patient within the medical facility identified by the user via the input peripheral using a computer [3]. The first location is displayed on a display device operatively connected to the computer, the first location being identified by a graphical marker representing the first location where the patient can be found. In response to a user interaction with the input peripheral, a second location of the patient is received, indicating movement of the patient from the first location to the second, different location.

H. Gamboa, et al (2010) has described about a wireless wearable sensing system designed to monitor patients within a building in real-time on a continuous basis [4]. The device automatically provides alarms to caregivers, based on bio signals measured by sensors integrated on a necklace worn by each patient. The device detects heart rate, involuntary falls, and location of the patient within a building.

UW Health Navigator is one of the application which uses Wi-Fi to determine the user's location, and then provides directions to any selected public destination in a hospital [5]. Users also can choose to find the closest of a certain type of facility, including clinics, hospital units, eating areas, shopping options, stairs/elevators and restrooms.

MyWay application is a personal guide to Boston Children's Hospital [6]. This features step-by-step navigation to help users find all of Children's locations, including emergency room facilities and find their way around the buildings once they arrive. MyWay application also connects with Children's internal support services, and features convenient listings, directions and information about nearby restaurants, hotels and attractions. Users have access to MyChildren's Patient portals to review and manage your child's appointments and securely message you're your child's clinician and view lab and health records.

PeaceHealth MediLocator application features navigation within any of the PeaceHealth Medical Centers, as well as to the locations of PeaceHealth Medical professionals, labs and offices [7]. Also this application allows users to look up Doctors and search by specialty.

Patient Records Doctor at Work application developed to manage the patient records, appointments, and visit notes the easy way. Bill patient, track customer payments and balance due can also be done using this mobile application [8]. This application is useful for medical professionals and students that visit patient every now and then.

Wifarer Indoor Navigator provides navigation inside any hospital. Provides useful medical information and staff directory [9].

Durdans Hospital application is one of the local applications developed for Durdans Hospital [10]. Application features Doctors availability, health check-ups, online payments and online appointments.

III. METHODOLOGY

At the initial step the team conducted a literature review on the existing applications to get an idea about the features of them, the usage, and the accuracy as well. At the same time, an online survey was also performed among a selected group of users and those results were evaluated accordingly. In order to identify the real situation in a hospital premises, the team visited a hospital and interviewed several members in its management board.

Based on those gathered information, the team intended the design and the implementation of the HospiX application.

When considering the explained solution of HospiX, it can be described as a combination of two main components. They are the desktop application, and the mobile application.

The desktop application is developed in NetBeans IDE 8.0, using Java language, while the mobile application is developed in Android Studio.

A. Desktop application

Initially, the team arranged several meetings with one of the leading private hospitals of Sri Lanka to gather the data which are important for the implementation of the desktop application. It was mainly focused on the basic idea of the patient records handling process in the hospital. After the data gathering completed, they were analysed and the decisions were made about the structure of the interfaces and the languages and the software to be used.

The desktop application will be updated with the details of the treatments provided, the response of a patient towards a particular treatment or a test. Those records will be saved in the

local database, which will be hosted online once the system completed and merged with the mobile application. Afterwards, the mobile application will be able to access the patient records in the desktop application using the API developed.

B. Mobile Application

The mobile application will be implemented to run in android platform, in an android operating system which is higher than Android 4.3.

The major capability of the android application is finding locations or providing navigation directions to the users while they are at hospital premises. This will be done by the iBeacons, which uses Bluetooth 4.0 connectivity. iBeacons broadcast their identifier to nearby portable electronic devices. This technology enables smartphones, tablets and other devices to perform actions when in close proximity to an iBeacon [12].

In order to work in that manner, the iBeacons need to identify the co-ordinates of a particular user location, because then only it can direct the user in to the preferred destination. To fulfil that purpose the team came up with an algorithm based on several mathematical concepts.

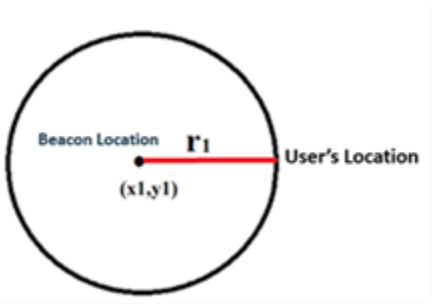

Figure 1 – User locations around one iBeacon

If there is an iBeacon in the centre of a circle with an r1 radius, there can be millions of co-ordinates (user locations) around it. In other words, it's infinite. Using two iBeacons that overlaps as follows can narrow down those user locations in to two. The user can be in one of those two locations.

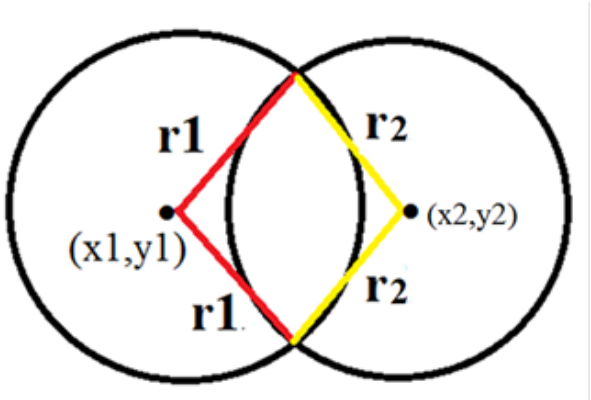

Figure 2 – User locations around two iBeacons

As a deal breaker, a third iBeacon can be used. It will limit the number of user locations to one.

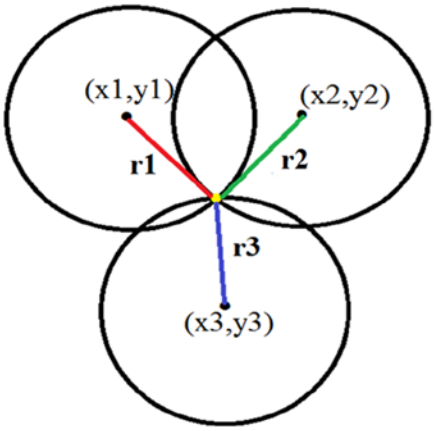

Figure 3 –User locations around three iBeacons

When the proximity of the third beacon crosses on of the users locations given in Figure 2, there it gives the exact location of the particular user. This defines that in order to identify a user location, it requires three iBeacons.

In order to calculate the value of X and Y, a relationship between them and proximity values or in other words r1, r2, r3 and r4, should be developed. In here, it has produced a Right triangle, and therefore the Pythagorean Theorem was used to determine the values for X and Y.

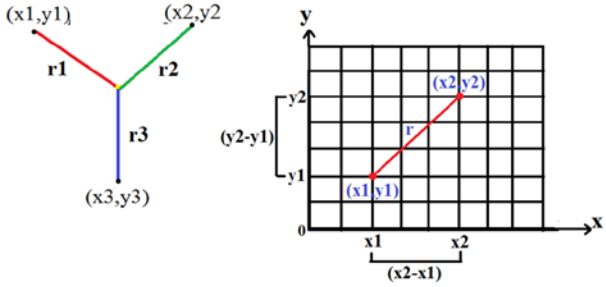

Figure 4 – Applying Pythagorean Theorem

The equation given as (1) was retrieved by applying the Pythagorean Theorem to the Right triangle given in Figure 4.

$$r_1^2 = X_1^2 + X_2^2 + Y_1^2 + X_2^2 - 2X_1X_2 - 2Y_1Y_2 \quad \text{——————} \quad (1)$$

Applying the same theory to the other r1 and r2 proximities, another three equations can be received as follows.

$$r_1^2 = X_1^2 + X^2 + Y_1^2 + Y^2 - 2XX_1 - 2YY_1 \text{——} \quad (2)$$

$$r_2^2 = X_2^2 + X^2 + Y_2^2 + Y^2 - 2XX_2 - 2YY_2 \text{——} \quad (3)$$

$$r_3^2 = X_3^2 + X^2 + Y_3^2 + Y^2 - 2XX_3 - 2YY_3 \text{——} \quad (4)$$

By solving the equations given by (2), (3), and (4) it can be further narrowed down to following two equations.

$$r_1^2 - r_2^2 = (X_1^2 - X_2^2) + (Y_1^2 - Y_2^2) - 2X(X_1 - X_2) - 2Y(Y_1 - Y_2) \text{——} \quad (5)$$

(6)

$$r_3^2 - r_2^2 = (X_3^2 - X_2^2) + (Y_3^2 - Y_2^2) - 2X(X_3 - X_2) - 2Y(Y_3 - Y_2) \text{ ——}$$

Assigning a1, b1, a2, and b2 for equation 5 and 6 as given below, they can be further simplified.

$$(X_1 - X_2) = a_1 \qquad (X_3 - X_2) = a_2$$
$$(Y_1 - Y_2) = b_1 \qquad (Y_3 - Y_2) = b_1$$

$$r_1^2 - r_2^2 = (X_1^2 - X_2^2) + (Y_1^2 - Y_2^2) - 2Xa_1 - 2Yb_1 \text{ ——} \quad (7)$$

$$r_3^2 - r_2^2 = (X_3^2 - X_2^2) + (Y_3^2 - Y_2^2) - 2Xa_2 - 2Yb_2 \text{ ——} \quad (8)$$

This leads to the co-ordinates of the location, indicated by the values for the X and Y which can be received by solving the following equations.

$$X = \frac{(r_1^2 - r_2^2) - (X_1^2 - X_2^2) - (Y_1^2 - Y_2^2)b_2 + 2Yb_1}{-2a_1} \text{ ——} \quad (9)$$

$$Y = \frac{(r_1^2 - r_2^2)a_2 - (r_3^2 - r_2^2)a_1 - (X_1^2 - X_2^2)a_2 + (X_3^2 - X_2^2)a_1 - (Y_1^2 - Y_2^2)b_2 + (Y_3^2 - Y_2^2)b_1}{2(a_1b_2 - a_2b_1)} \text{ —} \quad (10)$$

Based on these mathematical concepts, the team developed an algorithm and it was implemented using Android.

As noted previously, since the mobile application gets the ability to access the online database through API once it is hosted, the mobile application will be able to produce several information regarding patients. The mobile application will provide the users the capability of adding their patients to the local database of the mobile application, and once they are added it can map the details with the desktop application regarding those patients. The doctors can see the test results of the assigned patient, and come to a conclusion about the current health condition about the patient. The guardian of the patient can get push notifications about the patient's condition, and also if there are good to be bought from outside at the next visit.

IV. RESULTS AND DISCUSSION

A. RESULTS

Throughout this research the core finding that has been found was the possibility of using iBeacons to discover micro locations even in a limited area, using the algorithm developed by the team based on the mathematical concepts that have been discussed in Section 5, under methodology. The flow chart of the implemented algorithm is as follows.

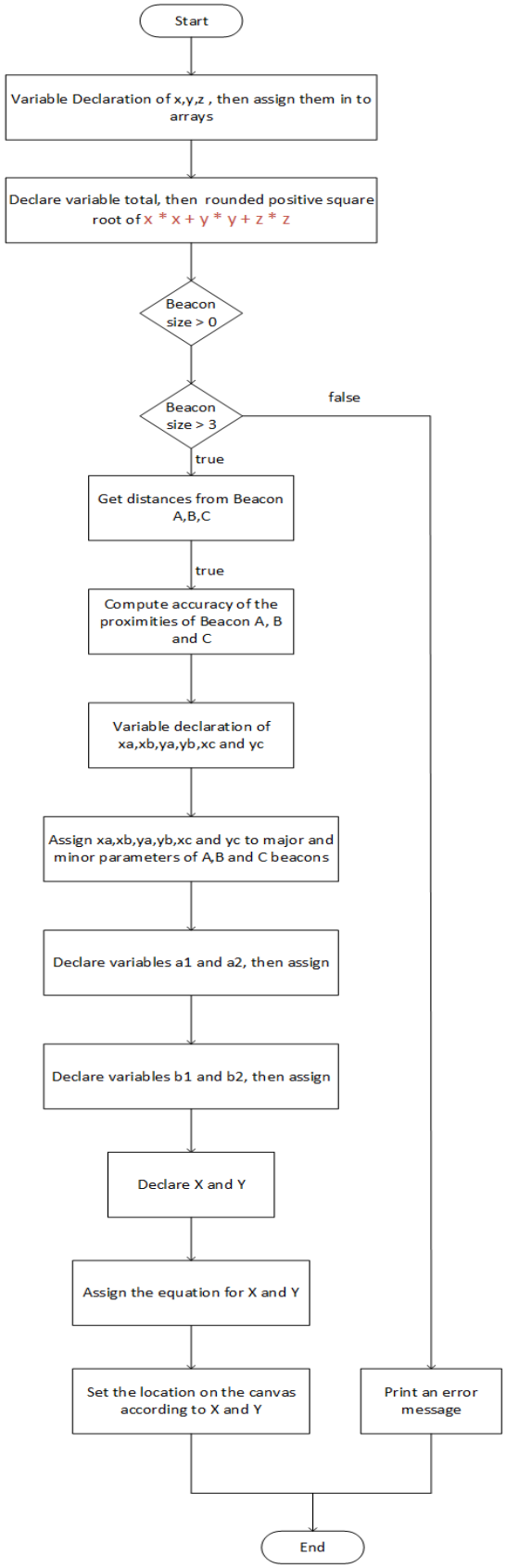

Figure 5 – Flow Chart of the algorithm

Besides the algorithm, the API that was developed to make the connection between the mobile application and the desktop

application is another finding that the team came across within the HospiX project. It has the most basic key words that can be usually found in Structured Query Language (SQL), so establishing the connectivity is quite easier with that API, since it does not require to include all the components of a particular SQL query.

B. DISCUSSION

This Bluetooth transmitting device technology has opened up a new page in the book of indoor navigation and opening up micro locations in it. There are several types of beacons, so the team conducted a separate observation regarding these beacons before making a selection.

As the team discovered, there are three types of iBeacons which act as Bluetooth transmitters. Those are,

- Apple iBeacons
- Eddystone
- Vendor Specific

The Apple iBeacons were introduced by Apple Inc., and they work comfortably with Apple devices. In the point of view of the team, it can be given as a development constraint, because only a user with an Apple device will get the use of this application, if the development was done using the Apple iBeacons.

Eddystone is an open source and cross-platform Bluetooth BLE beacon standard which was introduced by Google very recently to the field of Information Technology (IT). This is basically the open beacon format from Google. Since this is really new to the filed, there are no enough references, or resources that the team can use. So this left the team with the choice of Vendor specific beacons.

Vendor specific beacons, or in the case of HospiX, Estimote iBeacons support both android and iOS platforms, which means that any smart device can be used to take advantage of them. So the team identified it as the best choice of devices that can be used to develop the HospiX application.

During the testing phase, the team noticed that there is an attenuation, which reduces the strength of the signals that comes to the mobile phone, from the iBeacons due to the obstacles in the surface. As an example, if the user is in a hospital corridor which is filled with people, and if the iBeacons are placed on the corridor walls in an average height, it weakens the power of the Bluetooth signals that comes from them. Mostly this happens over long distances. Therefore, to overcome this issue, the team tested it by placing the iBeacons at a higher position on the wall, and it exhibited positive results by providing an accurate navigation service.

V. CONCLUSION AND FUTURE WORK

Walking in the hallways and buildings of a complex hospital can add an extra layer of anxiety to an already stressful experience for patients, their families and friends. So a navigation application like HospiX can give them some sort of relieve from that stress. Not only that, it improves the overall experience of those parties as well. Additionally, the HospiX application will be very much useful for the employees who join the hospital as new recruits. They will be able to locate the places in the hospital in an accurate manner and get directions to particular locations as well.

The doctors can easily view their patient's details via HospiX application, without even visiting the patient. This saves the time of the busy schedule of a doctor, so he/she can focus more on the patients who are in a critical condition.

Same applies for the guardians of the admitted patients. They can view the current condition of the patient before even visiting the hospital. It saves some breath for them, and saves time as well.

HospiX application currently has a limitation since it can be only used by the users with android devices. Therefore this mobile application can be modified to iOS platform as a next step beyond this research.

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