Indoor Positioning System using Magnetic Positioning and BLE beacons

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Abstract-*Global positioning system(GPS) does not work indoors due to attenuation of signals. Hence, creating indoor context aware applications using GPS is not possible. Indoor positioning systems locate objects, people and assets indoors. There is an array of indoor positioning techniques and technologies that have been developed till date. There is no standard technique for implementing Indoor Position Systems (IPS), as each technique has its own advantages and drawbacks. The best IPS implementations often employ the use of multiple techniques within a building in order to maximize precision. In this paper we present a technology known as magnetic positioning system) that determines location using disturbances of the Earth's magnetic field caused by structural steel elements in a building thus creating a magnetic fingerprint. We will be using IndoorAtlas's API for gathering the fingerprints. After fingerprint collection, a mobile application installed on a smart-phone that is equipped with magnetometer would make an API call to retrieve the location. Bluetooth low energy (BLE) beacons will be used to get a location fix quicker. Once the location of the smart-phone has been fetched, it can be used to create various context aware applications indoors.*

Keywords:
IPS: Indoor positioning system, GPS: Global Positioning system, Localization, Magnetic localization, IndoorAtlas, Bluetooth Low Energy beacons.

I. INTRODUCTION

An indoor positioning system (IPS) is a solution to locate objects or people inside a building using radio waves, magnetic fields, acoustic signals, or other sensory information collected by mobile devices. Global positioning system (GPS) is the most widely used satellite-based positioning system, which offers maximum coverage. However, GPS cannot be deployed for indoor use, because line-of-sight transmission between receivers and satellites is not possible in an indoor environment. Comparing with the outdoor environment, indoor environment is more complex. There are various obstacles, for example, walls, equipment, human beings, influencing the propagation of electromagnetic waves, which lead to multi-path effects. Some interference and noise sources from other wired and wireless networks degrade the accuracy of positioning. A number of indoor positioning techniques have been proposed, but none of them is deployable in most campuses, in spite of their acceptable accuracy in experiments. The primary reason is that, to work properly, all of them have specific assumptions about parameters, like infrastructure, environment, and user behaviours. Today, most application requirements are locating or real-time tracking of physical belongings inside campuses accurately; thus, the demand for indoor localization services has become a key prerequisite in some markets. Moreover, Indoor Localization technologies address the inadequacy of global positioning system inside a closed environment, like campuses. Indoor positioning systems have a lot of use cases, some of the applications of IPSs are hospitals and healthcare. IPSs can be integrated with GPS to guide patients from their home seamlessly all the way to the doctor's appointment. IPS can be used to automate check-ins and notify medical staff of patient whereabouts, locate staff, colleagues and equipment in real-time within the hospital. IPSs can also be used in retail to enable a personalized shopping experience in the visitors' smart-phones. IPSs can be used to provide Google navigation like way-finding indoors. IPSs can be used at public transport stations like airports, bus stops, railway stations, etc. to reduce the anxiety and stress for passengers by providing information relevant to their context, present the shortest route, and estimated walking time to the gate. Help passengers discover what restaurants are nearby, or where the closest toilet is located in the terminal. An accurate indoor positioning system opens a lot of doors and enables the implementation of a lot of use cases in virtual reality, augmented reality and context aware gaming.

II. LITERATURE SURVEY

The technologies for locating mobile nodes involve measuring the signal attenuation, the angle of arrival (AOA), and/or the time difference of arrival (TDOA). While these systems have been found to be promising in outdoor environments, their effectiveness in indoor environments is limited by the multiple reflections suffered by the RF signal, and the inability of off-the-shelf and inexpensive hardware to provide fine-grain time synchronization [1]. Some techniques have merged various technologies like Wi-Fi and cellular signals, BLE, etc. but all of them require some sort of infrastructure. Ultrasonic signals have been used in some solutions [2], but some form of external hardware is required for this type of solution. A few solutions use only Bluetooth low energy as in [3] or Wi-Fi as in [4]. BLE and Wi-Fi both use radio, which is not very stable due to multipath reflections and attenuation. Above all BLE and Wi-Fi cannot be used together effectively because it signal causes interference. There are a few solutions like Redpin [5], that use crowd-sourcing to collect the fingerprints, the implementation of crowd-sourcing may not be effective unless some incentives are given to the public for fingerprint collection and giving incentives cannot be feasible every time. Magnetic positioning is a new technology that uses the magnetic fingerprints to locate smart-phones. Magnetic positioning requires no infrastructure, most modern smart-phones are equipped with a magnetometer, compass. Above all, magnetic positioning can be coupled with BLE and W-Fi. IndoorAtlas's applications can be used to collect the magnetic fingerprints[6]. With the emergence of GPS the performance outdoors has become excellent, therefore indoor positioning became a focus of research, but there is no overall solution based on a single technology. Current systems require dedicated local infrastructure and customized mobile units. Different Indoor positioning techniques can be used such as Infrared, LAN/Wi-Fi, RFID, Magnetic systems etc for different applications as described by Dr. Rainer Mautz in [7]. The use of beacons has also increased in the domain of indoor positioning techniques, as they can communicate with most smart-phones. BLE is supported in android 4.3 and later, iOS 5 and later. Beacons are a piece of hardware which are not so expensive and utilize battery friendly connections to transmit messages [8]. Positioning systems for indoor areas using the existing wireless local area network infrastructure have been suggested. Such systems make use of location fingerprinting rather than time or direction of arrival techniques for determining the location of mobile stations as described in [9] by Kamol Kaemarungsi et.al..

III. PROPOSED SYSTEM

1. ARCHITECTURE

IndoorAtlas's API will be used for localization. IndoorAtlas provides a platform (a web app and an android/iOS app) that can be used for floor plan management, fingerprint collection, map generation and testing. The floor plan that has been scaled according to the actual size of the building is uploaded on IndoorAtlas using the web tool. The first step is to collect the magnetic fingerprint. IndoorAtlas not only collects the magnetic fingerprints but also collects the Wi-Fi and BLE beacon RSSI nearby, this enables better localization. We have used 3 beacons in our test facility which is our department's floor.

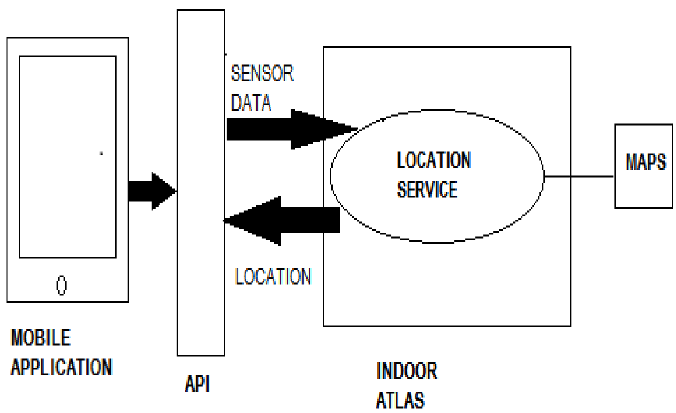

Fig-1: System Interaction

After magnetic fingerprint is collected any app can access the location making a call to the IndoorAtlas's API. The location obtained will be in the form of latitude and longitude. This location can be rendered on the ImageView in an android application. The following is a screenshot of IndoorAtlas's application, which shows the mapped paths.

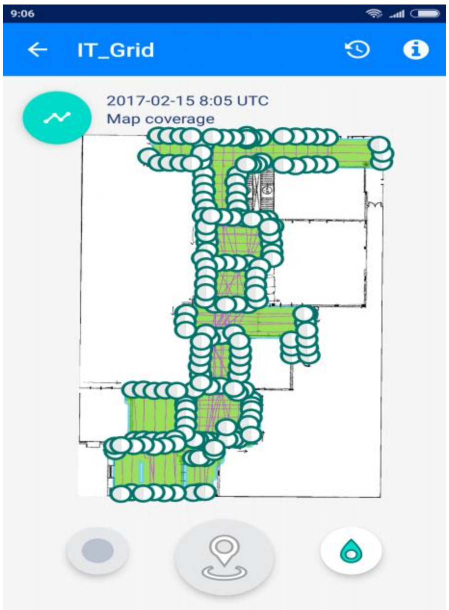

Fig-2: Mapped paths

An android application will be a client for the IndoorAtlas's API. The client would collect the fingerprint with the help of its magnetometer. When the client collects the signature, it would send the data to the server for localization. The server would then compare the measurement with all the fingerprints stored in its map and report back the position associated with the closest matching fingerprint. The location obtained can then be used as per requirements and use cases.

2. HARDWARE MODULE

The hardware requirements for this project are BLE beacons and the sensors present in phones.
Beacons have been used to increase the positioning accuracy. Sensors like gyroscope, magnetometer, accelerometers are used by the IndoorAtlas's API.

Fig-3: BLE Beacon

3. SOFTWARE MODULE

The software requirement for indoor positioning using magnetic positioning are as follows;
1) IndoorAtlas's tools: IndoorAtlas provides various web and android/iOS tools for uploading floor plan, resizing the floor plan, aligning the floor plan with the geo-coordinates. IndoorAtlas also provides an android/iOS application for collection of magnetic fingerprints.

2) Android 4.3 or higher: If BLE beacons are used then the minimum requirement is android version 4.3 or higher. Any android phone with the sensors mentioned above can be used.

IV. IMPLEMENTATION

Following steps have been followed for creating a context aware indoor application.

1. Uploading the floor plan

Floor plan of the site has to be uploaded on the IndoorAtlas's website. The floor plan must be according to scale. If there are not enough distinctive reference points on the floor plan, a grid can be drawn on the floor plan. The grid cell size can be 1.5 meters by 1.5 meters or less on the actual floor which should be scaled down according to the floor plan and then drawn on it. The tool uses MapBox and Here maps for floor plan alignment. The map can be aligned manually or exact coordinates can also be specified. The second option can be used if the context aware application is going to overlay the floor plan on Google Maps.

2. Fingerprinting

In this step magnetic, Wi-Fi and BLE fingerprints are to be collected. IndoorAtlas provides a map creator application that can be used to collect the fingerprints.

3. Map generation and testing

Once fingerprint collection is done, map generation is to be carried out. It is done by the click of a button on either IndoorAtlas's web tool or the android/iOS application. After map generation, testing should be done to check the accuracy. If the accuracy is satisfactory then one can go ahead and create the application.

4. Building the application

IndoorAtlas provides an API for localization and for fetching the floor plan. One can either place a floor plan overlay on Google maps or use an ImageView to render the location of the user. In the first case the floor plan should be exactly aligned as it was in the first step.

The location that is rendered by the API is in WGS84 format. This can be converted to image coordinates.

In our implementation the location of the user has been rendered on an ImageView hence the WGS84 coordinates have been converted to image coordinates.

An important caution to be taken is to get the user permission for accessing internet, storage, Wi-Fi, Bluetooth and coarse location.

The central component of the API is the class by the name IALocationManager, which has been instantiated by calling static method create() in the onCreate() method of the Activity that renders the location. An instance of IALocationListener has been created by creating a new anonymous class from IALocationListener. Now the onLocationChanged method has been overridden, this call back returns the coordinates in WGS84 format which can be used to render the location on the screen.

As the region changes, appropriate floor plan has to be downloaded from the IndoorAtlas's server. A region listener that listens to the region change events has been implemented. Two methods onEnterRegion and onExitRegion have been implemented from the IARegion.Listener interface. The method name onEnterRegion takes the argument as an object of IARegion which represents a region. The method from the class IARegion named getId() returns the ID of the region which can be used to retrieve the floor plan of the region. IAResourceManager is a helper class that is used to retrieve the floor plan. It has to be instantiated using the create() method. After the floor plan has been downloaded it can be rendered on the ImageView. A sub-sampling ImageView that supports pinch to zoom, panning, rotation and animation support which can display large images without OutOfMemoryError has been used.

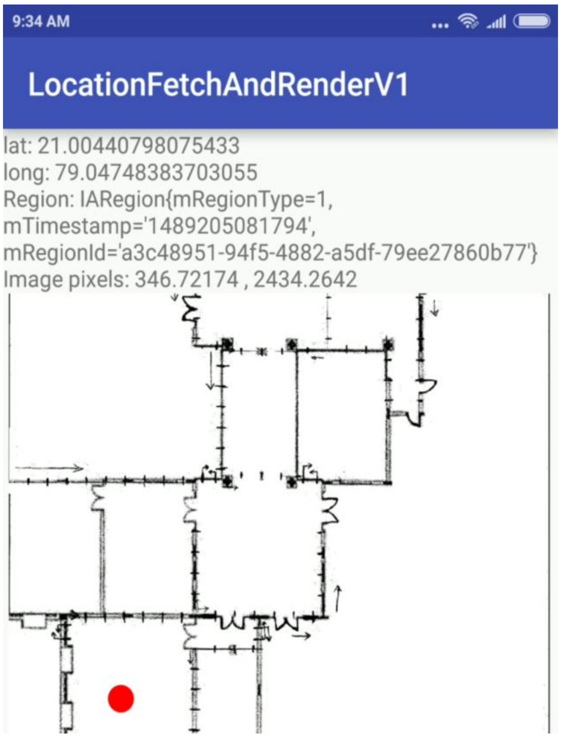

Fig-4: Application screenshot showing the WGS coordinates, region information and the image pixels

V. CONCLUSION

Due to the large market share of android smart-phones especially in India, and the availability of built in sensors like magnetometer, compass, accelerometer, etc., android has been chosen as the development platform. The magnetic positioning system is capable of fetching the magnetic fingerprints in real time, the fingerprints are collected using a mobile device using IndoorAtlas's application. The android application can be used to make a call to IndoorAtlas and then these fingerprints will be used to locate the mobile device accurately, the magnetic positioning is coupled with beacons to improve the positioning accuracy. No infrastructure cost is involved for localization using magnetic positioning. Magnetic positioning is easier to scale as compared to other indoor positioning solutions. A drawback that magnetic positioning has is that a lot of fingerprint collection is required, which is also required in Wi-Fi, BLE based fingerprinting techniques. Hence, magnetic positioning can prove to be a de facto standard for indoor positioning. An accurate indoor positioning system can be used to create a lot of indoor context aware applications like the ones that have been created outdoors using GPS.

VI. REFERENCES

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