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Development of an Indoor-Outdoor Positioning Android App for Anapji Tourist Guides

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Abstract

This paper introduces the development details of an Indoor and Outdoor Positioning Android app for Anapji, an artificial pond in Gyeongju National Park in Korea, tourist guide apps. There is a pathway around the pond, with around 10 viewpoints and Imhaejeon, a gazebo-like Korean traditional house, along this pathway. In Imhaejeon, we can find an Anapji bird's-eye view at the center and 12 cultural artifacts unearthed at Anapji displayed along the four edges of Imhaejeon. Tourists walk along the pathway and stop at a viewpoint to enjoy the scenic beauty at their wish. Most of them also enter Imhaejeon, walk along the edge, and stop in front of an artifact to watch it. Whenever a tourist stops to watch something, tourist guide apps show a content that is closely related to the thing that is being watched. The content can be a video clip describing how the artifact was crafted or a video game that mimics an ancient game played by the people in the 8th century. This kind of tourist guide app cannot be realized unless they can recognize the position where the user is located. This paper develops an indoor-outdoor positioning Android app that is an essential part of tourist guide apps. Our indoor-outdoor positioning app uses the GPS receiver for outdoor positioning whereas it uses the dead reckoning method for indoor positioning. Our test results showed that our indoor-outdoor positioning app is accurate enough to be used for practical tourist guide apps.

Keywords: *positioning; Android app; GPS; dead reckoning; indoor positioning.*

1. Introduction

As it is included in Korea's future strategic industries, Location Based services (LBS) have been intensively studied. Now, it matured and is widely used in our daily life and makes a good deal of contribution to the development of various industries. LBS should be available inside of manmade structures such as buildings, subways, and underground shopping malls because they are huge and people spend most of their time there. LBS provided in manmade structures is called indoor LBS. Kids care in amusement parks, senior care, building management, and personalized smart service are types of indoor LBS and indoor LBS performs crucial roles in life-saving in fire and emergency evacuation [1].

Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) provide the general solutions of positioning for outdoor LBS. Google maps, Naver Maps, Daum Maps and others provide the general solution of user interface for outdoor LBS. However, there are no general solutions of indoor positioning and of user

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interface for indoor LBS. Therefore, techniques for indoor LBS are still hot research topics [2, 3].

Tourist guide mobile apps explain the origins of manufacturing methods of, and historical facts associated with the ruins and relics of ancient times to tourists on behalf of tourist guides. Therefore, a tourist guide app must recognize the ruin and the relic that the tourist is watching. Recognizing the things that the user is watching requires recognizing the position where the tourist is located.

Nowadays, almost everybody carries a smartphone that is equipped with a fast processor, a large capacity memory, a GPS receiver, and various accurate sensors. Thus, smartphones are the best candidate platform where tourist guide apps run.

This paper provides the details on the development of an indoor and outdoor positioning app that can be plugged into a tourist guide app as an accurate location provider. Outdoor positioning can be done by using GPS. Once we have the position from the GPS, we can determine the things that the user is watching with the sensor values from the smartphone sensors.

There is no general solution of indoor positioning. We introduce an enhanced dead reckoning (EDR) indoor positioning. EDR recognizes the moment when the user is entering a manmade structure and uses the entrance as the start point of the dead reckoning process. EDR counts steps with accelerometer values and determines the direction with orientation values. With the step count and the direction, EDR determines the user's current position as the ordinary dead reckoning process does. The uniqueness of EDR is that it recognizes when the user is not moving, finds out the point of interest (POI) in which the user is interested, and adjusts the result of dead reckoning with the position of the POI.

We implemented our indoor and outdoor positioning app and tested it in Anapji, an artificial pond in Gyeongju National Park. Our test results showed that our positioning app is efficient and accurate enough to be used in practical tourist guide apps.

2. Related Works

As buildings and underground facilities such as shopping malls around subway stations are getting bigger numbers of people, the duration of time people work inside a building is longer than that of people working outside the building. It frequently happens to us to visit a huge manmade structure to do something. Therefore, indoor LBS and indoor positioning have attracted a lot of attention from researchers. The smart guide that shows the way to viewpoints [4], the museum guide [5], and the indoor navigation system [6] are a few examples of Indoor LBS.

The authors of [1] surveyed various indoor positioning techniques and emphasized that extending GIS (Geographic Information System) to manmade structures is a requirement for fostering indoor LBS industry.

So many indoor positioning techniques have been proposed. The techniques proposed in the early stage of the indoor positioning required special equipment dedicated to positioning. The method introduced in [7] required attaching beacons and sending out infrared to the moving objects and to install receivers at rooms so that the system could recognize in which room a user is located. The method introduced in [8] required attaching beacons to moving objects to send out both radio wave and sound wave and to install many receivers in the ceilings so that the system accurately estimated the moving object's position. The method introduced in [9] worked in the reverse way, in that the beacons are installed at fixed positions whereas a receiver is attached to a moving object so that the moving object could identify where it is located.

Using special equipment, we can extremely correctly estimate the location of a moving object. However, a technique that requires special equipment cannot be a general solution for indoor positioning. Meanwhile, wireless local area networks (WLAN) spread widely and became available almost everywhere. Thus, many WLAN based indoor positioning techniques were introduced and are still being studied. For example, the techniques introduced in [10, 11] are WLAN based.

Smartphones are equipped with various sensors, powerful processors, and large capacity memories. Smartphones have been so widely spread that almost everybody has a smartphone and carries the smartphone all the time because a smartphone has become a daily necessity. Therefore, smartphone based indoor positioning and indoor LBS have been hot research topics. For example, the authors of [12] introduced a smartphone based indoor positioning method. Since smartphone based indoor positioning uses the sensors equipped on the smartphone, it can be generally used in developing applications. Furthermore, a smartphone is a perfect candidate platform for indoor LBS because it has enough memory space to save floor maps and its computing power is more than enough to execute LBS applications.

As is discussed, the environments of indoor positioning have significantly evolved. However, the basic processes of determining the position have not changed much. They can be classified into the fingerprinting, trilateration, and dead reckoning. The deployment of fingerprinting consists of two phases: off-line phase and real-time phase. During the off-line phase, we create a fingerprint for all CP_i in candidate points. A fingerprint of CP_i is anything that identifies CP_i. All sensor values collected at CP_i can be used as a fingerprint of CP_i. During the real-time phase, it collects sensor values, X, finds the fingerprint that is closest to X, and returns CP_i that is associated with the closest fingerprint as the current position of the moving object. One of the disadvantages of the fingerprinting process is that the off-line phase of it is very time-consuming. However, the idea of the process is easy to understand and the result is relatively accurate, so the fingerprinting is still widely used [5, 13-20]. The trilateration process receives signals sent from fixed positions, transfers either or both of them into distances and orientations. With the coordinates of the fixed positions, distances (ranges), and orientations, the trilateration process calculates the position of the moving object. If the signal is reliable then the result is accurate. GPS and the methods used in [8, 9, 18-20] belong to this category. Examples of dead reckoning are introduced in [3, 20, 21].

The method introduced in [20] is a combination of dead reckoning and fingerprinting. The prediction methods such as the Kalman filter and particle filters are introduced in [22]. The collaboration method in which users exchange their positions is introduced in [6].

3. The Proposed Indoor Outdoor Positioning

The application should be run on a device that is possessed and carried by everyone and should not rely on special resources. Otherwise, we cannot generally use the application. As we discussed in the Related Works section, smartphone based dead reckoning for indoor positioning and GPS for outdoor positioning can be considered as a general solution. The GPS is run by the USA government and is available anywhere and anytime as long as satellite signals are receivable. According to our experimental results, the error range of the GPS is less than 6 meters. The dead reckoning indoor positioning relies only on the sensors inside the smartphone and it can be considered to be a general solution of indoor positioning even though the error of it increases as time goes by.

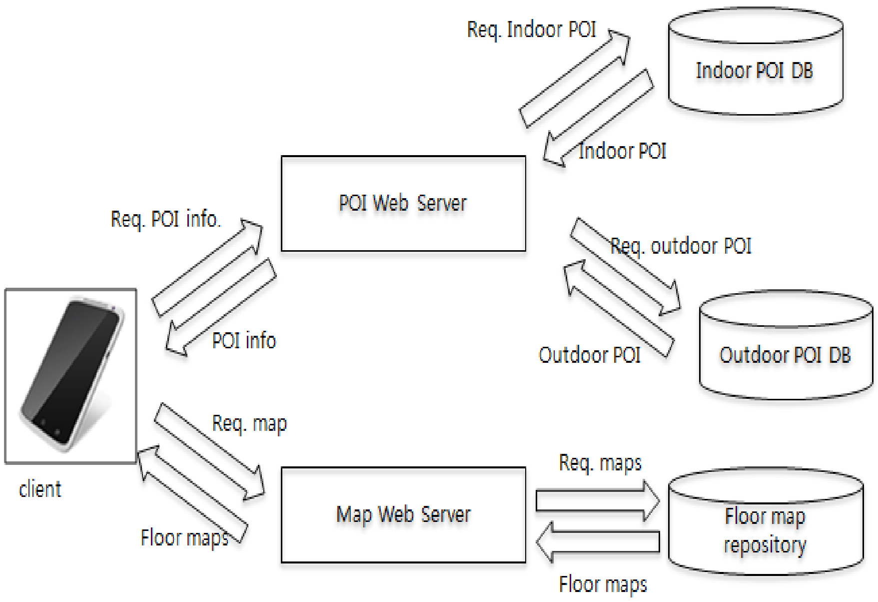

Figure 1. Important Components of our Indoor and Outdoor Positioning System

In this paper, we improve the accuracy of dead reckoning indoor positioning, making use of the information we can find on the map and floor maps. The important components of our indoor and outdoor positioning system are shown in Figure 1. In the floor map repository, the floor maps of the manmade structures in the domain are stored. Information on points of interest we can find indoor/outdoor is stored in the Indoor POI DB/Outdoor POI DB. Our app downloads information of POI and floor maps via the POI Web server and the map Web server.

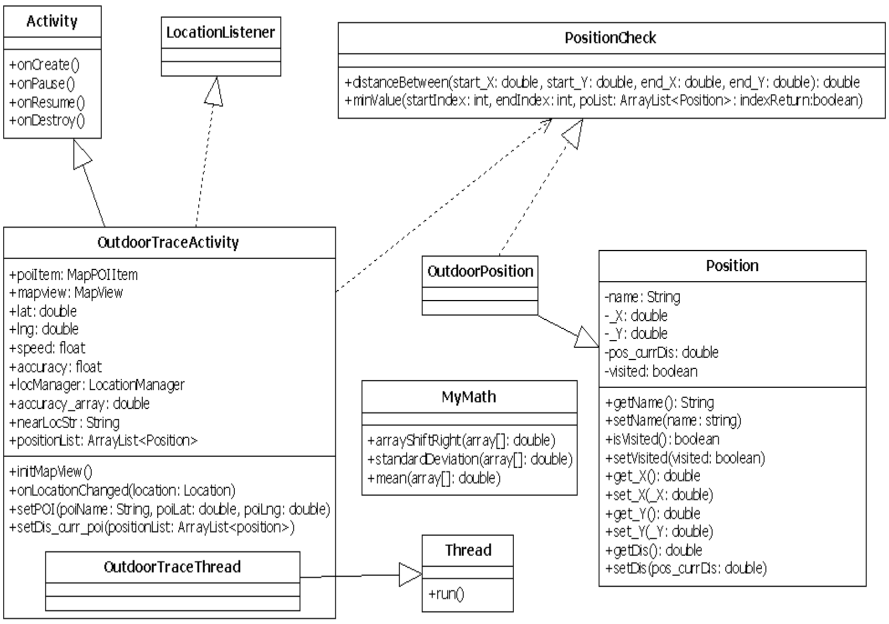

Figure 2. The Classes for Outdoor Positioning

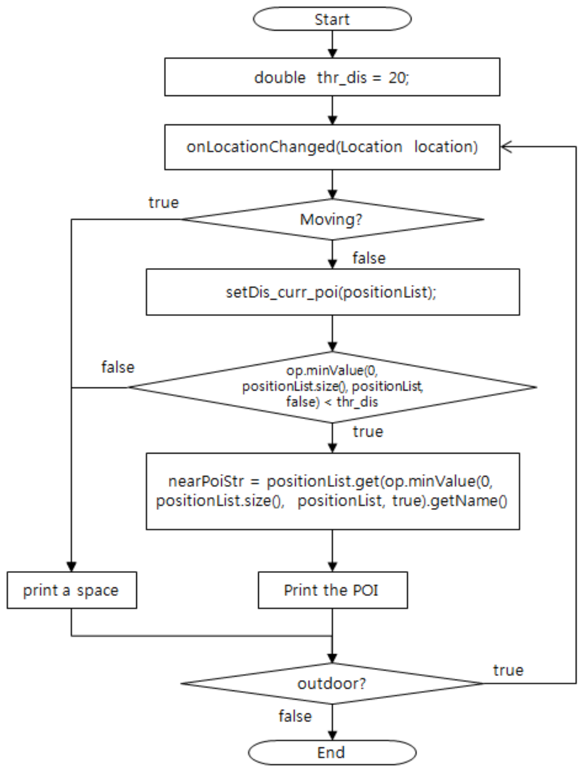

Figure 3. A Flowchart for OutdoorTraceThread

For outdoor positioning, we defined classes shown in Figure 2. OutdoorTraceActivity uses LocationManager provided by the Android operating system. MapView is a view which displays a map. In MyMath, the methods to calculate the mean and standard deviation are defined. OutdoorTraceThread reads GPS and checks if the user is moving or not by investigating the speed attribute obtained from the GPS receiver. If the user is moving, then it repeats reading GPS after sleeping for a while. Otherwise, it finds the POI that is nearest to the user's current position. If the distance between that POI and the user's current position is less than a threshold, then it determines that the user's current position is the position of the POI. It repeats this process until the user enters the building. This process of OutdoorTraceThread is described in Figure 3.

The process to determine whether the user is inside or outside a building is described in Figure 4. It collects GPS signals every one second. If the average of recently collected five accuracy attributes is greater than a threshold then it determines that the user is inside the building. As is shown in Figure 5, the accuracy is high when the user is inside a building.

For indoor positioning, we defined the classes shown in Figure 6. IndoorTraceActivity uses SensorManager in order to read the accelerometer and orientation sensors. IndoorTraceThread counts the number of steps taken by the user, determines whether the user is moving or not, and determines the direction the user is taking. The DownloadFloorPlanThread downloads floor maps via HTTP GET method. MyView is a View which displays a floor map.

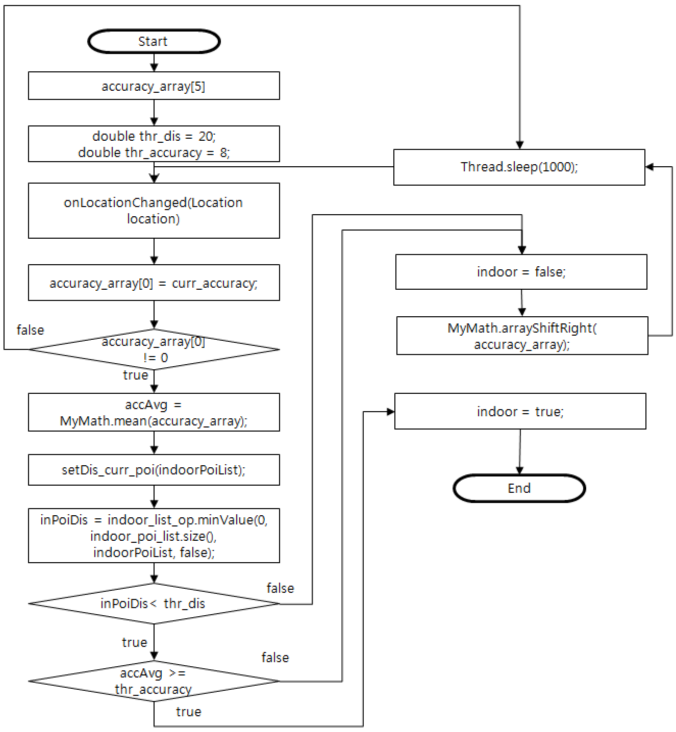

Figure 4. The Process to Determine whether the User is Inside a Building or Not

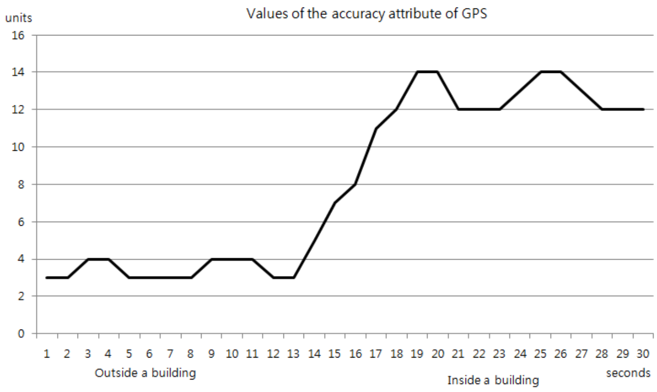

Figure 5. The Accuracy of GPS is High when the User is in a Building

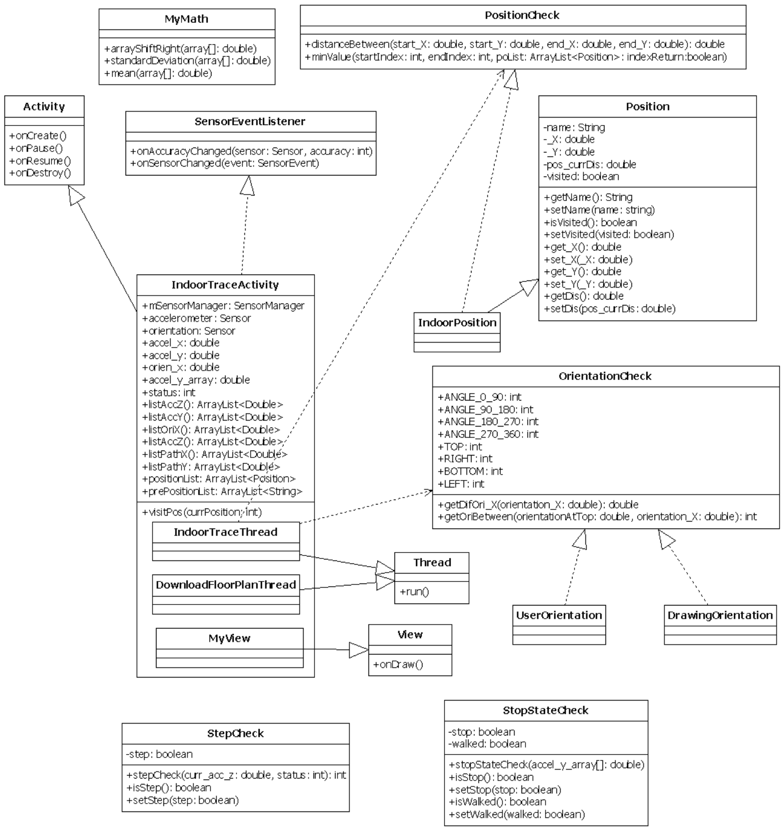

Figure 6. The Classes for Indoor Positioning

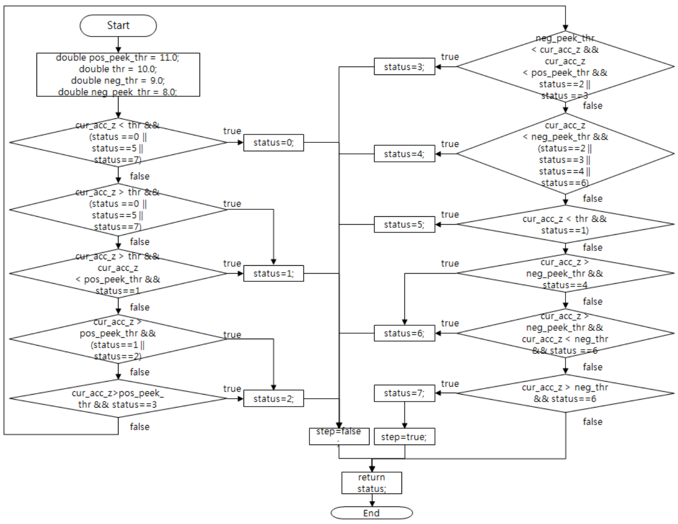

Figure 7. The Process of Recognizing a Step Defined in the StepCheck Class

Referring to the value of the accelerometer sensor, the StepCheck class recognizes a step taken by the user. While the user takes a step, the value of the accelerometer increases to the pos_peek value, and then decreases to the neg_peek value. Therefore, the

StepCheck increases the number of steps whenever the accelerometer value reaches the neg_peek after reaching the pos_peek as shown in Figure 7.

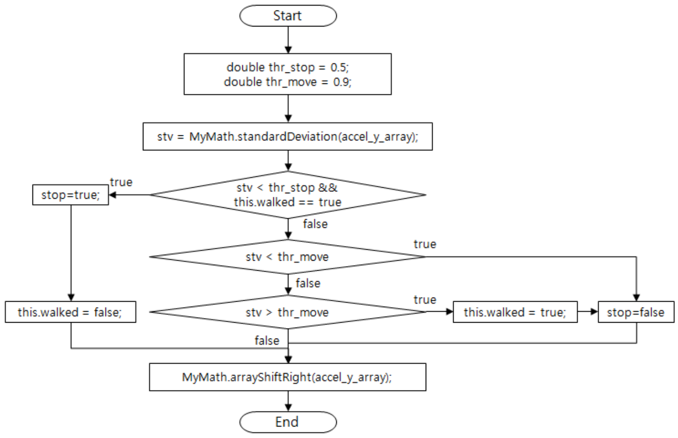

Figure 8. The Process to Determine whether the User is Moving or Not

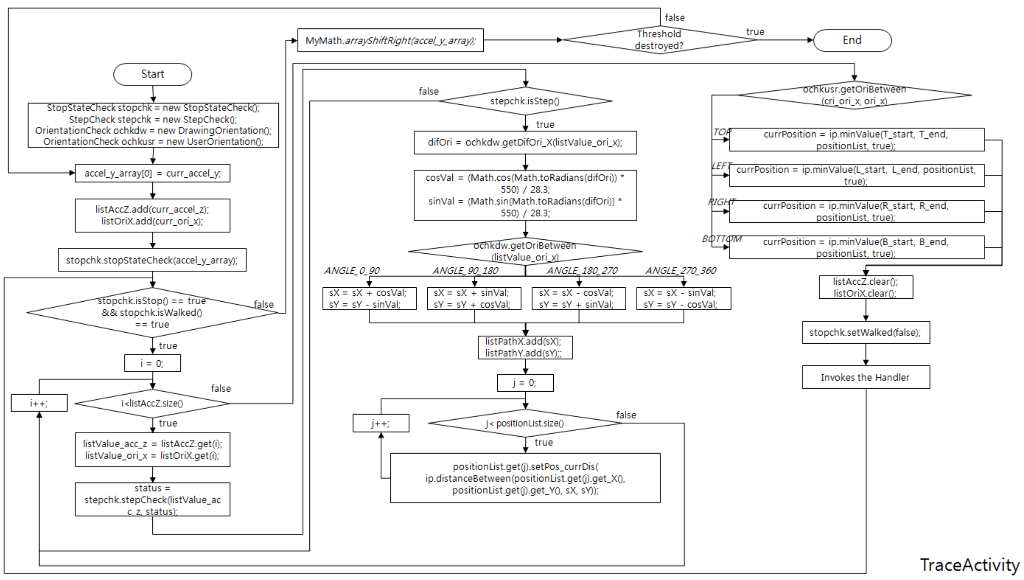

Figure 9. The Process of Recognizing the POI that the User is Watching

When the GPS is available, we can determine whether the user is moving or not by investigating the speed attribute of the GPS. In indoor positioning, the GPS is not available and we investigate the accelerometer values. If the standard deviation of recently collected k accelerometer values is less than a threshold, then we conclude that the user is not moving as shown in Figure 8.

The process of recognizing the POI that the user is watching is shown in Figure 9. This process uses the StopStateCheck, StepCheck, DrawingOrientation, and UserOrientation classes. Using the StopStateCheck class, it determines if the user is moving or not. If the user is moving, then it goes back to the step of reading the accelerometer sensor; otherwise it proceeds to the next step of recognizing the POI that the user is watching.

Using the StepCheck class, it recognizes a step taken by the user and updates the user's current position for every step until the last accelerometer value is reached. When the last accelerometer value is reached, it determines whether the user is facing north (TOP), south (BOTTOM), east (RIGHT), or west (LEFT), by using the UserOrientation class. Then, it finds the nearest POI. Assuming that the user's current position is the position of the nearest POI, we can update the user's current position to the position of the nearest POI.

We use the following expressions in order to find the relative x/y coordinate distance from the last position:

$$\cos Val = \cos(radians(difOri) * 550) / 28.3$$

$$\sin Val = \sin(radians(difOri) * 550) / 28.3$$

where, difOri represents the direction, 550 represents an average stride, and 28.3 represents the number of pixels in 1 cm.

4. Experiments

We have implemented the indoor-outdoor positioning system for Anapji, an artificial pond in Gyeongju National Park, on an LG G4 smartphone. We can find 11 viewpoints and Imhaejeon, a gazebo-like Korean traditional house in Anapji as shown in Figure 10.

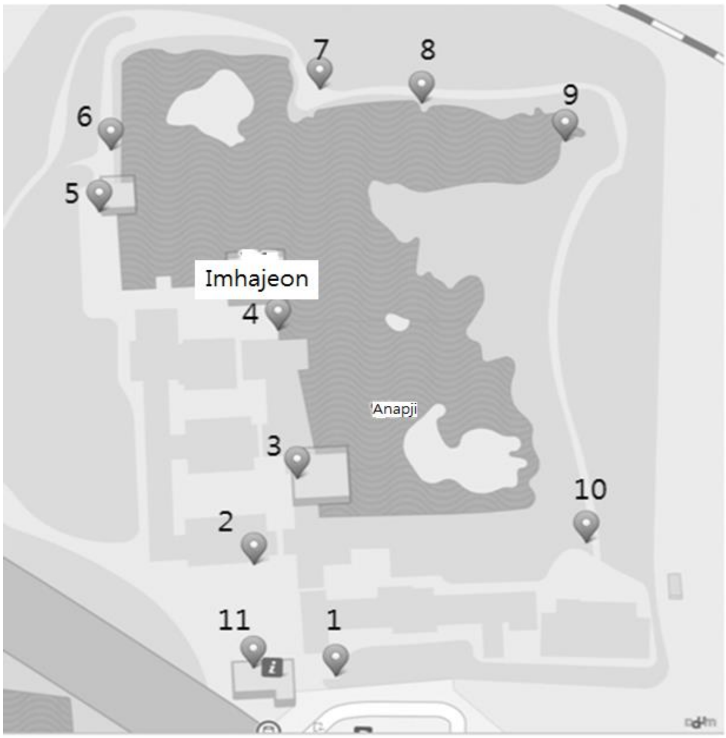

Figure 10. An Anapji Pond map

A list of the viewpoints in Anapji is shown in Figure 11. "Silk Carp" is a place where we can find a school of colorful carp.

No.	*Name*	*Latitude*	*Longitude*
1	*Outdoor theater*	*35.8334377*	*129.226881*
2	*Excavated building site*	*35.83382256*	*129.22655365*
3	*Restored building 1*	*35.8341224*	*129.2267243*
4	*Silk Carp*	*35.8346375*	*129.226638*
5	*Restored building 3*	*35.8350398*	*129.2259305*
6	*Shooting place 1*	*35.83525467*	*129.22597275*
7	*Shooting place 2*	*35.8354763*	*129.2267946*
8	*Shooting place 3*	*35.83542928*	*129.22719923*
9	*Shooting place 4*	*35.8353019*	*129.2277628*
10	*Water tank*	*35.83390647*	*129.22786741*
11	*Gift store*	*35.8334605*	*129.2265516*

Figure 11. A list of viewpoints in Anapji

Figure 12. An Example Outdoor Positioning Screenshot

A sample outdoor positioning screenshot is shown in Figure 12. The latitude, longitude, and accuracy read from the GPS are 35.83465756, 129.22662406, and 4.0, respectively. With the GPS data, it concluded that the user is at the 4th viewpoint.

In Imhaejeon, an Anpji bird's eye view and 12 cultural artifacts unearthed at Anapji are displayed as shown in Figure 13. The entrance of Imhaejeon is represented by B1 in the figure.

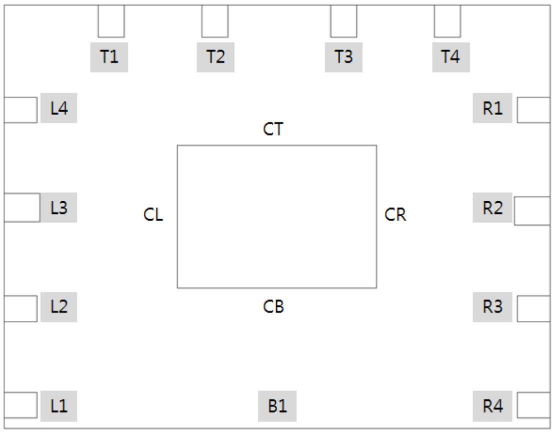

Figure 13. A Floor Map for Imhaejeon

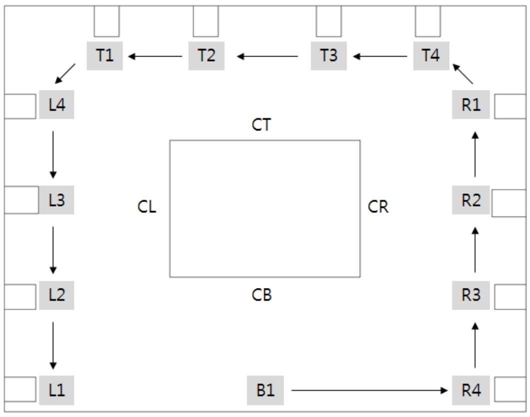

Figure 14. Scenario 1 to Test the Indoor Positioning App

We have implemented two versions of indoor positioning apps, A and B. In the A app, we implemented the dead reckoning process. In the B app, we implemented the dead reckoning that updates its position with the position of POI whenever the user stops. For example, it changes its current position to the position of R3 when the user stops at R3 as shown in Figure 15.

We have performed many experiments testing our indoor positioning app in Imhaejeon. The scenario 1 of our experiments is to stop and take a look at every exhibit as shown in Figure 14. We tested the scenario 1 30 times. A typical test result is shown in Fig. 15. During the experiment, we checked the user's position 360 (12 items * 30 reps) times. The A app correctly identified the positions 323 times out of 360 times whereas the B app correctly identified 348 times.

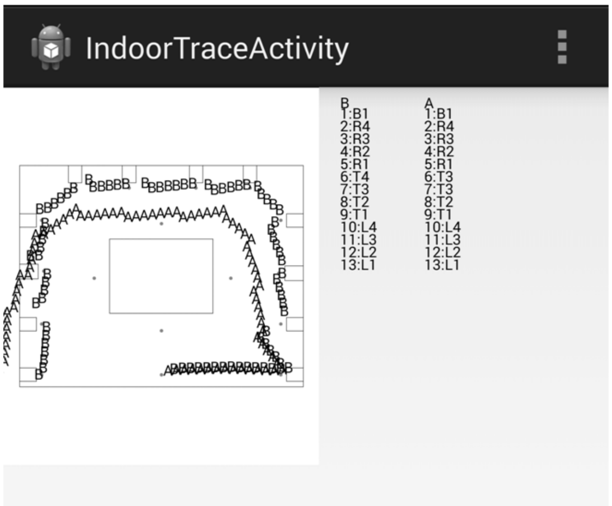

Figure 15. A Typical Test Result for the Scenario 1

We tried many other scenarios. Our experimental results showed that the B app about 95% correctly identified the position.

5. Conclusions

We described our implementation of an indoor-outdoor positioning Android application. Our experimental results showed that the outdoor positioning app 100% correctly identifies the user's current position when the user stops at a viewpoint in Anapji pond and the indoor positioning app about 95% correctly identifies the user's position when the user stops and watches an exhibit displayed in Imhaejeon. We are planning to develop a practical smart tourism guide app based on indoor-outdoor positioning app discussed in the paper.

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