The Development of WiFi-Based Indoor Navigation System Using Augmented Reality

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Abstract

Location-based systems have become an integral part of our daily lives. In recent years, many navigation applications using AR (Augmented Reality) technology have been released, but most of these applications are mainly designed for outdoor use and track location using GPS. On the other hand, research for indoor applications is still in its infancy due to the limitations of GPS satellites. In this paper, we propose to use existing WiFi access points for indoor positioning using the kinematic method. In addition, we present an augmented reality navigation solution that guides the user to the destination by displaying the route. As a result of implementing and testing the system, we found that it was successfully developed, but the effect of the experimental environment on AR was found to include errors in positioning under certain conditions, which is also discussed.

1 Introduction

1.1 Background

In recent years, various navigation systems using AR have emerged. AR is a technology that visualizes the real world by adding digital information such as voices, images, and texts. An example of its application is Google Map. It has a function called "Live View" that visualizes the direction to the destination by superimposing guide arrows on images of the surroundings taken with a smartphone camera (Figure1). However, many of these applications cannot be used indoors because they use GPS to determine location information. This is because GPS signals cannot be received well inside buildings, making it difficult to determine the exact location indoors. On the other hand, various methods for indoor location acquisition have been proposed in previous research papers. These include pedestrian independent navigation, WiFi positioning, geomagnetic positioning, and visible light positioning. We focused on WiFi positioning. We thought that by utilizing existing Wi-Fi access points and trilateration, we could develop a navigation application that can be used indoors without relying on GPS.

Figure. 1
Google Maps Live View

1.2 The goal of the thesis

The objective of this research is to develop a practical indoor navigation application for smartphones using the above method. In addition, by using AR techniques to visually support route guidance, we aim to realize guidance that is more visual, intuitive, and easier to understand than general navigation applications.

2 Development

2.1 Application details

In this study, we developed an indoor navigation application that guides users through the research quadrangle in the University of Aizu using their smartphones. The system uses WiFi Position tracking, which identifies the user's location using the RSSI (Recovered Signal Strength Indicator) obtained from WiFi APs (Access Points) already placed in the building as shown in Figure 2. This application is designed to help users reach the desired room without getting lost in buildings with complex internal structures.

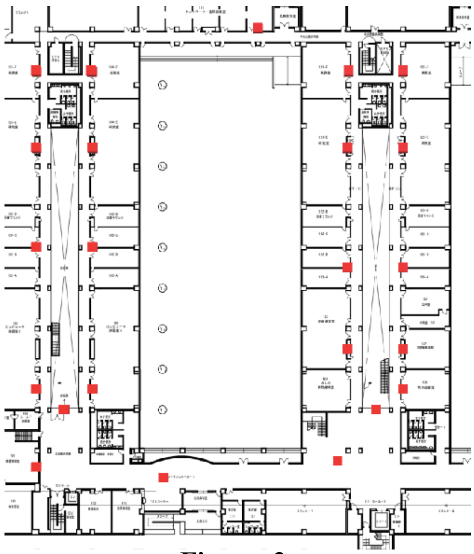

Figure. 2
WiFi AP layout map

The process of the application is as follows:

1. Position tracking by WiFi Trilateration.
2. The user selects the destination room in the room list.
3. Guide a user to the desired room using AR.
4. Users can also check their current location on a map of the facility.

Figure 3 is the workflow based on the above process.

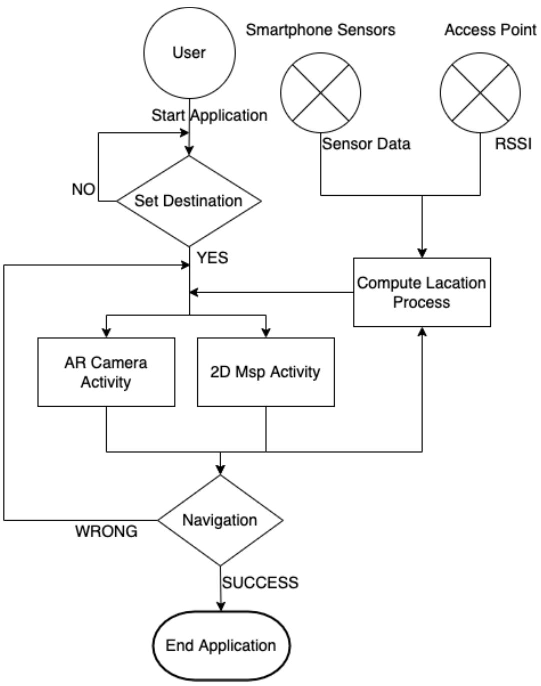

Figure. 3
The application workflow

2.2 Development Environment

In the section, we describe the development environment for this research. The software and device used in the development and experiment of this application are described below.

2.2.1 Unity

Unity [1] is a game engine provided by Unity Technologies. It is widely used to develop not only games but also various applications because it supports various platforms such as Windows, Mac, Linux, iOS, and Android, and has a wide range of assets.

2.2.2 AR Core

ARCore [2] is Google's platform for building augmented reality application. ARCore uses a variety of APIs to enable your phone to sense its environment, understand the world, and interact with information. Some of the APIs can be used and shared between Android and iOS.

・ARCore integrates virtual content with the real world through the phone's camera using three key features.

・Motion tracking allows the phone to know and track its position in the world.

・Environment recognition allows the phone to detect the size and position of any surface, horizontal, vertical or diagonal, such as the ground or a wall.

・The light level estimation function can estimate the current lighting conditions.

2.2.3 Device

In this study, we use an Android smartphone as an experiment. The device information is in the table below.

Table. 1 Data of the device used

Device Model	Galaxy S9
Android Version	10

2.3 Indoor Position Tracking

In this section, we describe two approaches to location tracking: RSSI calculation and WiFi trilateration. RSSI is the signal strength that a device like a smartphone receives from a WiFi AP. An AP is a connection point such as a router located in various places. As shown in Figure 4, the distance between each AP and the user is calculated using the RSSI received from three or more APs to evaluate the user's location.

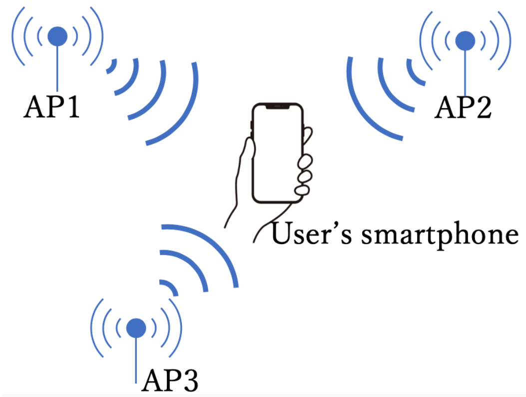

Figure. 4
Receive the RSSI signals from WiFi APs

2.3.1 RSSI calculation

The distance is calculated from each access point to the user using the following equation defined as RSSI in decibels [3]:

$$\mathbf{RSSI(dB)} = 20\log_{10}(\mathrm{d}) + 20\log_{10}(\mathrm{f}) - 27.55 \qquad (1)$$

$$\mathbf{d} = 10^{\frac{20\log_{10}(\mathrm{f}) - \mathrm{RSSI} - 27.55}{20}} \qquad (2)$$

where d is the distance in meters and f is the frequency in MHz.

Figure 5 shows the display screen of the RSSI calculation results of the application.

Figure. 5
RSSI calculation results

2.3.2 WiFi Trilateration

Referring to the approach in [4], The user's position can be estimated by finding the center of gravity of a polygon consisting of the intersection of the distances from three or more APs and the circles whose radii are those circles. If the position (xi,yi) of each AP is known, the user's position (x,y) can be obtained as follows. Figure 6 shows the above approach.

$$\begin{cases} d_1{}^2 = (x - x_1)^2 + (y - y_1)^2 \\ d_2{}^2 = (x - x_2)^2 + (y - y_2)^2 \\ d_3{}^2 = (x - x_3)^2 + (y - y_3)^2 \end{cases} \qquad (3)$$

A polygon with three or more vertices is created, consisting of multiple intersections obtained from the above simultaneous equations. Figure 7 shows case of four WiFi APs detected. As shown in Figure 8, the center of gravity of a polygon can be calculated by average of the centers of gravity of triangles divided into several parts. The following is the calculation equation.

$$gx = \frac{\Sigma S_n \cdot gx_n}{\Sigma S_n},\ gy = \frac{\Sigma S_n \cdot gy_n}{\Sigma S_n} \qquad (4)$$

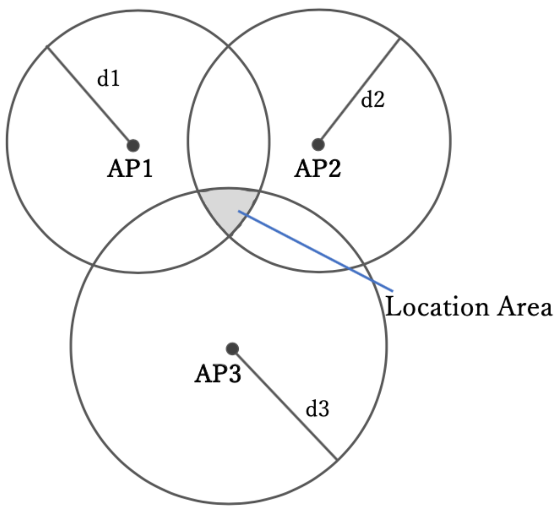

Figure. 6
Trilateration calculation

2.3.3 AR navigation

ARCore's environment recognition allows AR navigation to operate by detecting the size and position of any horizontal, vertical, or diagonal surface, such as the ground or a wall. By converting real spatial coordinates into virtual spatial coordinates, it spawns specific objects at the specified coordinates. This will display the route to the destination on the screen and the accompanying directions to go straight or turn right or left on the user's phone. Figure 9 shows an illustration of our understanding of AR navigation.

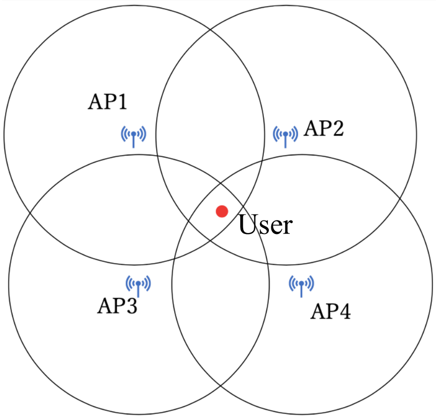

Figure. 7
The case of 4 WiFi APs detected

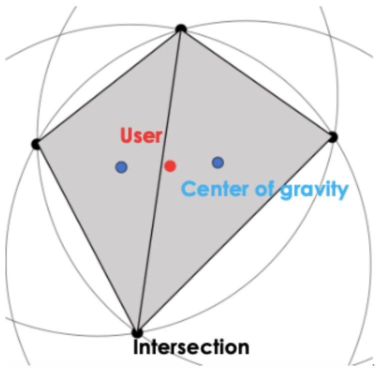

Figure. 8
Created polygons and center of gravity

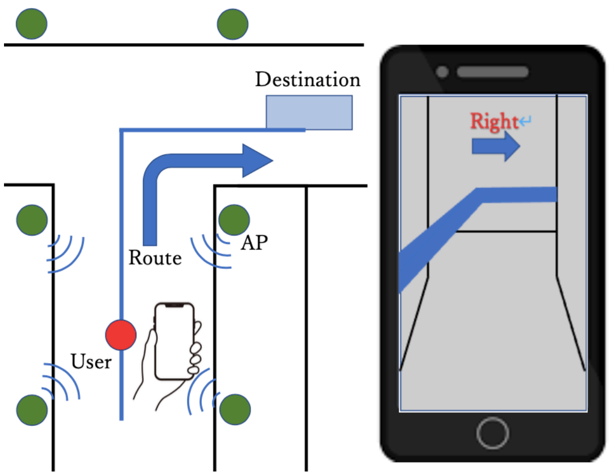

Figure. 9
Our understanding of AR navigation

3 Result

In this research, we succeeded in developing an AR navigation system that allows users to select and be guided to the destination room. Figure 10 is the screen of the AR navigation mode. At a turn, an arrow will be displayed in the direction of the turn, and when going straight, a sign with the approximate distance to the next corner will be displayed. In addition, the route line projected on the screen allows users to visually and intuitively understand the direction to go.

Figure. 10
AR Navigation

The application can also display a map. Figure 11 shows the image when the map is displayed on the screen. The user can see the current location and the trajectory to that location.

However, this application may cause errors in location tracking and may result in unusable levels of deviation. We worked to eliminate the error but could not.

4 Comparison

We couldn't find any indoor navigation application like the application we developed, so we compared "Google Map" with the application we developed. Table 2 shows a comparison between "Google Map" and the developed application.

The application we developed can only be used in very limited places. However, by expanding the target buildings, it will be possible to use our application in more places. In addition, by implementing outdoor location tracking functions using GPS, we expect to be able to develop hybrid applications that can operate both outdoors and indoors.

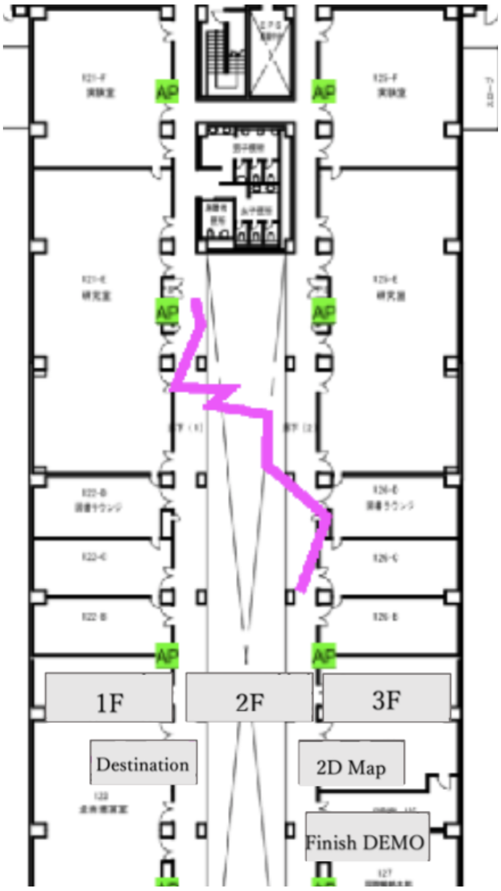

Figure. 11
The current location and the trajectory to that location.

Table. 2 Comparison

	This Application	Google Map
AR Navigation	○	○
Show map	○	○
Show the distance to the destination room	×	○
Show the movement trajectory	○	×
Usable in the buildings	○	×
Usable in outdoor	×	○

5 Conclusion

In this study, we developed an indoor AR navigation application using WiFi location tracking introduced in our previous study. As a result, indoor route guidance was successfully achieved. However, there are some errors and unavailability in the location tracking, but this research could not solve them and only identified the causes. Therefore, we were not able to complete the development perfectly, but we believe that we were able to fully demonstrate the potential of indoor navigation applications.

6 Future Works

We are planning to solve the following three issues in the future.

- Location tracking drift.
- Location tracking lost.
- The narrowness of this application.

6.1 Location tracking drifts

There are two things that we noticed during development as sources of drift in location tracking.

First, there is an increase in drift since the exact location of the APs is not known; the documents showing the location of the APs were marked roughly, so we developed an approximate location as the location of the APs. This may have amplified the measurement error.

The second factor is the influence of building columns and roofs. Since the RSSI signal used for positioning is a radio wave, it encounters various obstacles such as walls, pillars, and floors before the device receives the signal from the AP. In general, metal, concrete, and insulation may prevent or diminish radio waves from passing through. Thus, the RSSI is not quite stable in our test environment [5].

The location tracking drift is expected to be reduced by further increasing the number of WiFi APs. In the environment of this experiment, the maximum number of WiFi APs detected is seven. In theory, as the number of detected WiFi APs increases, the user's location area decreases. Therefore, the estimated location drift is expected to be smaller by increasing the density of placed WiFi APs.

6.2 Location tracking lost

Lost location tracking is thought to be caused by the density of APs placed. There are several ranges in the facility where the number of APs placed does not reach the required number. Therefore, the WiFi location tracking situation may not be working properly.

6.3 The narrowness of this application

In this study, we were not able to realize multi-floor due to the two problems mentioned above. Therefore, this application is limited to use only on the first floor of the research building of the University of Aizu.

7 References

[1] “Unity” https://unity.com/
[2] “ARCore” https://developers.google.com/ar
[3] Ghantous, Milad, Houssam Shami, and Rana Taha. "Augmented Reality Indoor Navigation Based on Wi-Fi Trilateration." International Journal of Engineering Research & Technology 7.07 (2018).
[4] Shchekotov, Maxim. "Indoor localization method based on Wi-Fi trilateration technique." *Proceeding of the 16th conference of fruct association*. 2014.
[5] Sun, Yuxiang, Ming Liu, and Max Q-H. Meng. "WiFi signal strength-based robot indoor localization." 2014 IEEE International Conference on Information and Automation (ICIA). IEEE, 2014.