Research on Improvement of the Hybrid Location Estimation System Using 2D Marker and Wi-Fi

-How to Decide the Radio Strength of Virtual Base Station-

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***Abstract*—Various method are proposed for the indoor positioning, and many methods such as using the radio wave or using various sensors are well known. We proposed the highly accurate indoor positioning method for using two measurement techniques seamlessly; the measurement using wireless radio wave strength, and the measurement using two-dimension marker. In our method, two measurement techniques can be appropriately used seamlessly by considering a new concept called *Virtual Base Station*. However, proposed method has a problem about the parameter setup of radio field strength of the virtual base station. To tackle this problem, we adopt an approximation curve about the relation between distance from base station and radio filed strength by measuring radio field strength in a real environment. And, it was clarified that the positional estimation accuracy become rises by using the approximation curve for the virtual base station.**

***Keywords*—RSS Based Method; Camera Based Positioning; Location-Aware Service; Human Navigation System; System for Mobile Phones**

I. INTRODUCTION

Recently, the GPS system is built into many cellular phones, and the location-based service for pedestrians is widely spread. However, the GPS system has a big restriction that it cannot be used in indoors or underground and it is a big problem to consider about positional service for pedestrians. To deal with this problem, a lot of pedestrian positioning systems such as using wireless radio wave, various sensors, and cameras are proposed. In the present study, we proposed a novel indoor positioning approach that enables to improve the positional estimation accuracy by focusing on the smart phone which widespread in recent years, and using both the camera built into a backside of smart phone and the WiFi interface. *Virtual base Station* is a new concept in the proposed system to use two measurement techniques of WiFi based measurement and camera based measurement seamlessly. However, it is necessary to setup the strength of *virtual* radio field of a virtual base station appropriately to achieve a highly accurate measurement. In this paper, we describe the method of appropriately setting up the radio field strength of a virtual base station through the experiment in a real environment.

This paper is organized as follow. The next section explains the related research for the indoor location estimation system. Our proposed method is described in section 3. Experiment results and discussions are conducted in section 4. Finally our conclusion of this paper is given in section 5.

II. RELATED RESEARCH

In this chapter, we introduce three methods that are typical used of indoor positioning, and explain features and subjects.

A. *Measurement using wireless LAN*

The measurement methods that use wireless LAN [1,2,3,4] can be roughly classified into the following three types, (1) using wireless radio field strength (RSSI), (2) using wireless radio wave arrival time difference (Time of Arrival), and (3) using direction of radio wave coming. Although comparatively highly position estimating is possible by using radio wave arrival time difference and using radio wave arrival directions, since special equipment or a special antenna are required to the terminal side, it is not suitable for a pedestrian using it. On the other hand, the receive signal strength (RSSI) method using the wireless LAN is becoming widely used for mobile devices. This is because this method enables to apply very easy to the common mobile terminal; however, this method has a limit that has estimation error about several meters.

B. Measurement using RFID

A basic idea to measure the location by using a RFID (wireless ID tag) assume to arrange a lot of RF tag in environment to be measured beforehand, adds the special equipotent called RFID leader to the terminal side, and estimate the position of terminal from ID information. Therefore, it is necessary to arrange a large amount of RF tag on an environmental side depend on the estimation accuracy. From this constrains, it is not suitable to apply for a general pedestrian's using.

C. Measurement using two dimension marker

A fundamental idea of this method [5] using two-dimensional markers which include position information such as longitude and latitude. Following figure 1 shows a flow of location estimation using two- dimensional markers. This method assumes an environment that is arranged many two-dimensional markers beforehand at the surface of walls, roofs, and floors. When terminal needs to take own location information, a program of terminal take photos automatically in fixed interval, and decoding the marker. This approach has high accuracy of estimation than other methods because of a feature of image processing, however, this method also has a disadvantage that system obtained completely no location information when camera fail to take a marker. Additionally, it is necessary to arrange a large amount of marker in the environment to estimate the position in high accuracy, and this is a problem of the maintenance cost and destroying the scenery etc.

As understood from these features, until recently among methods topic is many in the aspect of cost and estimation accuracy. Therefore, in this study, we examine the method that used radio wave strength of the wireless LAN with a two-dimensional marker together and suggest low-cost and highly position estimate method.

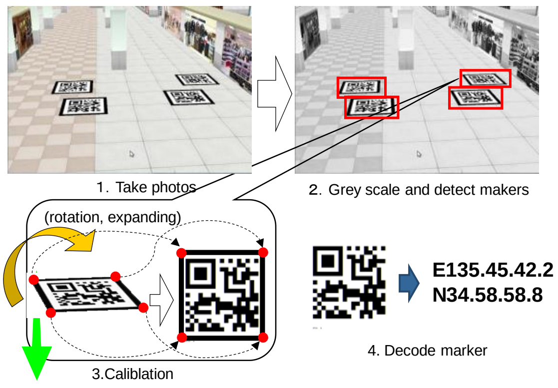


Figure 1. Flow of estimation using two-dimensional marker

III. Proposed Method

The positioning system that we proposed enables the position estimation with high accuracy needing neither a special antenna nor the extra equipment by using the following two techniques together in seamless; (1) A highly accurate, discrete measurement with and a camera and two-dimensional markers that involves the location information, and (2) low accuracy and continuous measurements that uses radio field strength. The following Figure 2 shows the outline of our system. In this method, we assume the environment that many two-dimensional markers which include location information and size information and many WiFi base stations are set up. The camera of a smart phone takes a picture of the environment when measuring, and if marker is taken, the position, the direction, and the passing speed of a smart phone can be acquired by image processing. On the other hand, when a smart phone fails to take markers, radio waves from WiFi base stations are received through the WiFi interface of a smart phone and the position of the smartphone is estimated by using centroid method based on received radio wave strength. The position estimation by the centroid method is obtained from equation (1) of the following. Parameters x and y in equation (1) represents the estimated position, and x_i, y_i represents the position of the ith base station. m_i represents the signal strength received by the smart phone, respectively. However, if two techniques were only simply integrated and using, the dispersion of the position error become higher because of the difference of the positioning accuracy of each technique. Then, we examine the improvement of the positioning accuracy of a smart phone by integrating two techniques in seamless by using the new concept that is called a virtual base station. The virtual base station is an idea to which the positioning accuracy is improved by using the radio wave strength from the virtual base station and radio wave strength from actual wireless base stations together. The flow of the measurement that uses a virtual base station is shown in the following Figures 3. We consider one example situation as follows; a smart phone that took a picture of the marker at time *t-1*, and failed to take a picture of other marker at time *t*, the position of smart phone is able to estimate at near position of marker that is taken at time *t*. Therefore, we assume a virtual base station that is set upon the marker. And the position of the smartphone is estimated by using the centroid method assuming that there is a virtual base station on the marker and using both radio field strength from virtual radio field strength output there and actual base stations together after having lost sight of the marker. As a result, the positioning accuracy increase because it can indirectly use the highly accurate location information acquired from the marker after it loses sight of the marker. However, this method has a problem how to set radio field strength from the virtual base station appropriately that a smart phone receives in this technique. We tackle this problem by the following two methods; (1) move distance estimation by using passing speed that can be calculated with marker; and (2) setup the radio wave strength based of virtual base station appropriately through experiments.

$$(x, y) = \sum_{i=1}^{N} m_i (x_i, y_i) \Big/ \sum_{i=1}^{N} m_i \qquad (1)$$

A. move distance estimation by using passing speed

Moved distance can be calculated by the time difference of taking pictures of the same marker two or more times. Additionally, it becomes possible to calculate the direction of the movement and the speed of a smart phone by measuring the time when taking pictures.

B. setup the radio wave strength based of virtual base station appropriately through experiments

It is necessary to setup the radio field strength of the virtual base station to the value that radio field strength of the base station actually arranged is near the characteristic. Then, an appropriate value is setup by measuring an individual radio wave characteristic with the spectrum analyzer by constructing the experimental environment in the rooftop in the schoolhouse, and arranging wireless WiFi base stations actually in the present study.

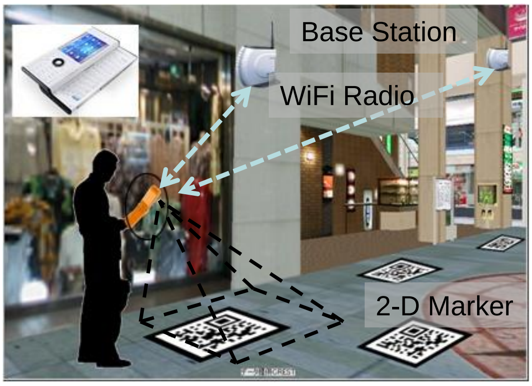


Figure 2. Flow of estimation using two-dimensional marker

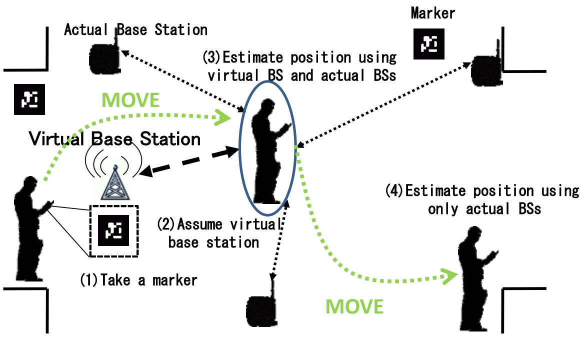


Figure 3. Flow of measurement that uses virtual base station

IV. EXPIMENT RESULTS

The experimental environment was constructed in the rooftop of the schoolhouse, and nine wireless WiFi base stations are arranged as following in the figure 4. And, the radio wave characteristics of individual base stations were measured with the spectrum analyzer. Square markers in figure 4 show two-dimension markers for the comparison proposed method. The results of measured radio field strength from each base station are drawn in the graph of following figure 5. In this graph, the horizontal axis indicates the distance from each wireless base station to the measurement point, and the vertical axis indicates the power of radio wave strength, respectively. Each color of graph corresponds to the each base stations measured data. The following graphs show the result of approximating the function based on these results of measurements. Here, radio field strength of a virtual base station in the present study used the value in which radio field strength in the previous approximation graph from all the base stations was averaged. The moving speed of the terminal can be calculated by using the distance difference and the time difference by taking a picture several times and measuring the same marker as we previously described. The existence area of the terminal can be limited to the area of diameter R that centers on the marker by using the elapsed time after the terminal movement speed and the terminal lose sight of the marker. The radio field strength of the virtual base station can be appropriately set by using this radius R and referring to a previous approximation curve. We experimented on the position estimation that used both the radio wave of a virtual base station and the radio wave of actual base stations to verify the validity of the method of virtual radio wave strength setting of the virtual base station. To evaluate the performance of the proposal method, we compared the positional estimation result by the centroid method that used only radio field strength from actual base stations with the result of the proposal method. The following figures 7 show the result. In the figure 7, the positional estimation results of two methods are shown to two types of walk patterns of a straight advancement movement and a zigzag movement in the centroid method and the proposal method. Here, the point shows estimated positions, and yellow points show estimated positions by the centroid method that uses only the radio wave strength. Moreover, blue points show estimated positions with markers and red points show estimated positions that use a virtual base station, respectively. Green dashes line in this Figure 7(a) shows an actual walking route.

It is understood that the positional estimation accuracy by the proposal method that uses both virtual base station and markers is high from the result of experiments. This is because the proposal method is able to achieve the position estimation in high accuracy by using both a highly accurate measurement with markers and the measurement that uses a virtual base station. Especially, when zigzag walking, accurate position estimation can be achieved by suppressing the influence of the radio wave of the real base stations because the virtual base station functions after terminal loses sight of the marker. Next, we pay attention to the mean value of the positional estimation error margin; the result of the proposal method that used a virtual base station is 1.05m; while the result in the method that used only a simple centroid method is 2.45 meters. From these results, the efficiency of the proposal system on the estimation accuracy of a virtual base station was clarified.

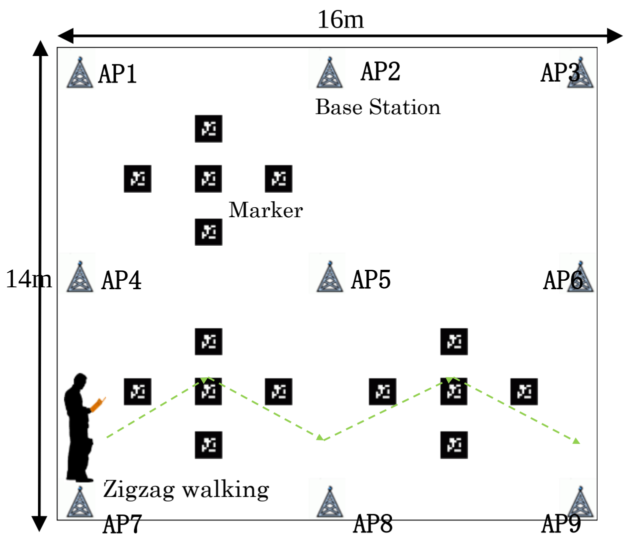


Figure 4. Experimental environment

V. CONCLUSION

In this study, we examined an appropriate setting method of the strength of radio wave of virtual base station necessary to highly accurate measure for the proposed method that use seamlessly two measuring techniques; (1) Measuring with two dimension marker and (2) measuring with base stations radio wave strength. The feature of our proposed method is a new highly accurate indoor measurement method for enabling a continuous, highly accurate measurement by focusing on two individual techniques with a new concept idea called virtual base station; (1) measurement technique based on radio wave strength that can continuously be measured though it is low accuracy, and (2) measurement technique based on the image recognition that can be discrete measured though is highly accurate. However, proposed method has a big issue how to set the radio field strength of a virtual base station appropriately. To address this problem, we examined an appropriate setting method by measuring radio field strength of an actual space based on the result of a measurement. As a result of evaluation experiments to verify the effectiveness of the proposed method, the proposed method in a variety of walking patterns, revealed that it is a very good estimation accuracy compared with existing methods using only the signal strength.

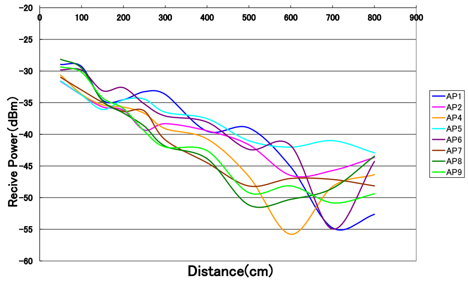


Figure 5. The result of measured radio field strength from each base station

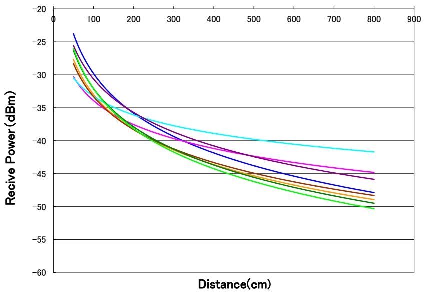
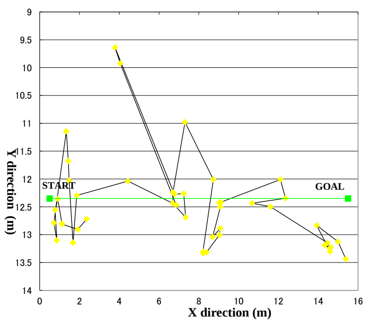
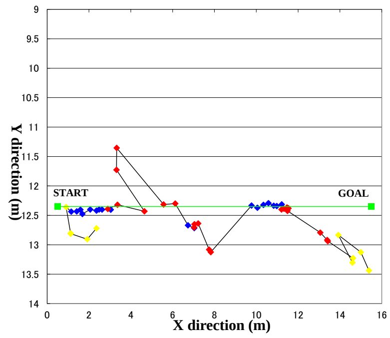


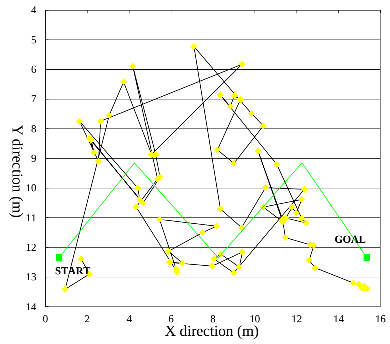
Figure 6. Approximation curve of measured radio field strength from each base station



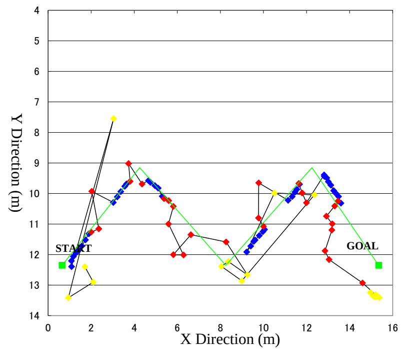
(a) Simple centroid method (straight walking)



(b) Proposed method using virtual base station (straight walking)



(a) Simple centroid method (Zigzag walking)



(b) Proposed method using virtual base station (Zigzag walking)

Figure 7. The result of move history of two method; (a) simple centroid method, and (b) proposed method using virtual base station.

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