A STUDY ON CONTINUOUS POSITIONING METHOD USING INTERLOCKING RFID AND GPS

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ABSTRACT GPS(Global Positioning System) data has a high accuracy at outdoor positioning generally, but its accuracy decreases in the urban areas with dense buildings. Moreover insufficient number of satelllites prevent us GPS positioning at inside of buildings. To complement these shortcomings of GPS, RFID(Radio Frequency IDentification) has been studied on indoor positioning parts. In Ubiquitous environment, LBS(Location Based Service) which can be used anytime and anywhere is an essential component. We use kalman filter to estimate the real location in GPS and RFID handover area. This study's purpose is to make a continuous positioning system using interlocking RFID and GPS.

KEY WORDS: GPS, RFID, Kalman Filter, continuous positioning

1. INTRODUCTION

As the interest in location-based services and ubiquitous environment increases, techniques to determine locations indoors and outdoors are basically demanded for providing various location-based services of good quality. Generally GPS(Global Positioning System) is the most well known wireless positioning system. GPS data has a high accuracy at outdoor positioning but its accuracy decreases in the urban areas with dense buildings and indoors because of the weakness of the positioning signal, NLOS(non-line of sight) and multipath. To complement these shortcomings of GPS, many studies have been conducted about the positioning methods using indoor wireless communication network. Among them, RFID(Radio Frequency IDentification) is highlighted as it is an efficient indoor positioning system. Lionel(2004) present LANDMARC, a location sensing prototype system that uses RFID technology for locating objects inside buildings. Wang(2006) conducted a case study that demonstrated RFID integration into the medical world at one Taiwan hospital. But in most cases these systems were limited to relatively confined areas such as hospital, factory floors and shipping docks because of its expensive costs.

In ubiquitous environment, LBS(Location Based Service) which can be used anytime and anywhere is an essential component. Therefore indoor and outdoor Pedestrian Navigation system with different sensors has been studied actively. Masakatsu(2006) described an embedded pedestrian navigation system composed of a self-contained sensors, the Global Positioning System(GPS) and an active Radio Frequency Identification (RFID) tag system. Jang(2007) used distance of GPS and RFID data's epoch to detect the time of outlier occurrence which determine to change the sensor.

We use GPS outdoor positioning, and in indoor environments where the GPS is unavailable, we use an active RFID tag system placed in key spot areas such as entrances and hallways. In handover area of GPS and RFID, Kalman filter and point-to-point distance method is used to estimate the real location. In this way a continuous positioning system is possible using interlocking RFID and GPS.

2. METHODOLOGY

2.1 Forecast of positioning using Kalman filter

The Kalman filter is essentially a set of mathematical equations that implement a predictor-corrector type estimator that is optimal in the sense that it minimizes the estimated error covariance(G. Welch,2004). We proposed a method of dead-reckoning in the Kalman filter. the related equations are as follows :

$$x(k+1) = Fx(k) + w(k) \text{ (system dynamic model)} \quad (1)$$

$$y(k+1) = Hx(k) + v(k) \text{ (Measurement model)} \quad (2)$$

In the above equations, F and Hx are matrices; k is the time index; x is called the state of the system; y is the measured output; and w and v are the noise. The vector x contains all of the information about the present state of the system, but we cannot measure x directly. Instead we measure y, which is a function of x that is corrupted by the noise v. The variable w is called the process noise, and v is called the measurement noise. We have to assume that the average value of w is zero and the average value of v is zero. At any time k, $w(k)$, and $v(k)$ are independent random variables.

$$K(k) = AP(k)C^T(CP(k)C^T + S_v)^{-1} \quad (3)$$

$$X(k+1) = (AX(k)) + K(k)(y(k+1) - CX(k)) \quad (4)$$

$$P(k+1) = AP(k)A^T + S(w) - AP(k)C^TS(v)^{-1}CP(k)A^T \quad (5)$$

The K matrix is called the Kalman gain, and the P matrix is called the estimation error covariance. $S(w)$ and $S(v)$ are the noise covariance matrices and defined as:

$$S(w) = E(\, w(k)w(k)^T\,) \quad (6)$$

$$S(v) = E\,(\, v(k)v(k)^{T)} \quad (7)$$

where wT and vT indicate the transpose of the w and v random noise vectors, and E(·) means the expected value.

2.2 2-dimensional point-to-point distance method

We use 2-dimensional point-to-point distance method to estimate location from GPS and RFID in the handover area. Figure 1 shows principle of 2-dimensional point-to-point distance method and the related equation is as follows.

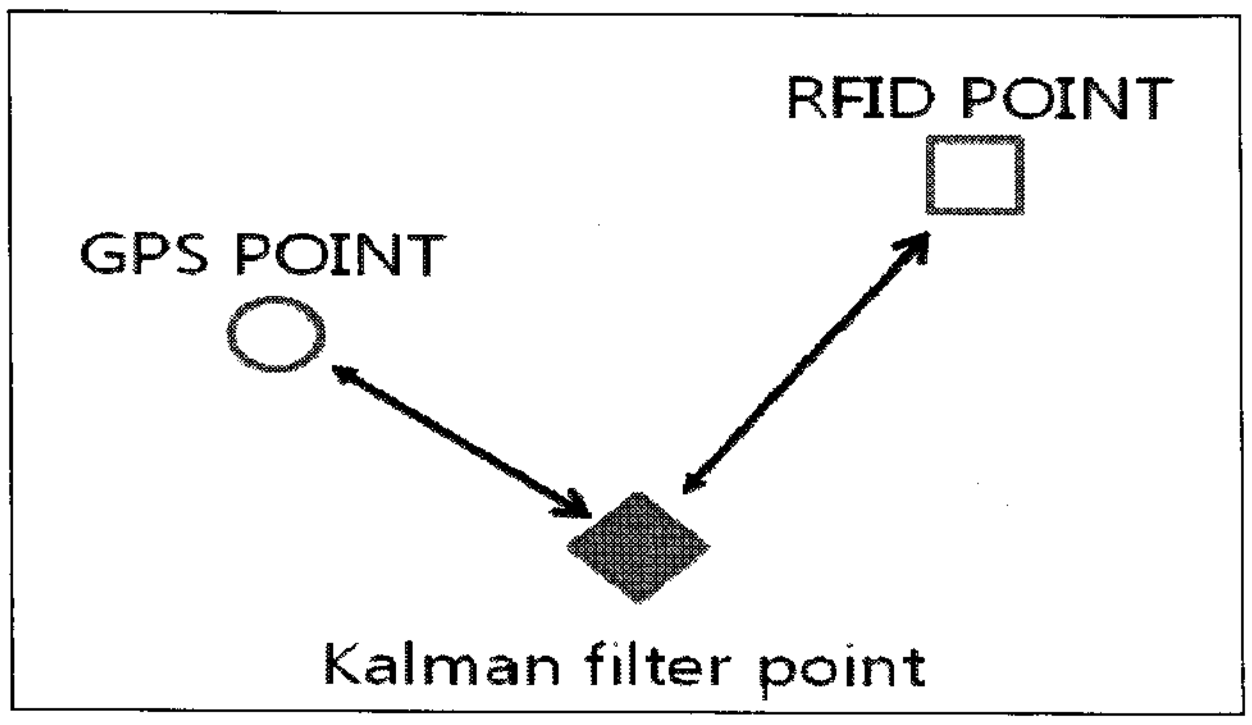


Figure 1. Location estimate

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (8)$$

where x_2 and y_2 are locations using kalman filter x_1 and y_1 are locations using RFID or GPS. After location using kalman filter is calculated, we calculated the distance between location coordinates using kalman filter and GPS, and location coordinates using kalman filter RFID. We compared the results and the smaller one is considered as the real location coordinate.

2.3 RFID system using TDOA Methodology

TDOA is one of the simplest network-based methods and it uses the time it takes for a signal to travel as an indirect method of calculating distance. With a minimum three base stations receiving a signal from a RFID tag, the difference in time when the signals reach each RFID receiver can be used to triangulate the position of the tag. To achieve accurate positioning, the base stations must be precisely synchronized in time.

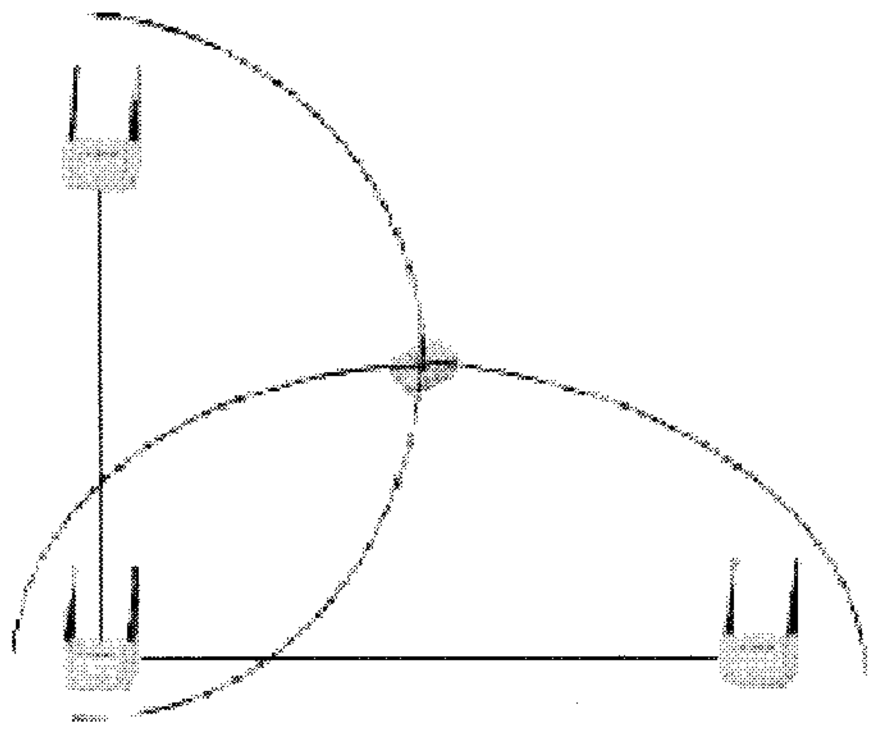


Figure 2. Concept of TDOA

3. RESULTS AND DISCUSSIONS

3.1 Experiment Equipments

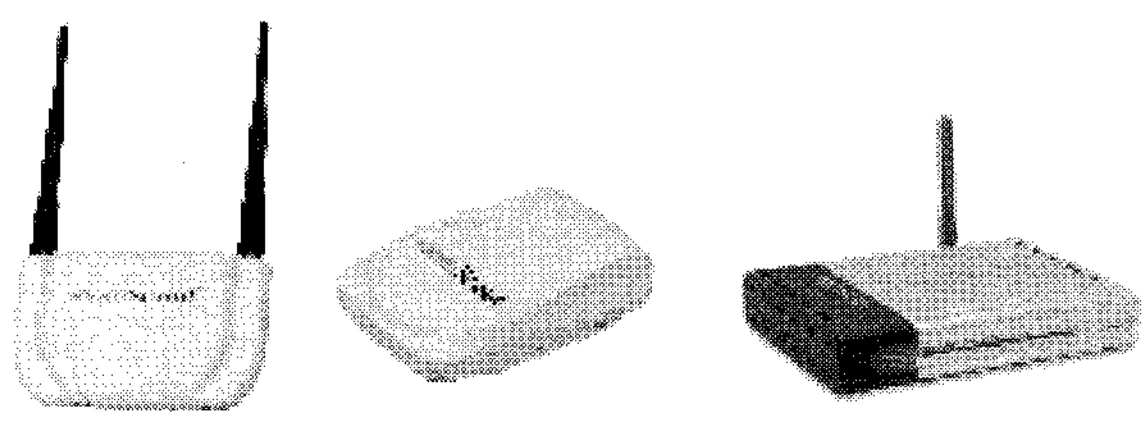
Active RFID is used for indoor positioning and DGPS is used for outdoor positioning in this study.

The GPS module in the system is MobileMapperTM CE which is the handheld GPS mobile mapping device from Thales. It surports software for GIS and many other mobile mapping applications. With its fully integrated 14-channel GPS receiver, MobileMapper CE offers real-time, sub-meter positioning accuracy through WAAS/EGNOS or external differential corrections.

(a) MobileMapper CE (b) Mobile Mapper Beacon

Figure 3. configuration of MMCE

We use active RFID tags and receivers from AeroScout Inc. AeroScout Tags utilize standard Wi-Fi networks to track profile in real time, from indoor location such as hospitals to open outdoor locations. Its outdoor range is up to 200 m (600 feet) and indoor range is up to 80m (240 feet). And its accuracy is 5m at indoor location and 3m at outdoor location.



(a) Receiver (b) Tag (c) Wireless lan

Figure 4. RFID SYSTEM

3.2 Experiments and Analysis

To apply our proposed approach, we selected a common building in Seoul National University. The test area has no hindrance around the building for using DGPS. A man moves from outsides to insides with GPS and RFID tag in his hands. We conducted the same experiments along two different routes. Figure 5 shows test area and number 1 and 2 indicated the test routes.

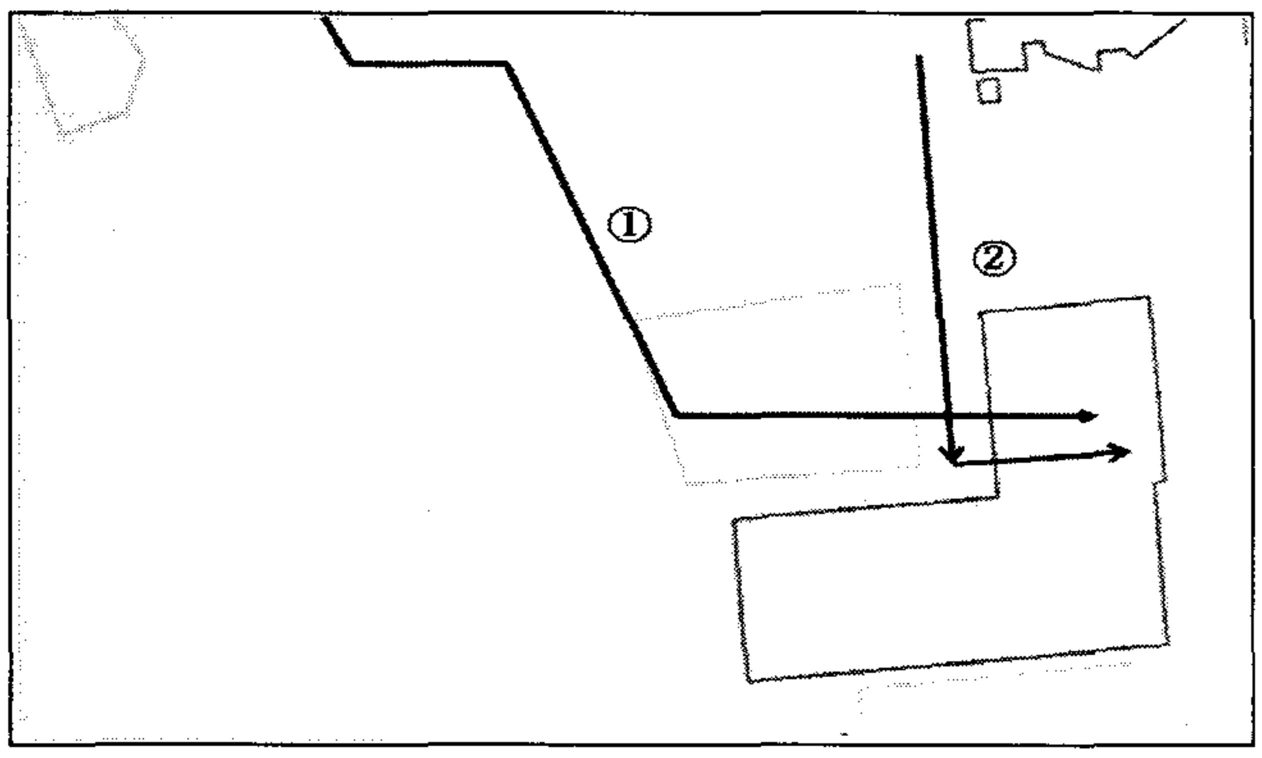


Figure 5. Test Area and Route

Three RFID receivers are placed at the building entrance. Figure 6 shows the arrangement of RFID receivers at building entrance.

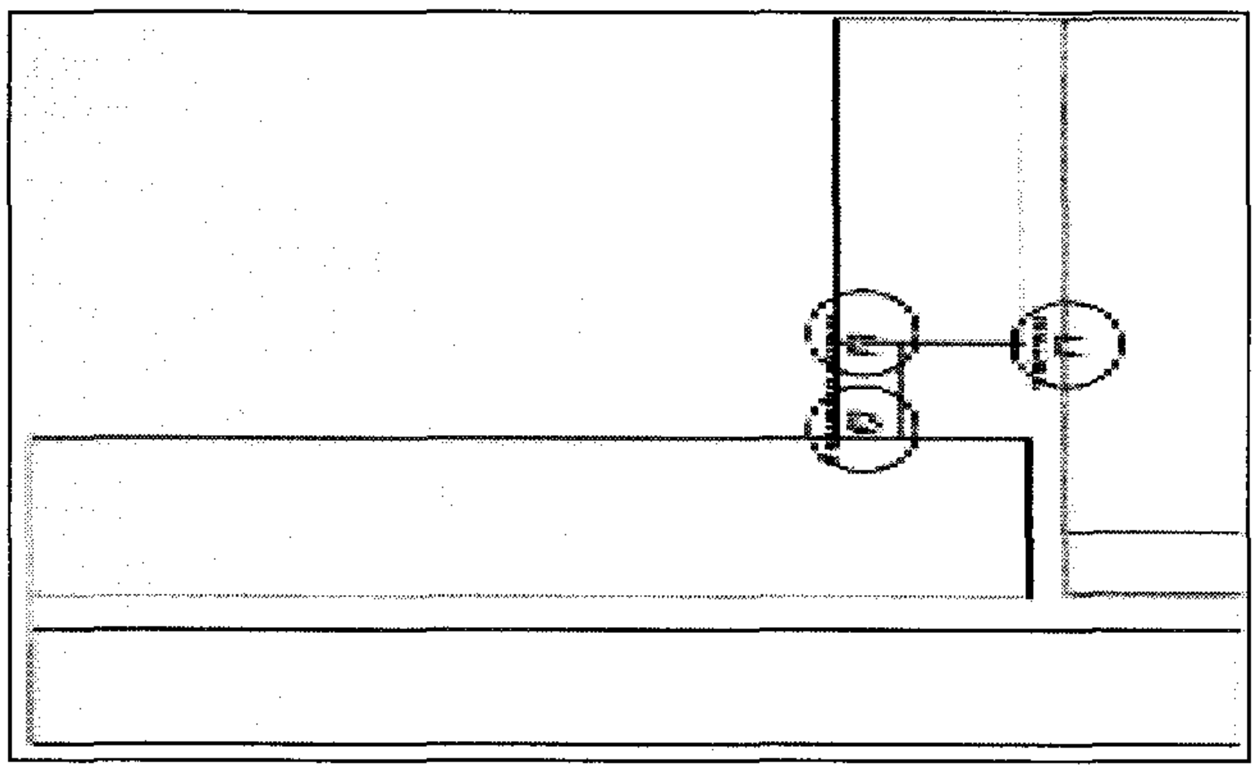


Figure 6. RFID Receiver's Location

Because of the limitation of RFID range, location information of only GPS is acquired in the areas far from the entrance where the RFID receivers are installed. RFID Tag starts to transmit location information to RFID receivers when the man with RFID tag approaches the entrance. From this time to starting time of GPS NLOS, both locations from GPS locations from RFID are acquired near the entrance of the building. In the building no GPS signal can be received, so location information of only RFID is acquired. Locations of a tag using GPS and RFID are shown in the figure 7and 8.

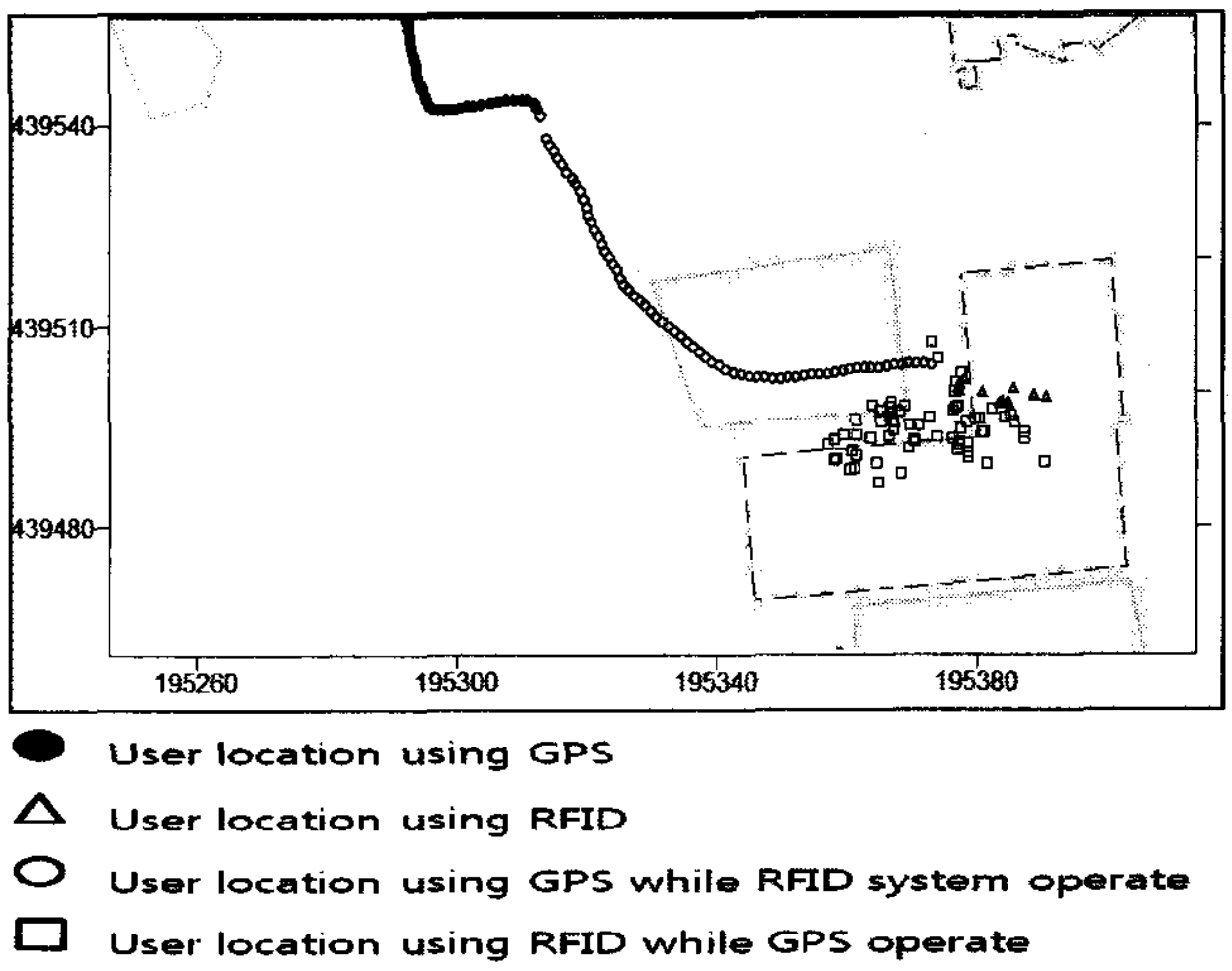


Figure 7. ①Route Result

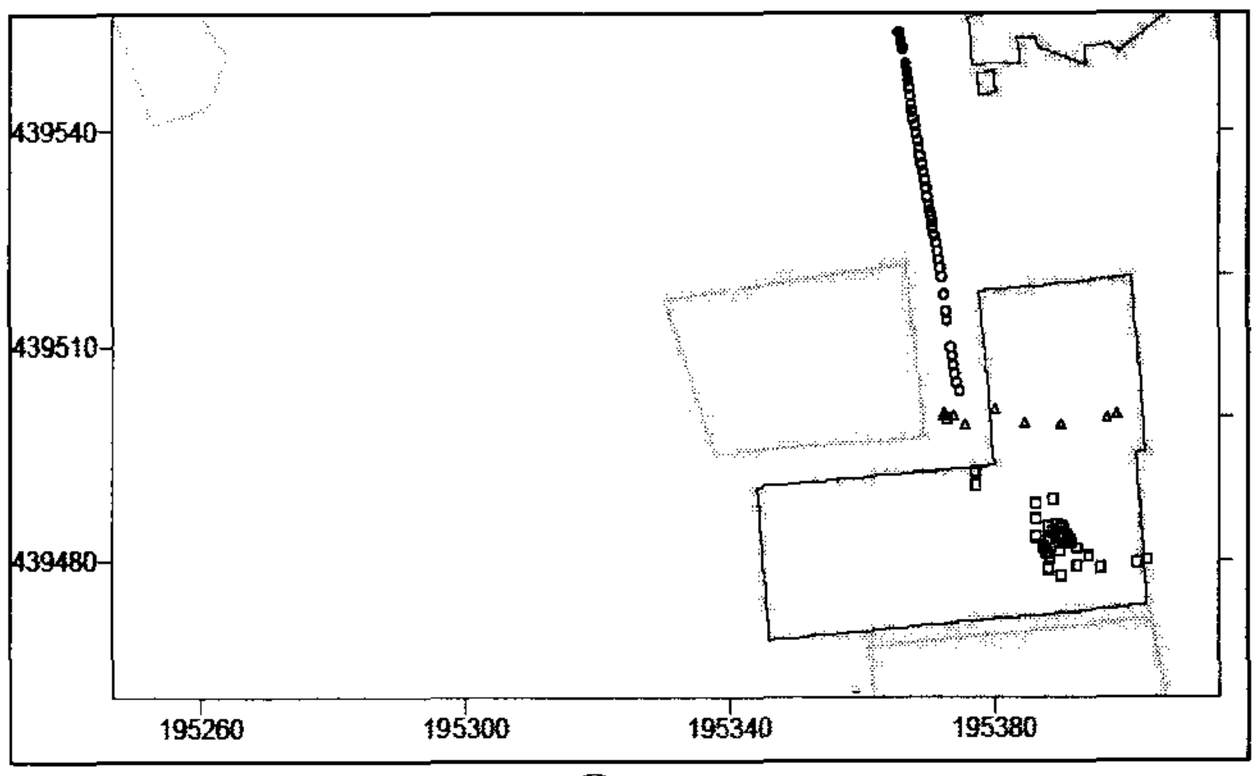


Figure 8. ②Route Result

RFID system has a feature that when RFID tag exists at the outside of receivers-network or far away from receivers, the accuracy of RFID system falls down sharply. Moreover the accuracy of several initial data from RFID is also very low. Near the building, the accuracy of location data from GPS decreases because of the weakness of signal, NLOS and multipath. Therefore we apply Kalman filter and 2-dimentional point-to-point distance method to determine locations of user and to raise the accuracy. We use 2-dimentional point-to-point distance method to compare a location using Kalman filter with location using GPS and location using RFID. We decide the real location which has the smaller distance from the location using Kalman filter. Figure 9 and 10 show the result by our proposed method.

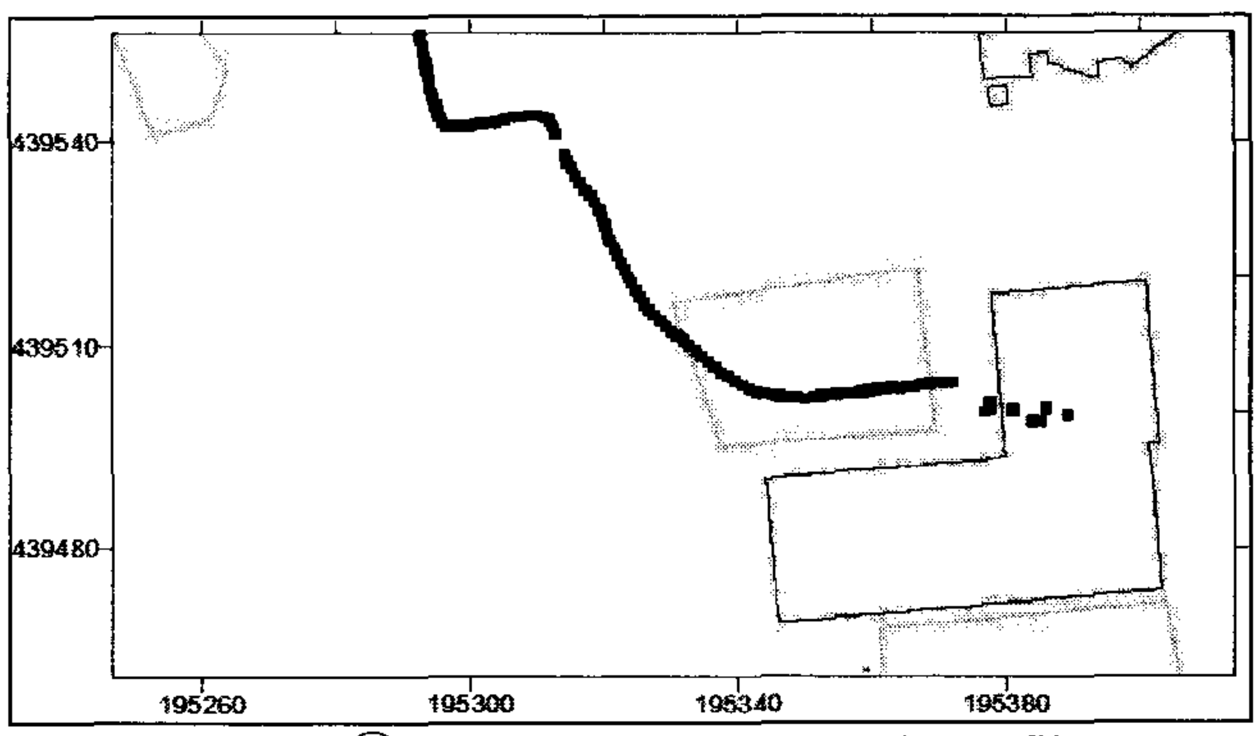


Figure 9. ① Route Result using Kalman filter

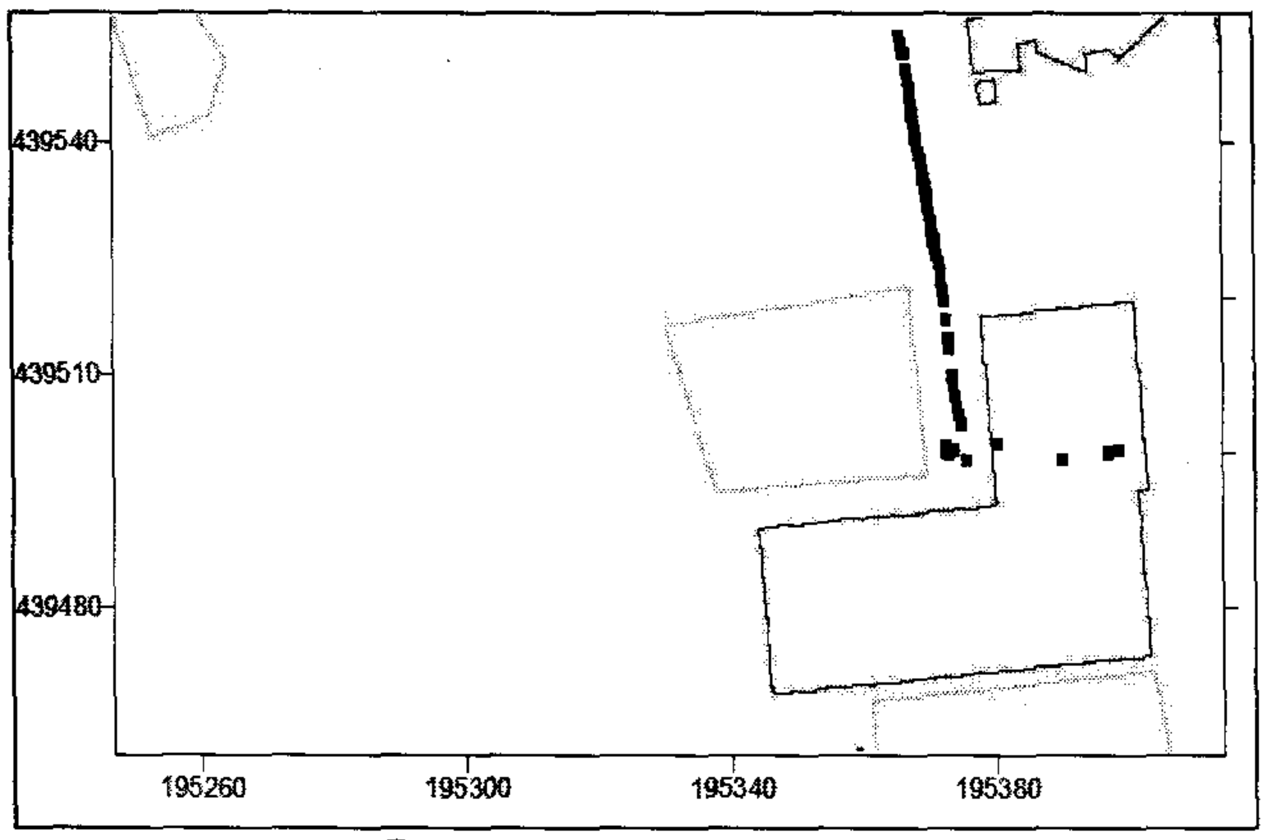


Figure 10. ②Route Result using Kalman filter

It can be seen that some GPS points and RFID points near the building are revised by Kalman filter and distance method. Comparing the real route with that calculated by our method reveals that they are similar and measured values are revised correctly.

4. CONCLUSION

In this paper, we proposed a continuous positioning system using interlocking RFID and GPS. To interlock GPS and RFID, data analysis in handover area is very important. We use Kalman filter and 2-dimensional point-to-point distance method to determine location of a tag and to raise the accuracy in handover area. Our result will be useful to determine accurate indoor and outdoor positioning. Future work will be focused on accuracy assessment in GPS and RFID handover area and positioning method in case that moving direction is changed reversely, from insides to outsides.

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