Feasible Calibration of DOD-Based BLE Beacon for Indoor Localization Application

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***Abstract*— In this paper, the authors proposes a easy calibration of DOD-based BLE beacon system for an indoor localization application. By the proposed calibration method, we can easily recognize the orientation and location of the beacon even though the beacons are roughly installed. The method uses DOD calculated from RSSI of received beacon signals and sensor information of the mobile handset for calibration. The experimental results showed the median angular error of the estimated beacon orientation was 2.8~3.9°. Also, the median distance error of the estimated beacon location was 0.69~0.72 m.**

Keywords*— *Calibration, DOD, RSSI, Sensor Information

I. Introduction

The direction-of-departure (DOD) based localization system performs highly accurate position estimation without pre-learning [1], [2]. However, this technique has problem that the precise information of the anchor position and direction is necessary. In the reference [2], the signals transmitted from Bluetooth Low Energy (BLE) beacons are observed at the receiving terminal, and DOD is estimated. Even though the commercially available BLE receiver can only measure RSSIs, the phase information is reconstructed in this method. After that, DOD is calculated by using MUltiple SIgnal Classification (MUSIC) method, and the receiving terminal determines its position by using triangulation technique using DODs from multiple beacons. Though the location of the receiving terminal can be estimated by using the geometrical information, such as the orientations and locations of the beacons, this information needs to be measured in advance of system operation.

This paper presents a simple calibration method of the orientation and location of the beacons, which is needed for initial installation of the localization system. In the proposed method, when the operator moves with a receiver equipped with sensors, it automatically calculates geometrical information of the beacons. In the following part of this paper, the experimental results of the estimation accuracy of the proposed method are presented.

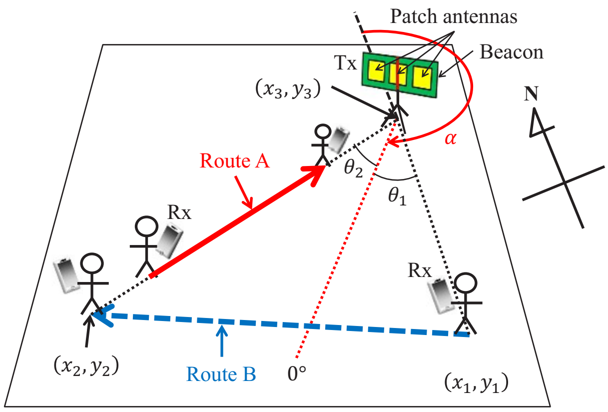

Fig. 1. Outline of proposed calibration method

II. Proposed Calibration Methed

Fig. 1 shows the outline of the proposed calibration method. In the DOD based localization system using only RSSI [2], the accurate orientation and location information of the beacons is needed. The beacon consists of three-element microstrip array antenna, feed network, switching circuit and BLE beacon, and transmits 4 beams with different directivities. In the proposed calibration method, the operator walks a specific route with holding a receiver, and the signal transmitted from the beacon is observed. The receiver is a mobile terminal incorporated with an acceleration sensor and a geomagnetic sensor. The DOD is estimated from the RSSIs of the observed beacon signals. The orientations and the location of the beacons are estimated from the DOD information and the sensor information observed at the mobile terminal.

First, the beacon orientation is estimated. The operator walks straightly to the beacon direction in route A in Fig. 1 during holding the receiver in front of operator's body. The route direction can be easily measured by using the geomagnetic sensor at the receiver, and the receiver also calculates DOD from the beacon at the same time. α is defined as the orientation of beacon with respect to north, and is estimated by the relation between the calculated DOD and the route direction.

Second, the beacon location is estimated. The operator walks transversally to the beacon direction, like Route B in Fig. 1, where it is assumed that the accurate walking direction and distance are available by using the acceleration sensor and the geomagnetic sensor of the receiver. In Fig. 1, θ_1 is the DOD at the measurement start point, θ_2 is the DOD at the measurement end point. (x_1, y_1) is the coordinate at the measurement start point. The beacon location relative to the measurement starting point is estimated. The ideal DOD along the path is calculated from the operator's orientation, moving distance, and the beacon orientation. The location of the beacon is estimated by searching for the location of the beacon with the minimum error between the ideal DOD curve and actually measured curve along the path.

III. EXPERIMENTAL RESULT

Fig. 2 shows experimental environment. This experiment was carried out in an indoor environment, where the size of the tested area was 6 m × 7 m. The beacon (Tx) was located at the corners of the room as shown in Fig. 2. The sleeve antenna was used at the receiver side. The receiver was moved on the route shown in Fig. 2, and measured the transmitted beacon signals and the sensor information at the same time. The operator walked with holding the mobile terminal in front of the body. The BLE-advertising channels, #37, #38, and #39, were used, and their frequency was 2.402, 2.426, and 2.480 GHz, respectively. To estimate the beacon orientation, the receiver was moved along the arrow shown in Fig. 2(a), and the number of the trials was 30 for each of three route directions, 0°, −20° and +20°. To estimate the beacon location, the receiver was moved along the arrow shown in Fig. 2(b), and the number of trials for location estimation was 30 for each of the routes, C and D. The lengths of the route C and D are 3 m and 4 m, respectively. The direction of route C is not orthogonal to the normal direction of the beacon while that of route D is orthogonal.

Fig. 3 shows cumulative-distribution-function (CDF) of the angular error of the estimated beacon orientation. The median angular errors for 0°, −20°, and +20° directions, were 3.0°, 2.8°, and 3.9°, respectively. This means the orientation of the beacon can be actually estimated with fairly high accuracy.

Fig. 4 shows CDF of the distance error in the estimated beacon location. The median values for route C and D were 0.72 m and 0.69 m, respectively. It is found that the beacon location can be estimated within 1 m accuracy in this experiment even when the arbitrary route is used.

IV. CONCLUTION

In this paper, we have proposed a calibration method to recognize the orientation and position of the beacon for the initial beacon installation. The experimental results showed that the proposed method offers highly accurate calibration within the 3.9° orientation error and 0.72 m location error.

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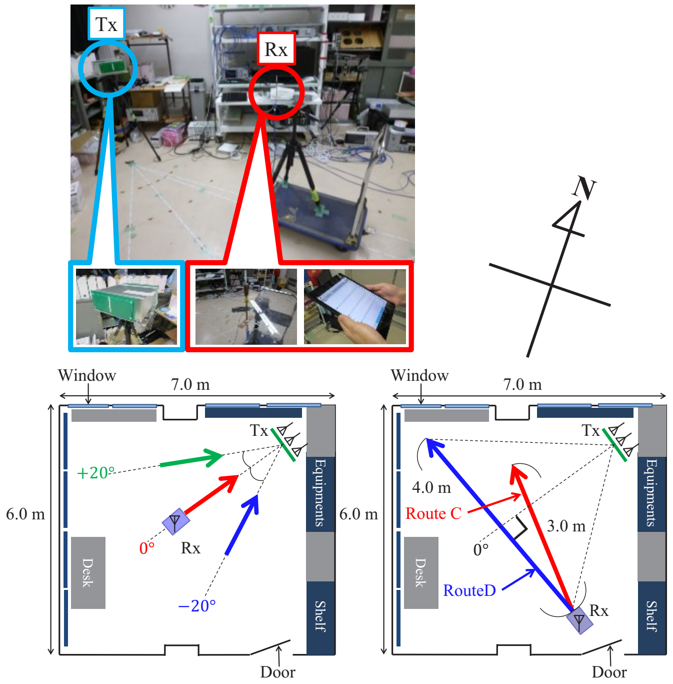

(a) Orientation (b) Location

Fig. 2. Experimental environment.

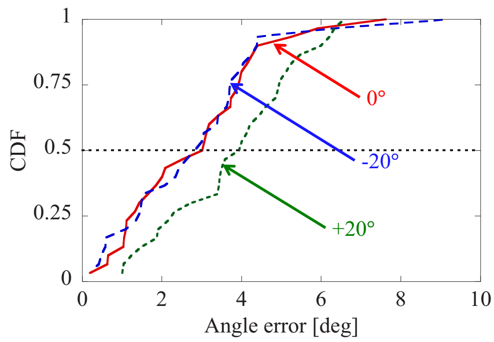

Fig. 3. CDF of orientation estimation error.

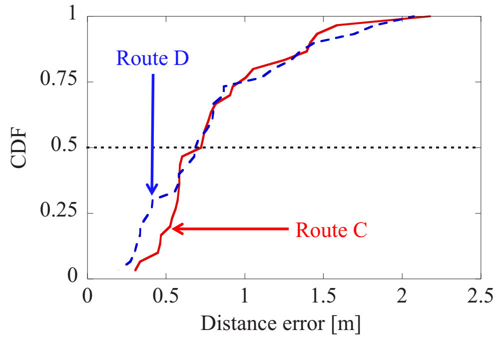

Fig. 4. CDF of location estimation error.

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