Development of Precise Indoor Location System Using Multi-directional Beacon

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Abstract—This paper proposes a precise indoor positioning system using multi-directional beacons. The proposed multi-directional beacon has several directional antennas that transmit radio signals. The position and direction of the pedestrian and the vehicle can be estimated using the received signals of the antennas. When transmitting radio waves from multiple directional antennas, the received signal of the antenna close to the receiver is generally strongest, and the received signal of the antenna in the opposite direction is weakest. By using this point, the position of the receiver can be obtained more precisely. Using the PDR and map matching as an auxiliary, seamless positioning can be performed in the indoor space. To verify the performance of the proposed positioning system, we conducted an appropriate experiment.

Keywords—CLOBER; Beacon; Smartphone; RSS; PDR

I. INTRODUCTION

Since the development of smartphones, the demand for indoor location information has increased. Accordingly, several indoor positioning techniques have been developed. The existing smartphone-based indoor positioning technologies studied include Multi-lateration, Fingerprinting, Pedestrian Dead Reckoning (PDR), Geomagnetic Map, and Beacon. Multi-lateration is a technique for estimating the location of a smartphone using distance measures estimated from the received signal strength [1]. The fingerprint technique compares the pre-measured radio wave map at each location in the room with the current received signal strength [2]. Both methods have the advantage of being able to take advantage of existing wireless infrastructure and to be positioned to the maximum extent that wireless infrastructure is provided. However, since a wireless communication system compatible with a smart phone is mainly used in an ISM band having a large amount of interference, it is sensitive to a channel environment and has a disadvantage of poor positioning accuracy. PDR is a method of accumulating the position of a pedestrian using the footsteps and directions of a pedestrian estimated by a IMU sensor [3]. This method has an advantage that the position of the pedestrian can be continuously provided for a short time. However, since the position error is accumulated depending on the time and the moving distance, it is not suitable for long time operation. The method using the geomagnetism map is a technique for determining the position of the smartphone by comparing the geomagnetism map measured at each position of the room with the currently measured geomagnetic sensor value as in the Fingerprinting technique [4]. This method does not guarantee accuracy because it is likely to cause errors due to magnetization of geomagnetic sensor or geomagnetic interference sources in pedestrians or vehicles. Finally, in the case of beacons, it is a method of determining the position of a smartphone by determining the degree of proximity to the smartphone using the received signal strength [5]. Beacons have the advantage of minimizing channel interference and radio interference. However, there is a disadvantage in that the positioning accuracy and the positioning range are inversely proportional, so there is a cost disadvantage that many beacons must be installed to guarantee both the position accuracy and the positioning range.

In this paper, we propose Cross-shaped Location BEacon Radio (CLOBER) to solve the problem of existing beacon. CLOBER is an RF beacon for precise indoor positioning, and transmits radio waves in various directions using a multi-directional antenna. It is possible to extend the positioning range while maintaining positioning accuracy by using this, and it is possible to judge at least which zone is within the appropriate radio interference environment. We also studied fusion with PDR and Map Matching to realize a seamless positioning system at minimum cost.
II. CLOBER BASED LOCALIZATION

A. Principle of CLOBER

CLOBER has a multi-directional antenna and can estimate precise indoor positioning information and traveling direction information. As shown in figure 1, this multi-directional antenna is designed so that the directional antenna is arranged in a cross shape, that is, in four directions. And transmits a signal having a different address for each antenna. After receiving these signals from the smartphone, the direction of the smartphone is determined from the beacon using the received signal strength measured by the smartphone. If all directional antennas transmit the same signal strength, the signal strength of the directional antenna towards the smartphone is generally measured the most and the signal strength of the directional antenna towards the opposite direction of the smartphone is measured the weakest.

Experiments were performed to verify the assumptions defined above. Bluetooth Low Energy (BLE) based CLOBER was installed on the ceiling as shown in figure 2. Then, the vehicle with the smartphone is moved from antenna 1 to antenna 2. The location of the smartphone was calculated using the IR-UWB Two Way Ranging (TWR) measurement [6]. Figure 3 is a graph of CLOBER signal while moving. In this graph, when the smartphone is close to the antenna 1, the signal of the antenna 1 is large. When the smartphone is close to the antenna 2, the signal of the antenna 2 is large. That is, it proves that the assumptions defined above are correct.

After determining the direction in which the smartphone is located from the beacon by comparing the signal strengths of the respective antennas, the position from the beacon can be defined using distance measurements estimated from the signal strength of the nearby antenna. If there is an error in the measurement direction or distance due to radio interference, the accuracy can be determined by comparing with the measured value from the adjacent beacon. If the accuracy of positioning results can be defined, only accurate measurements can be fused with the PDR to provide more accurate indoor positioning results.

Also, by monitoring the direction of the smartphone from the beacon for a certain period, it is possible to estimate the progress direction information, that is, the direction in which the smartphone has passed the beacon.

Figure 4 is a photograph of the proposed CLOVER, which is implemented to transmit radio waves with different addresses in four directions as suggested above.
A typical wireless communication system compatible with smart phones is Wi-Fi and BLE. Wi-Fi and BLE measurement results are different from those provided by smartphones. If you scan with Wi-Fi, it will return the measured result for about 2 ~ 4 seconds at a time. If you scan with BLE, it will return the measured result for about 0.1 second. If a smartphone in a car driving a parking lot at 20 km / h is scanned for 3 seconds with Wi-Fi, it is difficult to apply it to a real-time indoor car navigation system because it moves about 16m when performing a scan. Therefore, if it is necessary to perform real-time indoor precision navigation, it is appropriate to implement it as BLE.

III. FUSION WITH PDR AND MAP MATCHING

In previous studies, CLOBER, PDR, and map matching techniques were designed as shown in figure 5. The experiment was about the performance of Wi-Fi CLOBER, PDR, and map matching in an indoor environment. Wi-Fi CLOBER and digital map were produced for this experiment. And walking experiment was performed in the experimental environment. The trajectory of the pedestrian for the experiment is shown in figure 6. [7]

IV. CONCLUSION

In this paper, we can estimate the precise position and direction using CLOBER. If CLOBER, PDR and map matching are used appropriately, it is possible to provide the minimum cost of indoor precision positioning results in real time. If the indoor precision positioning results are provided in real time, we expect to be able to provide indoor pedestrian route guidance, sightseeing guide, parking guide, and in-car search service in large buildings such as large hospitals, large marts and public institutions. Future research will focus on BLE CLOBER and PDR fusion filters and map matching.

REFERENCES