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An Analysis of the Optimal Placement of Beacon in Bluetooth-INS Indoor Localization

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Abstract.

The placement of Bluetooth beacon has immediate impact on the accuracy and stability of indoor positioning. Affected by the shelter of building and human, Bluetooth shows uncertain spatial transmission characteristics. Therefore, the scientific deployment of the beacon nodes is closely related to the indoor space environment. In the study of positioning technology using Bluetooth, some scholars have discussed the deployment of Bluetooth beacon in different scenarios. In the principle of avoiding shelter, general method deploys Bluetooth beacon under the triangular grid staggered deployment with 6-8 meters of equal spacing. Although this kind of method can provide good positioning accuracy with a high-density placed Bluetooth, it also increases the cost and cause waste of resources. Bluetooth combined with INS (Inertial Navigation System) is a new trend in indoor positioning and has good performance in application. However current research mostly focused on the fusion of the two techniques during the positioning process, but rarely considers the influence of combinatorial positioning on the deployment of Bluetooth beacon. Also the study of the placement of Bluetooth has not yet fully utilized the characteristics of INS.

This paper proposes an optimal Bluetooth beacon nodes placement method using the minimum number of beacons in the general space scene, making
full use of the characteristics of the high efficiency of Bluetooth triangulation and the high accuracy of inertial navigation positioning in short-range. First of all, this paper studies the effective positioning distance of Bluetooth signal in corridor, room and other indoor space environment, analyzes the accuracy attenuation characteristics of INS and the relationship between pedestrian activity and INS. Next, constructs the indoor positioning spatial data model, obtains the probability distribution of common locating area by collecting the characteristics of pedestrian trajectory distribution in video surveillance data. Then, based on the experimental analysis, the paper summarizes the set of rules for the deployment of Bluetooth beacon nodes, and proposes the optimal scheme of Bluetooth beacon nodes under different positioning accuracy intervals. Finally, compared to current Bluetooth positioning system of large-scale shopping malls in the same accuracy, this method has wider applicable area using same number of Bluetooth beacons and same applicable using fewer beacons. In the next study, in order to improve the universality of the deployment method, we will carry out experiments in different space scenes.

Keywords. Indoor Positioning, Bluetooth, Bluetooth Placement, INS

1. Introduction

Nowadays, with the growing demand of LBS, indoor positioning is requested to get a higher stability, precision and less difficulties to deploy. Bluetooth positioning technology can measure short distance with safety and reliability, also provide small range positioning with an accuracy of 1~3m. Bluetooth devices are small, easy to integrate in the PDA, PC and mobile phones, so it is easy to promote. For customers who have mobile devices integrated with Bluetooth, the Bluetooth indoor positioning system can determine the location of the device as long as the Bluetooth function of the device is turned on. The use of this technology for indoor short-range positioning is easy to find equipment. Compared to several other popular indoor positioning methods, low-power Bluetooth 4.0 standard indoor positioning method have advantage in low cost, simple deployment plan, fast response.

Many scholars have studied Bluetooth positioning technology because it is an important part of indoor positioning technology. The existing basic Bluetooth positioning technology is divided into two categories, fingerprint positioning and triangulation positioning. Bluetooth fingerprint, just like fingerprint for human being, is unique Bluetooth signal collection in specific position. Once the Bluetooth positioning system find a similar Bluetooth fingerprint comparing to Bluetooth fingerprint library, the system can provide the position of device using coordinates in the fingerprint database.
This method can achieve a very high accuracy, but it may cost a lot of resources in fingerprint library establishment and fingerprint matching. Comparing to the high cost of Bluetooth fingerprint positioning, Bluetooth triangular positioning has a lower cost and easier to realize. Bluetooth use signal strength to measure the distance between device and Bluetooth beacons, lower signal strength means the device is far from the beacon. The Bluetooth signal strength is inversely proportional to the beacon distance, and the distance between the signal acquisition point and the Bluetooth beacon can be estimated based on this characteristic. To ensure that the distance measurement has a good result during the positioning processing, it is necessary make a suitable Bluetooth beacons placement plan based on Bluetooth signal transmission characteristics. In the present study, in order to achieve better positioning effect, the Bluetooth beacon is often arranged as a very small lattice, this layout can cover the positioning area and make it easier to support high accuracy positioning, but this placement method is too expensive to apply in large areas. Therefore, based on the study of INS navigation experiment and the pedestrian indoor trajectory, this paper obtains the probability distribution of the pedestrian trajectory in the common locating area. Then we can narrow the indoor localization task area and get a Bluetooth beacon deployment plan which satisfies the requirement of pedestrian trajectory distribution.

2. Bluetooth triangulation

RSSI (Received Signal Strength Indication), indicates the distance from the Bluetooth beacon to the device (Chawathe, S. S. 2008), but RSSI can’t distinguish distance when the device is too far from the beacon. In order to get specific distance, an attenuation model is promoted like formula (1)

\[ P = A - 10n \log(d) \]  

(1)

\( P \) represents the value of the receiver RSSI at the distance from the transmitter \( d \), \( A \) represents the RSSI value at the reference distance of 1 m, and \( n \) is the path loss factor.

Figure 1 shows that the RSSI of Bluetooth is related to the distance, and the distance measurement does not work if the distance is more than 10 m.
3. Bluetooth-INS Analysis

Bluetooth positioning results are discrete points, and inertial navigation is a continuous track point, the fusion method can obtain a better performance than single source positioning method. During the analysis of the pedestrian trajectory in the interior space video, we find that the trajectory of the pedestrian is regular, that is, people are more inclined to choose the route that is shorter and avoid the obstacle. For example, select a smaller turning radius at the corner or walk in the middle of the road rather than against the wall. Therefore, in order to improve the utilization of Bluetooth beacons, Bluetooth beacon layout should be placed around the pedestrian trajectory. There are many methods to evaluate the positioning points, this paper, refers to the GPS horizontal accuracy factor HDOP, studies the quality of Bluetooth beacon placement. We tested some Bluetooth beacon deployment methods, Figure 2 shows a larger coverage area using 3 sites. It also suggested that in the corner, placement method like Figure 3 will cover more pedestrian activity area.

Figure 1. Bluetooth RSSI decline with distance.
4. Bluetooth Beacon Placement Rules

(1) No obstacle between the beacon and the terminal. After the penetration of walls and other obstacles, Bluetooth signal will have a sharp decline, and the data could not support the positioning. Therefore, Bluetooth beacon placement method should consider avoiding the wall and other indoor ob-
stacles. Also, around the bearing columns, corners, etc. we should increase the density of the Bluetooth beacon.

(2) The distance between terminal and beacons should be apposite, too far and the RSSI lost the ability to measure distance. According to signal characteristic of Bluetooth, a spacing of 4-6m is an optimal Bluetooth placement plan.

(3) The optimal positioning point is the triangular center, that is, the angle among terminal and the beacons is equal (Piwowarczyk, K., Korbel, P., & Kacprzak, T. 2013).

5. Conclusion

In this paper, we study the spatial transmission characteristics of Bluetooth signals and the characteristics of indoor pedestrian trajectories based on inertial navigation. Then, we study the optimal beacon deployment scheme in Bluetooth room, and take a series of experiments on the quality evaluation of different deployment schemes. Finally, summarize the basic rules of Bluetooth beacon deployment.

The next step is to design the deploy algorithm based on the Bluetooth deployment rules proposed in this paper. Given the Bluetooth parameters and indoor space data, the model will automatic make the optimal deployment plan. In addition, design verification test to examine the Bluetooth placement method.

References
