AN INDOOR SPACE PARTITION METHOD AND ITS FINGERPRINT POSITIONING OPTIMIZATION CONSIDERING PEDESTRIAN ACCESSIBILITY

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ABSTRACT:

Fingerprint positioning method is generally the first choice in indoor navigation system due to its high accuracy and low cost. The accuracy depends on partition density to the indoor space. The accuracy will be higher with higher grid resolution. But the high grid resolution leads to significantly increasing work of the fingerprint data collection, processing and maintenance. This also might decrease the performance, portability and robustness of the navigation system. Meanwhile, traditional fingerprint positioning method use equational grid to partition the indoor space. While used for pedestrian navigation, sometimes a person can be located at the area where he or she cannot access. This paper studied these two issues, proposed a new indoor space partition method considering pedestrian accessibility, which can increase the accuracy of pedestrian position, and decrease the volume of the fingerprint data. Based on this proposed partition method, an optimized algorithm for fingerprint position was also designed. A across linker structure was used for fingerprint point index and matching. Experiment based on the proposed method and algorithm showed that the workload of fingerprint collection and maintenance were effectively decreased, and poisoning efficiency and accuracy was effectively increased

1. INTRODUCTION

It is estimated that over 80% of people's activity is carried out in indoor space. Indoor positioning and navigation has a wide rage demand and huge application prospect. The most common positioning signal used for out-door area is GPS. But indoor environment has many signal-shelters such as walls, which leads GPS signal hard to be used for precise indoor positioning and navigation. There have been many researches on indoor positioning, such as 2D code scan, UWB, RFID, sound wave and lamplight, terrestrial magnetism and electromagnetism, WIFI and Bluetooth etc. (Powell, 2009; Lifang ZHAO, 2015). Among these methods, signals like WIFI and Bluetooth can support Mobile Terminals like smartphone so no extra hardware equipment is required for end users. With the advantages of low cost, mall size, easy to integrate, easy to popularize, WIFI and Bluetooth are widely used for indoor positioning (Lifang ZHAO, 2015). The two main methods in WIFI and Bluetooth positioning are RSSI (Received Signal Strength Indication) triangle localization method and fingerprint positioning method (Rui ZHOU, 2013; G. Chen, 2013). We take the fingerprint positioning method to conduct our study.

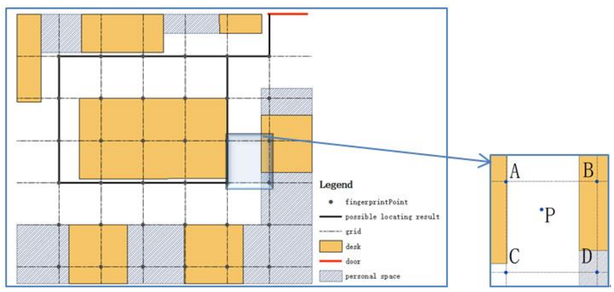
The general process of fingerprint positioning is as follows.

Step 1: Divide position area evenly into grids M*N, vertexes of grids are fingerprint collection points (as shown in figure 1); set signal transmitting terminal (anchor node) in the area.

Step 2: Measure the signal strength (RSSI) of every fingerprint points, and build fingerprint database.

Step 3: When real-time positioning, based on current time RSSI and use fingerprint matching algorithm, such as k－Nearest Neighbor (KNN) (Khadayari, 2010), to get the nearest fingerprint point, which should be the positioning result.

Step 4: Output the positioning result to position terminal.



(a) (b)

Figure 1 General Fingerprint Grid and Positioning Result

However, this might lead some unreasonable results. For example in Figure 1 (a) the possible locating route (bold black lines) is just in the edge of desks, in Figure 1 (b) while the mobile terminal is actually in point P, the positioning results may be fingerprint point A to D, among them A and B are points where pedestrians cannot reach. Some researchers used map matching to solve this problem (Rui ZHOU, 2013), but unreasonable results still not be avoided.

This paper considered the spatial feather and pedestrian accessibility of the indoor space, proposed an space subdivision

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method for pedestrian positioning, and optimized the fingerprint positioning algorithm based on the subdivision method.

Following this introduction of this paper, we introduced the indoor space partition method considering pedestrian accessibility in section2, and presented the optimization algorithm in section4. We gave the experiment results and analyse in section4 and conclusions in section 5.

2. INDOOR SPACE PARTITION METHOD CONSIDERING PEDESTRIAN ACCESSIBILITY

2.1 Indoor Space Classification Considering Pedestrian Accessibility

Indoor positioning is a coupling process that constrained by multiple factors including spatial constraint. Considering characteristics of indoor pedestrian activity, this paper subdivides indoor space into pedestrian accessible area and pedestrian unreachable area.

Definition 1: Indoor space = pedestrian accessible area, pedestrian unreachable area.

Among them,

Definition 2: Pedestrian accessible area = passageway-like area, non-passageway-like area, link area.

Link area is used to express correlation between passageway-like area and non-passageway-like area

Among them,

Definition 3: non-passageway-like area = personal space, public activity area.

2.2 Partition Based on Indoor Space classification

Different kinds of area have different constrains to pedestrians. So we use different methods to subdivide different space based on space classification described in above section.

2.2.1 Partition Methods of Passageway-like Area: In Passageway-like area, we first extract skeleton line, then take feature points of the skeleton as fingerprint points, thus to get the centre line along the passageway.

(1) Extract skeleton line of passage way: Use the method of Delaunay triangulation network to extract skeleton line. Firstly, disperse the boundary of indoor passageway polygon into spatial point group, then build Delaunay triangulation network, use the side boundary midpoints of triangles as the nodes of axle wire, link these nodes in order, get axle wires of passageway. Then build topology route based on these axle wire to get the connected route network skeleton lines.

(2) Mesh dissection considering characters of skeleton line: After get skeleton lines of route network, select turning points as feature points, assign it as fingerprint points. Thus we got the n Meter (n is the interval resolution of grid) interval grid along the direction of passageway. Between these feature points, divide equally to set fingerprint points on skeleton lines and control the interval of grid in n meter too.

(3) Multi-scale Mesh dissection: Considering different width of passageway, set different scale of grid.

R<=n 1 line (axle wire);

R > n 2*R/n-1 lines;

R (meter) is the radius of passageway, n (meter is the interval resolution of grid).

When radius of passage is less than n, one axle wire is enough to meet the need of positioning; When R>n, passageway is wider, bisectrix between boundaries should be extract as skeleton lines of fingerprint, together with the axle wire. Then subdivide grid and get fingerprint points with the methods described above.

2.2.2 Partition Method of Non-passageway-like Area: Including personal space and public area, with following methods:

(1) Personal space: Personal work space usually is private space of the owner. We set the central point of polygon as the fingerprint point and the polygon as the grid. If required, we can define the personal space as public area.

(2) Public area: Public area is usually more broad and do not have a clear direction like passageway. We subdivide the public area into grid. The resolution of grid can be changed according to the size of the space and other requirements.

3. INDOOR POSITIONING ALGORITHM OPTIMIZATION

With the method described in section 2, we can reduce the number of fingerprint. Now we propose a fingerprint data index structure based on across linker, to improve the computational efficiency of fingerprint matching.

3.1 Data Structure of Fingerprint Point

Traditionally, one fingerprint point is described with location ID, RSSI attribute and coordinates. The matrix is stored in linear data structure (Hang GUO, 2014; Ying ZHOU, 2007). Each time we scan the fingerprint point we need to traverse the whole database. The efficiency of fingerprint matching will be reduced due to large number of fingerprint when the size of position area is big. To solve this problem, we proposed the across linker structure:

Definition 4: Across linker fingerprint point data storage structure(arc) = (location number, RSSI data, up point, down point, left and right point, spatial data).

With this structure we furtherly define data structure of indoor space,

Definition 5: Passageway area L= (location number, {[link point]},{[vertex point]})

Definition 6: Un-passageway-like area S= (location number, data, {[link point]},{[vertex point]})

Definition 7: Link point C= (location number, {[linking location number]})

Every element in the across linker has a precursor and a subsequence in both vertical and horizontal axis. That is to say, each element at the same time belongs to rows and columns. When scanning, it does not need to traverse the entire database, only need to traverse the surrounding points.

3.2 Build Fingerprint Point Index

According to definition 1, indoor space can be represented as ({[L]}, {[S]}, {[C]}). After subdividing, we use the following step to build fingerprint data index.

(1) traverse IS, to each L,S and C, build ARC_L, ARC_S, ARC_C;

Nested traverse each fingerprint point in L,S and C.

Fingerprint point Fi=(xi, yi), if next point whose x > x_i, then this point is the right point, otherwise is the left point; if next point y> y_i,, then this point is the up point, otherwise is the down point.

(2) Unite ARC_L, ARC_S and ARCc

Traverse link point C and its fingerprint point F_C.

Traverse ARC_L, ARC_S and ARCc, if they have same fingerprint data F_C, then build connections.

3.3 Optimized Positioning Process

The process includes 3 step: off-line preparing, building index , on-line positioning:.

Step 1: Off-line Data Preparing

(1) Classify indoor space(s) basing on pedestrian accessibility. S= {[(passageway, link area)],[(personal space, link area)],[(public area, link area)]}

(2) Using methods presented in section 2.2, subdivide S.

(3) Collect fingerprint data and use the storage format that presents in definition 7 to storage them. Build general fingerprint point gather G={(general fingerprint point)}.

Step 2: Building Index

Based on the fingerprint date collected in stage Step1, using algorithm descriped in section 3.2, build data set of across linked list: ArcG = {(across linked fingerprint point)}.

Step 3: On-line Positioning

Assuming current position is P0, next measured fingerprint data is Li, time difference is t and current speed is v (use average walk speed, or use gyroscope and speedometer in cellphone to get current speed), give specific process as follow.

(1) decide scan depth L: assume n=(t*v/length of one cell in grid), n shows prospected working distance: if n<2, then L=1; else, if n<3, then L=2; And By This Analogy until L= length of the link list.

(2) start with P0, nest traverse all the point around P0 in L depth, calculate their distance to Li.

(3) choose a nearest point as candidate point set(Goal) of positioning result.

(4) if there is more than one point in Goal, using gyroscope , speedometer and current direction to further calculate position relation between Li and points in Goal, choose a point that has a same direction as position result.

4. EXPERIMENT

4.1 Experiment area

We used the office of one company in Nanjing, as shown in figure 2, with 18 meters in length and 14.5 meters in width. The total working area is about 300 square meters.

4.2 Space Classification, Grid Subdividing and Fingerprint Points setting

Using the method described in section 2.1 to classify the experiment area into passageway, personal space and public area. The passageway includes aisles in conference room, computer room and staff office area. We use 1m as the interval resolution of grid for passageway. Personal space includes president staff office, vice president office and CTO office, using geometric centre as fingerprint point. Public area is the broad area in the middle, set 77 fingerprint points with 1m interval. Figure 3 shows the classification and the fingerprint points.

Figure 2 Layout of Experiment Area

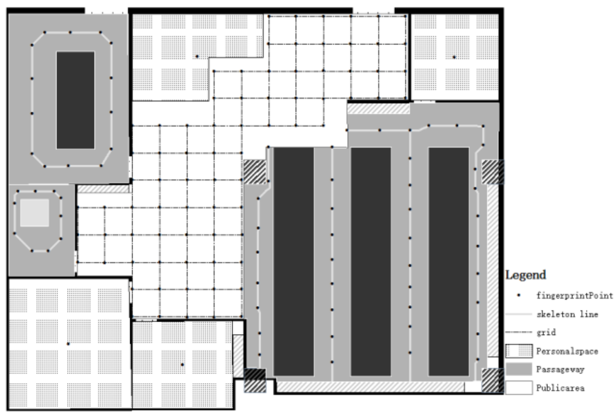

Figure 3 Space Classification and Fingerprint Points

4.3 Positioning Results and Analysis

Set 13 IBEACON Bluetooth devices in the room, use smartphone HUAWEI G750-T01 as mobile terminal. In each fingerprint point collect 2000 sample data. Filter the RSSI data with Kalman filter to reduce the signal noise. Then save the RSSI data of each fingerprint got from anchor nodes into the fingerprint point database.

The experimenters entered the area from the entrance, and walked in different area. The positioning results were recorded, as shown in figure 4.

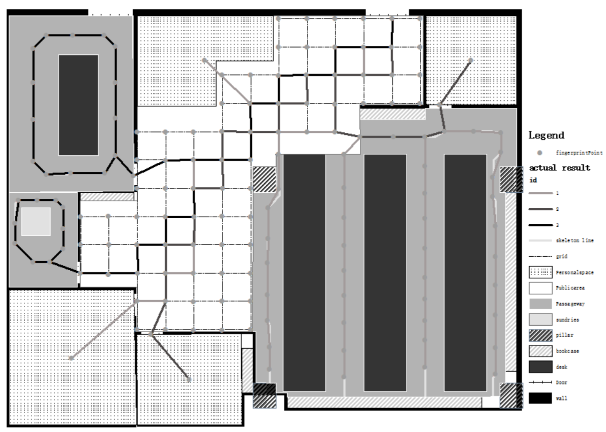

Figure 4 Positioning Results

We tested the computing efficiency and positioning accuracy by walking in a same route for many times, as shown in figure 5.

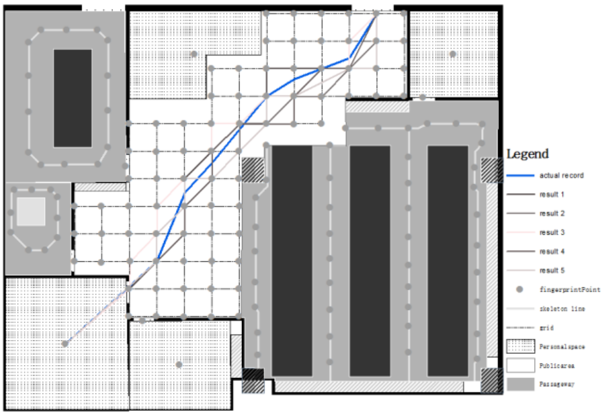

Figure 5 Efficiency and Accuracy Testing Results

As shown in figure 4, figure 5 and table 1, the mobile terminal was located at fingerprint points in the passageway area, at real position in the public area, and at geometric centre in the personal space. All these results are reasonable. And the number of fingerprint point had been reduced around 30% that greatly increased the overall efficiency.

Methods	Number of fingerprint point	Matching times for one point	Result reasonability
Traditional method	210	210 times	/
This paper's method	146	1-4 times	100%

Table 1 Compare with Other Methods

5. CONCLUTION

This paper was aimed at increasing the efficiency and accuracy of indoor position with fingerprint method, proposed an indoor space partition method considering pedestrian accessibility. Base on this method, optimized the algorithm of fingerprint positioning by using across link list as data structure. Experiments indicate that this proposed method can reduce the number of fingerprint point in the positioning area, and increase the efficiency and accuracy of indoor positioning.

Furtherly, we will try to use mobile terminal trajectory analysis technics for real time discovering and reacting to the indoor environment change.

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