Manage the Data from Indoor Spaces: Models, Indexes & Query Processing

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Overview

1. **1. Outlines**

2. 2. Indoor Space Models & Applications

3. 3. Indoor Data Cleansing

4. 4. Indoor Movement Analysis

5. 5. Appendix

About This Work...

Probabilistic Threshold k Nearest Neighbor Queries over Moving Objects in Symbolic Indoor Space. [3]
B. Yang, H. Lu, and C. S. Jensen.

- Published in year 2010 at the *EDBT* conference.
- **Minimal Indoor Walking Distance**(MIWD) along with algorithms and data structures are proposed for distance computing and storage.
- Effective object indexing structures, also capture the uncertainty of object locations.
- On this foundation, Probabilistic threshold kNN (PTkNN) query is studied.

Motivation

- Indoor positioning makes it possible to support interesting queries over large populations of moving objects.[4]
  - shopping mall, airports, office buildings
  - kNN queries over indoor moving objects enables the detection of approaching potential threats at sensitive locations in a subway system
- Existing kNN techniques in spatial and spatialtemporal databases are inapplicable in indoor spaces.
  - complex entities and topologies
  - indoor positioning techniques differ fundamentally from outdoor GPS, low sampling frequency and accuracy

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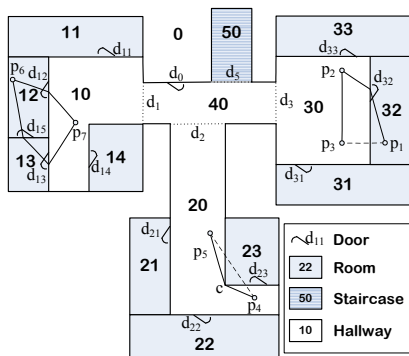The mapping $Rooms$ determines the room of an indoor position:

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The mapping $Doors$ maps a room to the doors that connect the room to an adjacent room:

$$Doors : \Sigma_{rooms} \rightarrow 2^{\Sigma_{doors}} \tag{2}$$

Minimal Indoor Walking Distance

- intra-room obstructed distance, termed as d_o. E.g., $d_o(p_2, p_3) = |p_2 p_3|$ and $d_o(p_4, p_5) = |p_4 c| + |c p_5|$.
- if in different rooms, it should take into account the doors connecting the rooms. E.g., $d_{MIN}(p_1, p_2) = |p_1 d_{32}| + |d_{17} p_9|$.
- if there exist several paths, the correct path should be the shortest one. E.g., $d_{MIN}(p_6, p_7) = |p_6 d_{12}| + |d_{12} p_7| \neq |p_6 d_{15}| + |d_{15} d_{13}| + |d_{13} p_7|$.

Minimal Indoor Walking Distance

Doors Graph is capable of retrieving the connecting doors between two rooms, which is convenient for computing MIWD.

Doors Graph

- $G_d = \{D, E, l_{weight}\}$
- $D = \Sigma_{doors}$ is the set of the vertices
- E: An edge $\{d_i, d_j\}$ exists if a room rm exists in Σ_{rooms} such that $\{d_i, d_j\} \subseteq Doors(rm)$
- $l_{weight} : E \to R$ assigns to an edge the obstructed distance between the two doors as $d_o(d_i, d_j)$

Minimal Indoor Walking Distance

All **door-to-door shortest path distances** can be computed and recorded in a hash table $D2D$ according to the Doors Graph.

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2.3 Probabilistic Threshold k Nearest Neighbor Queries over Moving Objects in Symbolic Indoor Space

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$$\text{D2D} : \{(d_p, d_j)\} \rightarrow R, \quad d_p, d_q \in \Sigma_{doors}. \tag{3}$$

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$$d_{MIN}(d_p, d_q) = d_o(p, d_p) + \mathrm{D2D}(d_p, d_q) + d_o(d_q, q) \tag{4}$$

where $d_p(d_q)$ ranges over all doors of room $p(q)$.

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Algorithm 1 d_{MIW}(Position p, Position q)

1: **if** $Rooms(p) = Rooms(q)$ **then**
2:     $minDist \leftarrow d_o(p, q)$;
3: **else**
4:     $minDist \leftarrow +\infty$
5: **for** each door d_p in $Doors(Rooms(p))$ **do**
6:     **for** each door $d_q \neq d_p$ in $Doors(Rooms(q))$ **do**
7:        $l \leftarrow d_o(p, d_p) + d_o(d_q, q) + D2D(d_p, d_q)$
8:        **if** $l < minDist$ **then**
9:           $minDist \leftarrow l$;
10: **return** $minDist$;

it is possible to adapt this notion of distance to accommodate other semantics. For example, a person might prefer a longer indoor path that passes as few doos as possible.

References

📄 C. S. Jensen, H. Lu, and B. Yang.
Graph model based indoor tracking.
In *MDM*, pp. 122–131, 2009.

📄 B. Yang, H. Lu, and C. S. Jensen.
Scalable continuous range monitoring of moving objects in symbolic indoor space.
In *CIKM*, pp. 671–680, 2009.

📄 B. Yang, H. Lu, and C. S. Jensen.
Probabilistic threshold k nearest neighbor queries over moving objects in symbolic indoor space.
In *EDBT*, pp. 335–346, 2010.

📄 Jensen, Christian S and Lu, Hua and Yang, Bin
Indoor-A New Data Management Frontier.
In *IEEE Data Eng. Bull.*, pp. 12–17, 2010.

The End. Thanks :)