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

Huan Li

Database Laboratory, Zhejiang University

lihuancs@zju.edu.cn

March 21, 2016

Overview

1 1. Outlines

2 2. Indoor Space Models & Applications

3 3. Indoor Data Cleansing

4 4. Indoor Movement Analysis

5 5. Appendix

Aims

- To give a brief review introduction to *indoor data management techniques*.
- To review a series of works in this field, including their proposed *models*, *indexes* and *algorithms*.
- To discuss how to bring those advanced theoretical contents into practice.

About This Work...

Probabilistic Threshold k Nearest Neighbor Queries over Moving Objects in Symbolic Indoor Space. [4]
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.
  - 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

Minimal Indoor Walking Distance

Minimal Indoor Walking Distance(MIWD) is used as the distance metric in indoor spaces.

Minimal Indoor Walking Distance

Minimal Indoor Walking Distance(MIWD) is used as the distance metric in indoor spaces.
The mapping $Rooms$ determines the room of an indoor position:

Minimal Indoor Walking Distance

Minimal Indoor Walking Distance(MIWD) is used as the distance metric in indoor spaces.

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

$$Rooms : positions \rightarrow \Sigma_{rooms} \tag{1}$$

Minimal Indoor Walking Distance

Minimal Indoor Walking Distance(MIWD) is used as the distance metric in indoor spaces.
The mapping $Rooms$ determines the room of an indoor position:

$$Rooms : positions \rightarrow \Sigma_{rooms} \tag{1}$$

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

Minimal Indoor Walking Distance

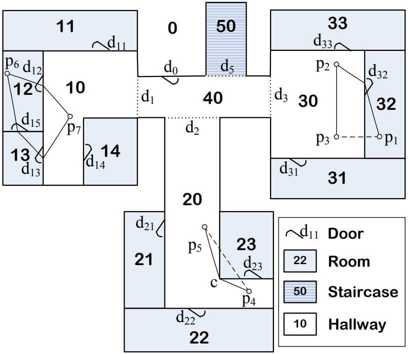
Minimal Indoor Walking Distance(MIWD) is used as the distance metric in indoor spaces.
The mapping $Rooms$ determines the room of an indoor position:

$$Rooms : positions \rightarrow \Sigma_{rooms} \tag{1}$$

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

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

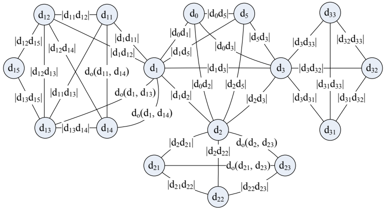
Minimal Indoor Walking Distance



- 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 $\mathrm{D2D}$ according to the Doors Graph.

Minimal Indoor Walking Distance

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

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

Minimal Indoor Walking Distance

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

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

Consequently, for two positions p and q in different rooms.

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.

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

Consequently, for two positions p and q in different rooms.

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

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

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

```
if Rooms(p)=Rooms(q) then
    minDist ← d_o(p, q);
else
    minDist ← +∞
for each door d_p in Doors(Rooms(p)) do
    for each door d_q ≠ d_p in Doors(Rooms(q)) do
        l ← d_o(p, d_p) + d_o(d_q, q)+ D2D(d_p, d_q)
        if l < minDist then
            minDist ← l;
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

M. F. Worboys.
Modeling indoor space.
In *ISA*, pp. 1–6, 2011.

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.

References

H. Lu, B. Yang, and C. S. Jensen.
Spatio-temporal Joins on Symbolic Indoor Tracking Data.
In *ICDE*, pp. 816–827, 2011.

H. Lu, X. Cao, and C. S. Jensen.
A foundation for efficient indoor distance-aware query processing.
In *ICDE*, pp. 438–449, 2012.

X. Xie, H. Lu, and T. B. Pedersen.
Efficient distance-aware query evaluation on indoor moving objects.
In *ICDE*, pp. 434–445, 2013.

The End. Thanks :)