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

Huan Li

Database Laboratory, Zhejiang University

lihuancs@zju.edu.cn

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Overview

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3. 3. Indoor Data Cleansing
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1. Outlines

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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.

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About This Work...

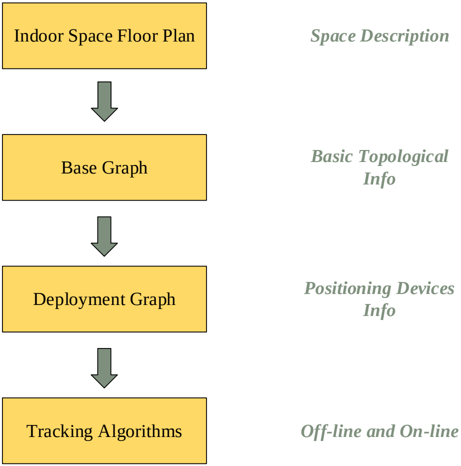
Graph Model Based Indoor Tracking. [2]
C. S. Jensen, H. Lu, and B. Yang.

- Published in year 2009, *MDM* conference.
- A pioneering work that introduces base graph model to indoor data management.
- Detailed tracking algorithms are designed for RFID-based positioning.
- Easy to understand, with comprehensive concepts.

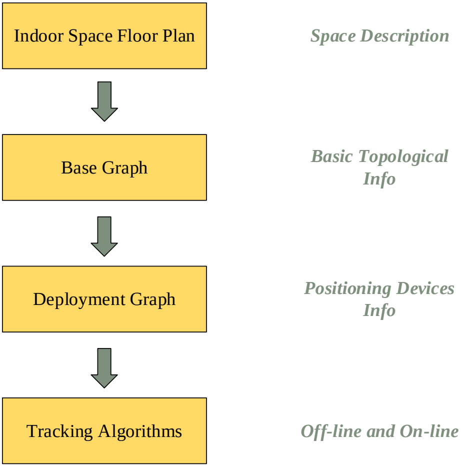
Motivation

- We are spending most of our time in indoor spaces
  - Office building, University, Shopping Centers, etc.
- We cannot use GPS-based tracking indoor movements
  - Indoor navigation and route guidance (museum)
  - Flow analysis
    - how do people use the indoor space $\rightarrow$ important in pricing of advertisement space in store rental
- We can use other technology...
  - Wi-Fi, Infrared, Bluetooth or RFID
  - This paper is focusing on RFID, since it is now mature and effortless
  - RFID tags are cheap and RFID reader are expensive

Idea


Indoor Space Floor Plan
Space Description
Base Graph
Basic Topological Info
Deployment Graph
Positioning Devices Info
Tracking Algorithms
Off-line and On-line

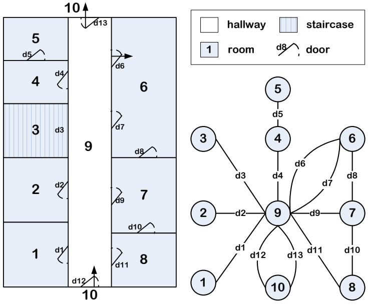
Idea



Goal: Improve indoor tracking accuracy from a data management perspective, to capture where a particular object can be at a particular time.

Base Graph Model

By capturing the essential connectivity and accessibility, **Base Graph** describes the topology of a floor plan of a possibly complex indoor space.



(a) Floor Plan (b) Connectivity Base Graph

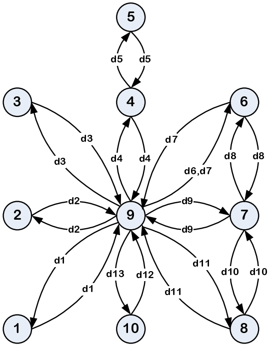
Connectivity Base Graph

a labeled, undirected graph.

- $G_{conn} = \{V, E_d, \Sigma_{door}\}$
- V: each separate partition is represented as a vertex
- E_d: each door is captured as an edge
- Σ_{door}: a set of edge labels that represent connections

Base Graph Model

Accessibility Graph is constructed to represent the movement permitted by doors or connections.



Accessibility Graph

a labeled, directed graph.

- $G_{accs} = \{V, E, \Sigma_{door}, l_e\}$
- V: the set of vertices
- E: the set of directed edges, i.e., $E = \{\langle v_i, v_j \rangle | v_i, v_j \in V \wedge v_i \neq v_j\}$
- l_e: a function that maps edges to subsets of the set of doors, i.e., $l_e : E \rightarrow 2^{\Sigma_{door}}$

Base Graph Model

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The *Doors Mapping* is defined as:

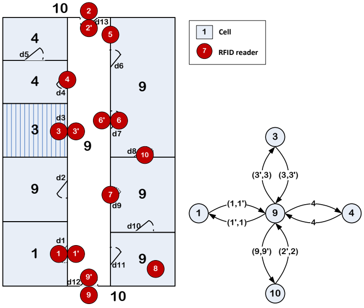
$$Doors : \Sigma_{door} \rightarrow Line\ Segments \tag{2}$$

RFID Deployment Graph Model

- RFID based proximity analysis
  - RFID readers deployment may cover only part of the space, or it may be capable of only detecting some movements in the space.
  - assume that all RFID readers have disjoint activation ranges.
- Types of RFID readers
  - **Partitioning Readers** partition the indoor space into cells in the sense that an object cannot move from one cell to another without being observed.
  - **Presence Readers** simply observe the presence(and non-presence) of tags in their activation ranges.

RFID Deployment Graph Model

Vertices represent cells. A directed edge indicates that one can move from one cell to another without entering other cells, which is detected by a corresponding partitioning reader.



(a) Readers Deployment (b) Readers Deployment Graph

RFID Deployment Graph

a labeled, directed graph.

- $G_{RFID} = \{C, E_r, \Sigma_{reader}, l_e\}$
- C: the set of the vertices
- E_r: An edge is an ordered pair $\langle c_i, c_j \rangle$ of distinct vertices from C
- l_e maps an edge to a partitioning reader (pair), i.e., $E_r \rightarrow 2^{\Sigma_{reader}} \cup 2^{\Sigma_{reader} \times \Sigma_{reader}}$

RFID Deployment Graph Construction

Each cell created by partitioning readers corresponds to one or more base graph partitions.

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$$\begin{aligned} \mathit{Mapping}\ 1 : \Sigma_{reader} \rightarrow \{(loc, range, flag) | loc \in R^2 \wedge \\ range \in (0, d_{max}] \wedge flag \in PAR, PRE\} \end{aligned} \tag{4}$$

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A mapping of readers to the cells that their activation ranges intersect is introduced:

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$$Mapping\ 2 : \Sigma_{reader} \rightarrow 2^C \tag{5}$$

Motivation

Scalable Continuous Range Monitoring of Moving Objects in Symbolic Indoor Space. [3]

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

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

Spatio-temporal Joins on Symbolic Indoor Tracking Data

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A Foundation for Efficient Indoor Distance-aware Query Processing

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Efficient Distance-aware Query Evaluation on Indoor Moving Objects

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References

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

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

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

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

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

The End. Thanks :)