CrowdX: Enhancing Automatic Construction of Indoor Floorplan with Opportunistic Encounters

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Introduction

- Automatic Construction of Indoor Floorplan

- Opportunistic Encounters
  - Bluetooth
  - Audio
  - PDR

- Advantage
  - not restricted by sparse landmark distribution
  - not rely on motion pattern or conscious motion

Outline

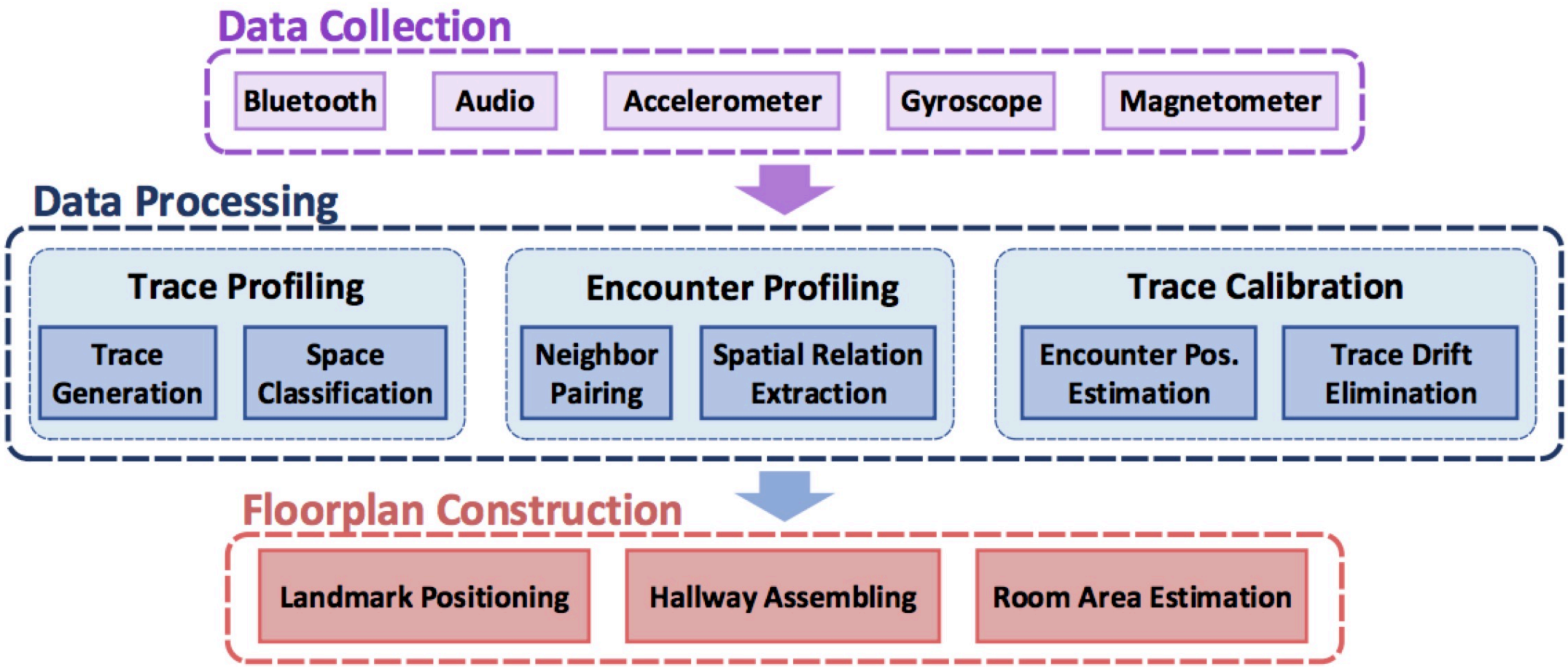


Fig. 1. The system overview of CrowdX.

Outline

- Trace Profiling
- Encounter Profiling
- Trace Calibration

Trace Profiling

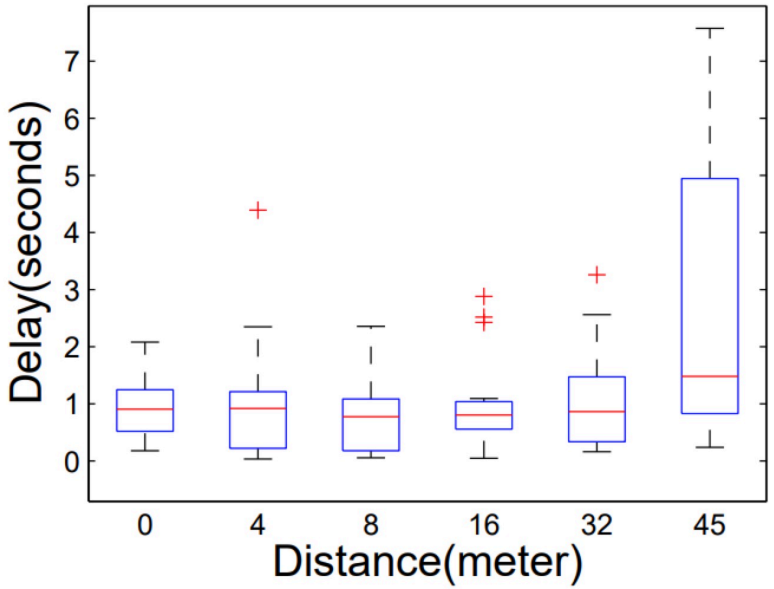
- Trace Generation
- Space Classification
  - Step Periodicity
  - Motion Change Frequency

Outline

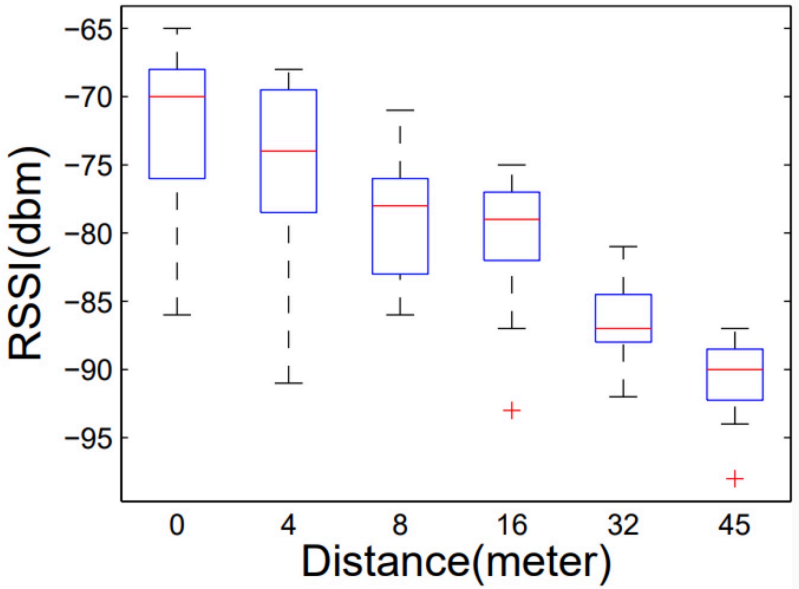
- Trace Profiling
- Encounter Profiling
- Trace Calibration

Encounter Profiling

- Neighbor pairing
  - large discovery range
  - low latency



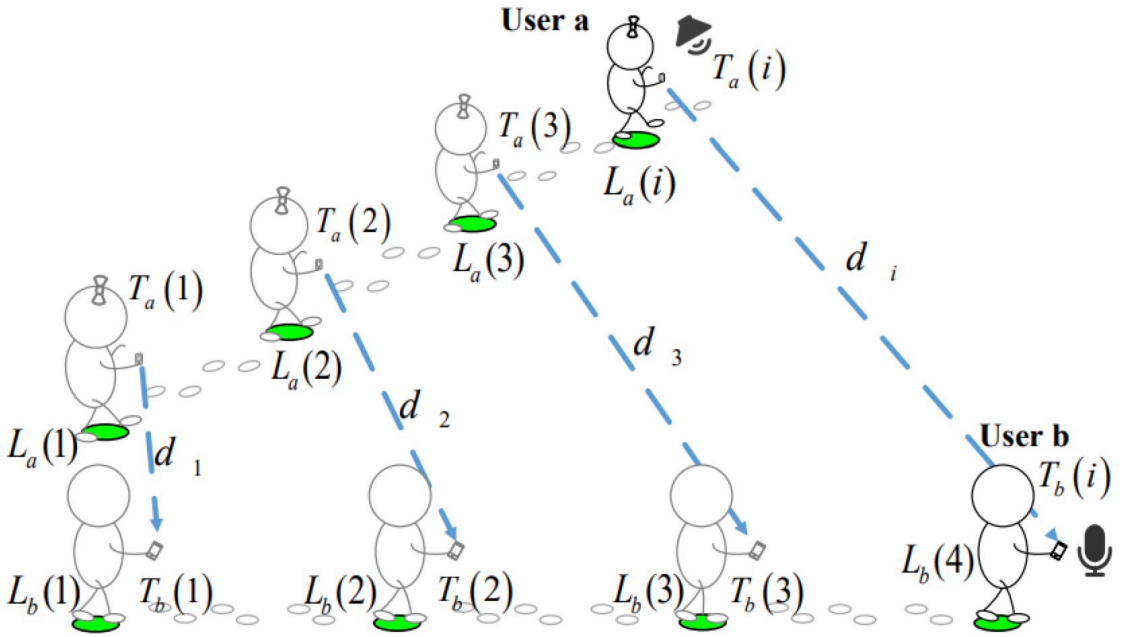
(a) Neighbor discovery delay



(b) RSSI vs. Distance

Encounter Profiling

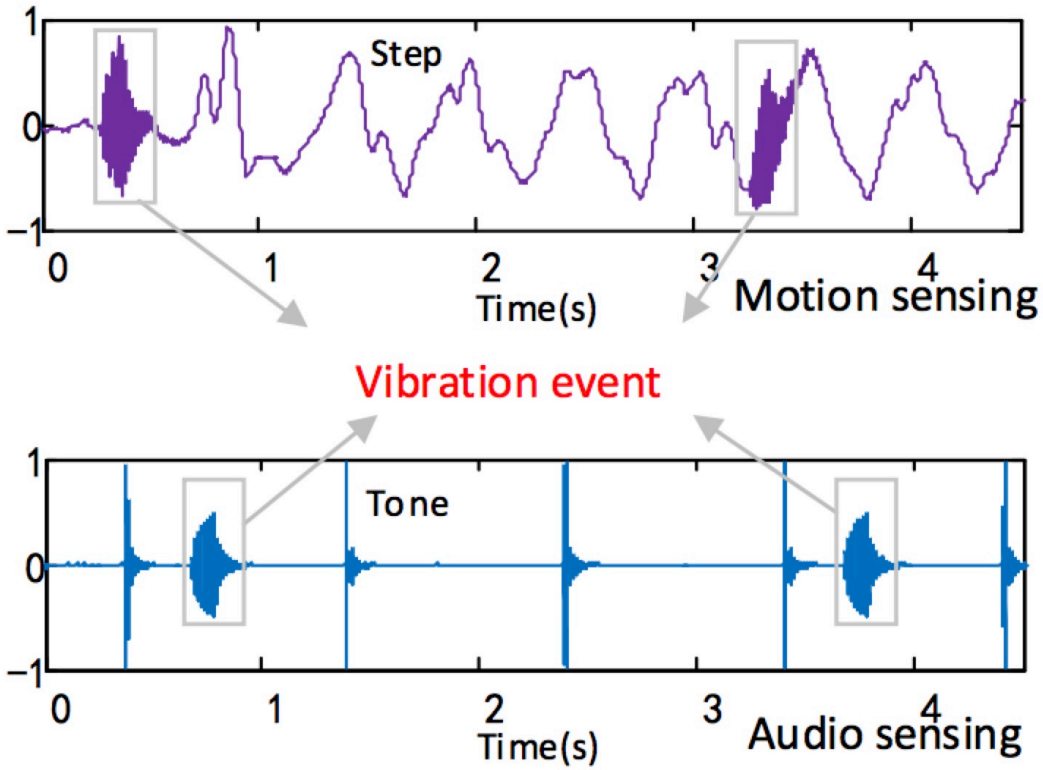
- Spatial Relation Extraction
  - TDoA
  - anti-multipath and anti-environmental noise
  - inaudible for humans
  - can be sensed by motion sensor

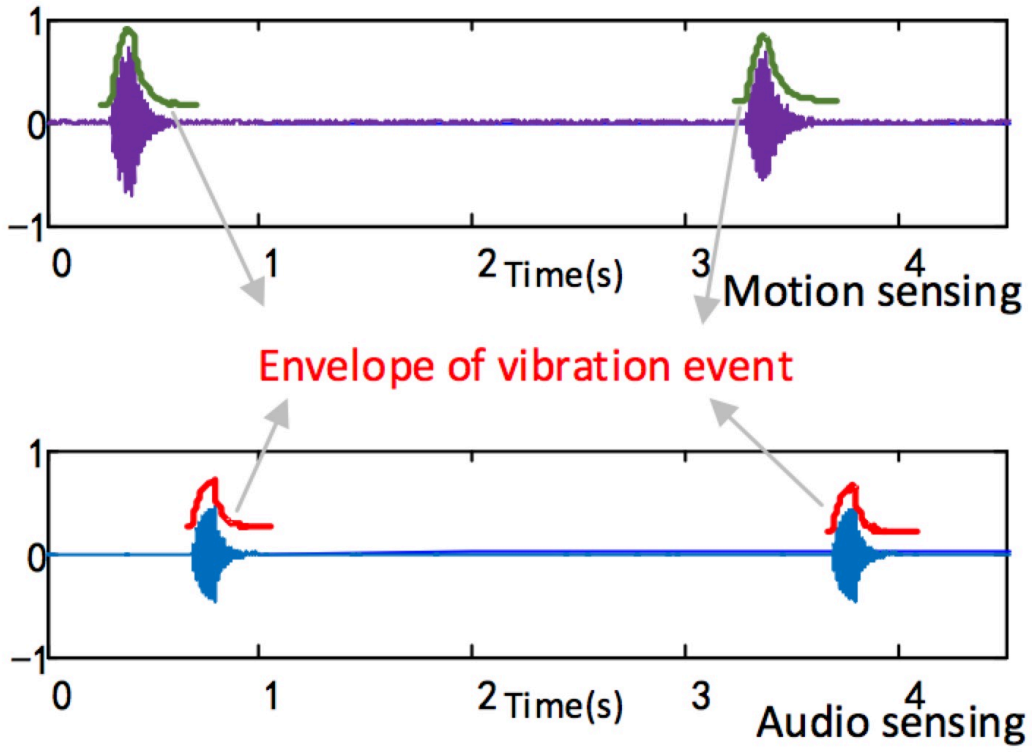


(a) Encounter scenario

Encounter Profiling

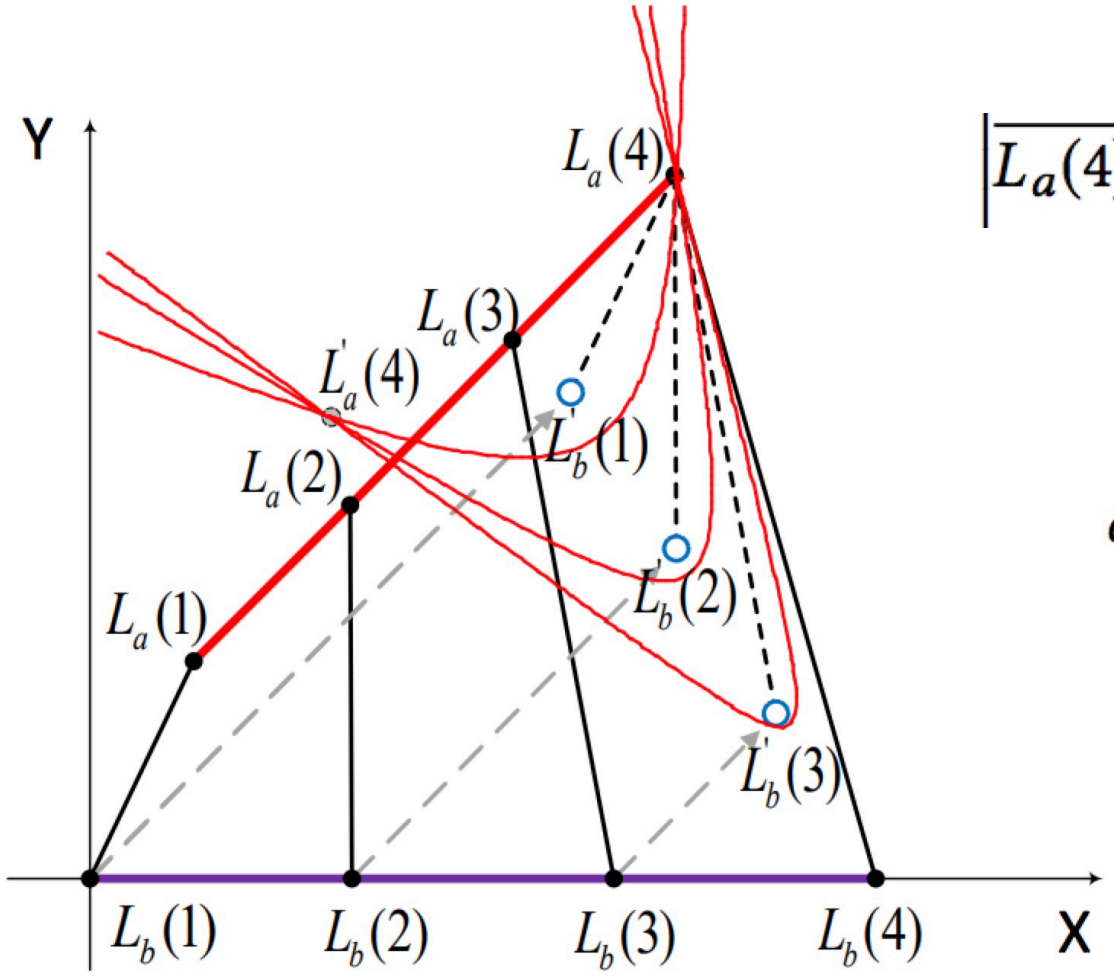
- Spatial Relation Extraction
  - can be sensed by motion sensor





Encounter Profiling

- Spatial Relation Extraction



(b) Hyperbola based localization

$$\left|\overline{L_a(4)L_b(4)}\right| - \left|\overline{L_a(4)L'_b(i)}\right| = \Delta d\,(4,i),\ i \in \{1,2,3\}$$

$$e_i = \left|\overline{L_b(i)\hat{L}_a(i)}\right| - \left|\overline{L_b(i+1)\hat{L}_a(i+1)}\right| - \Delta d\,(i,i+1)$$

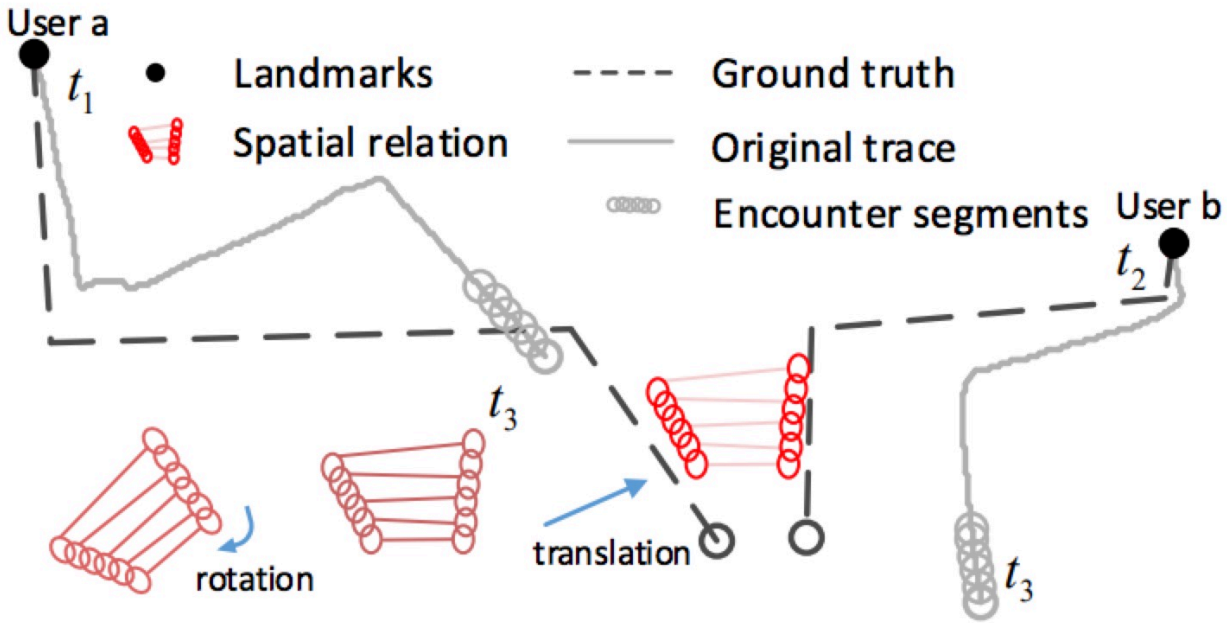
$$(\hat{x}_a(1), \hat{y}_a(1), \hat{\alpha}) = \underset{(\hat{x}_a(1), \hat{y}_a(1), \hat{\alpha})}{\arg\min} \sum_{i=1}^{n} e_i^2.$$

Outline

- Trace Profiling
- Encounter Profiling
- Trace Calibration

Trace Calibration

- Encounter Position Estimation



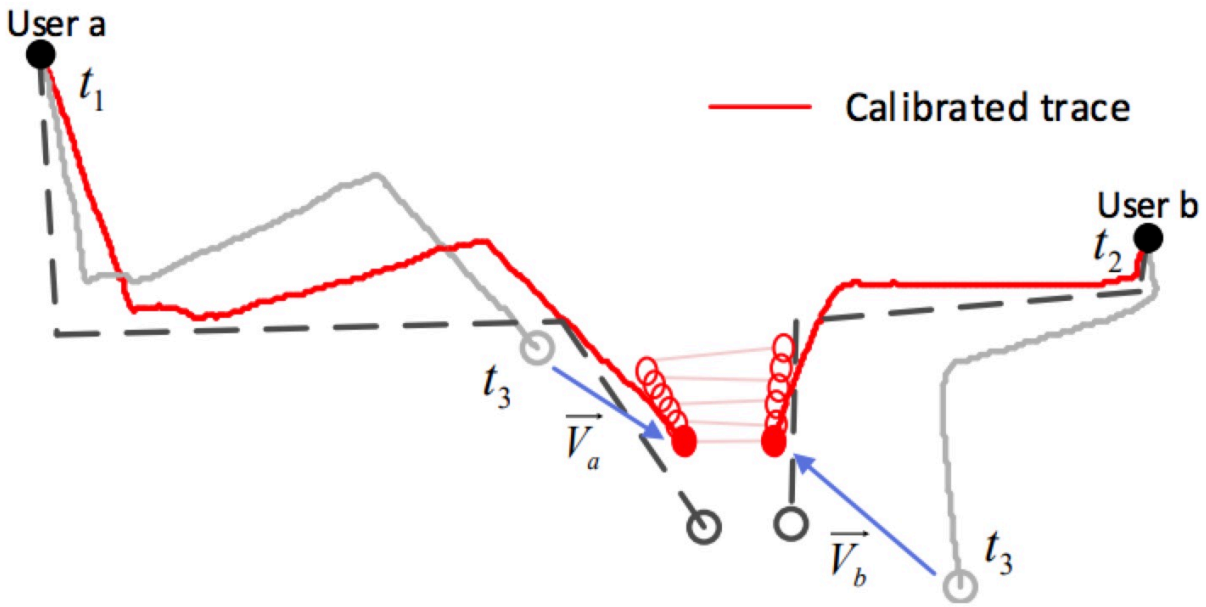
(a) Position correction with spatial relation

$$e_u(i,(x,y),\beta)=\left|\overline{G_u(i)-T_r(L_u(i),(x,y),\beta)}\right|^2,$$

$$\hat{G}_u(i)=\arg\min_{x,y,\beta}\sum_{u\in U}\alpha_u\sum_{i=1}^{n}e_u(i,(x,y),\beta),$$

Trace Calibration

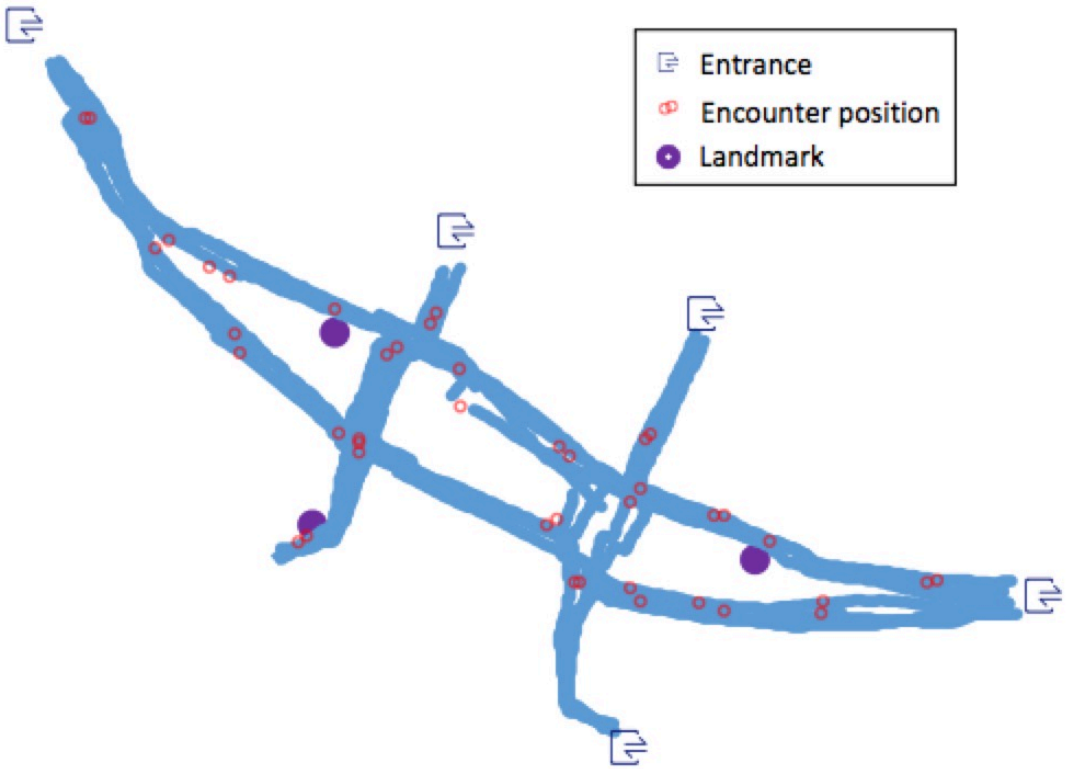
- Trace Drift Elimination



(b) Trace drift cancellation

$$P_u'(t) = P_u(t) + \overline{V_u}\frac{t - t_u(s)}{t_u(e) - t_u(s)},$$

Output



(a) Hallway shape

(b) Estimated room area

Evalution

- Landmark Positioning
  - 1m error

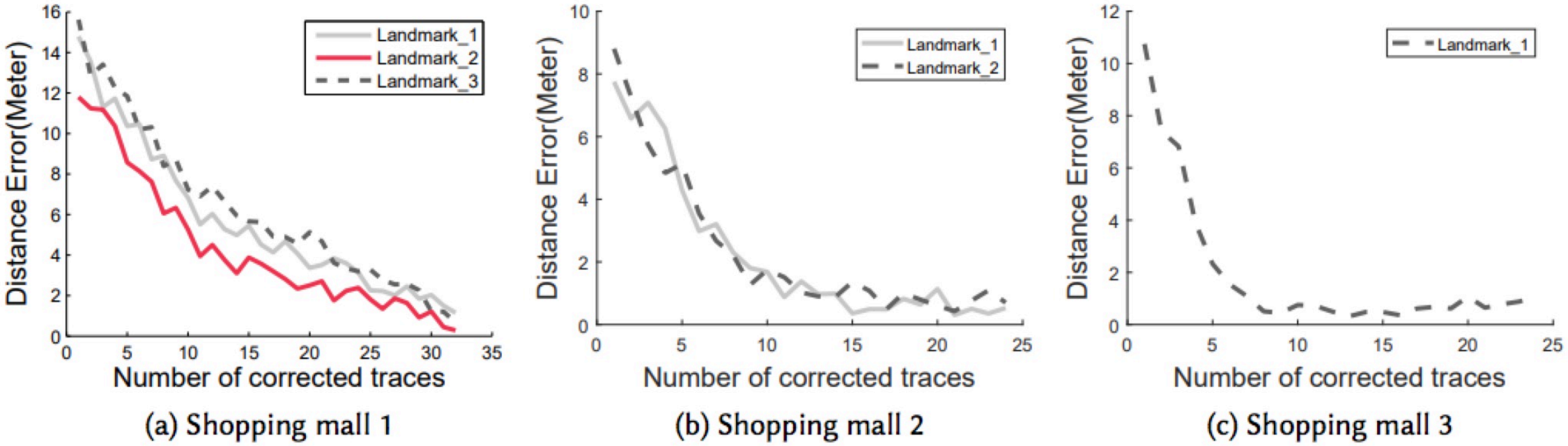
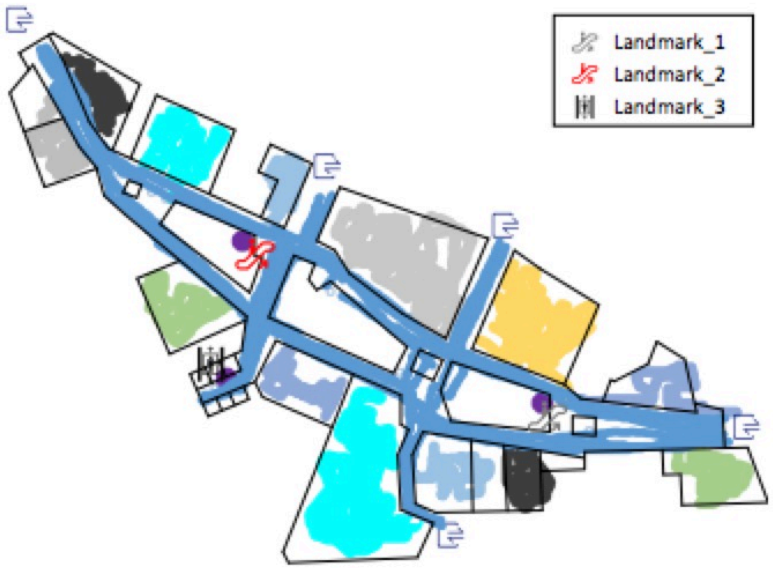


Fig. 11. The accuracy of landmark positioning.

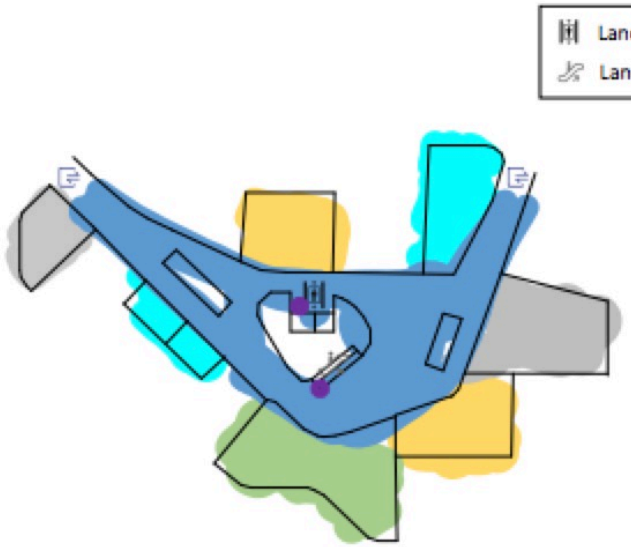
Evalution

Table 1. Collected traces and other parameters.

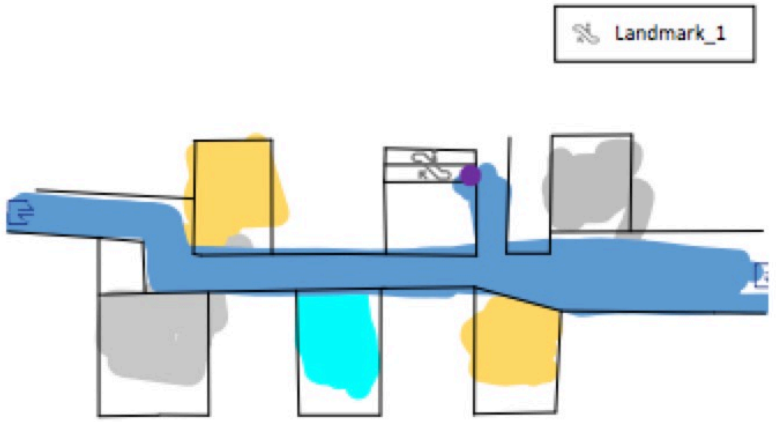
	Participant number	Collected traces	Encounter number
Shopping mall 1	8	87	22
Shopping mall 2	6	72	19
Shopping mall 3	6	67	18



(a) Shopping mall 1



(b) Shopping mall 2



(c) Shopping mall 3

Evalution

- Hallway Shape Detection

$$\mathcal{P} = \frac{\mathcal{S}(\mathcal{H}_{esti} \cap \mathcal{H}_{true})}{\mathcal{S}(\mathcal{H}_{esti})};$$

$$\mathcal{R} = \frac{\mathcal{S}(\mathcal{H}_{esti} \cap \mathcal{H}_{true})}{\mathcal{S}(\mathcal{H}_{true})};$$

$$\mathcal{F} = 2\frac{\mathcal{P}\mathcal{R}}{\mathcal{P} + \mathcal{R}},$$

Table 2. Hallway Shape Evaluation

	Precision	Recall	F-Measure
Shopping mall 1	93.7%	86.1%	89.7%
Shopping mall 2	88.4%	94.7%	91.4%
Shopping mall 3	83.9%	87.6%	85.7%

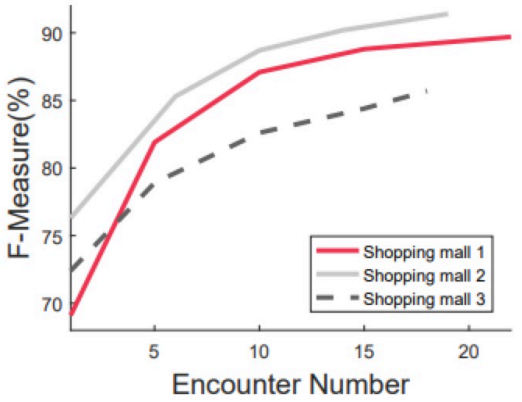
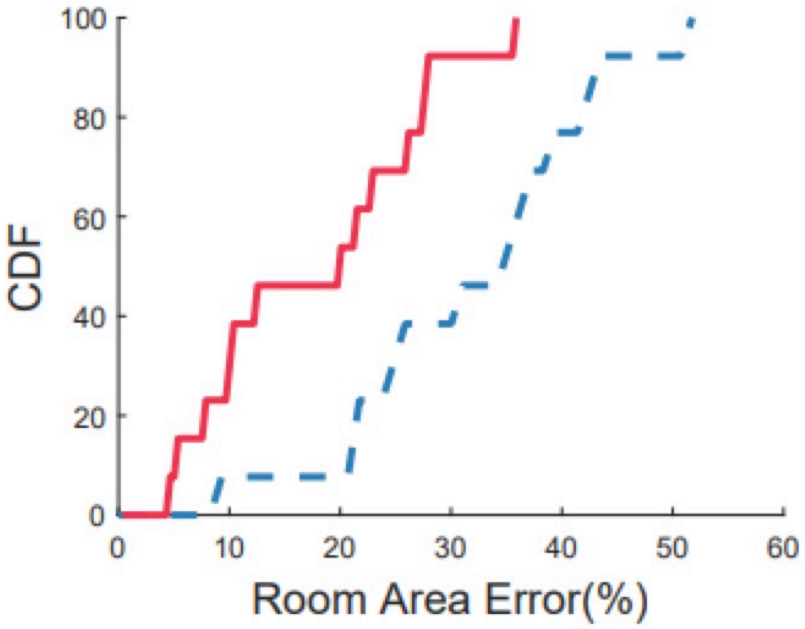


Figure 12. Hallway shape evaluation vs encounter number.

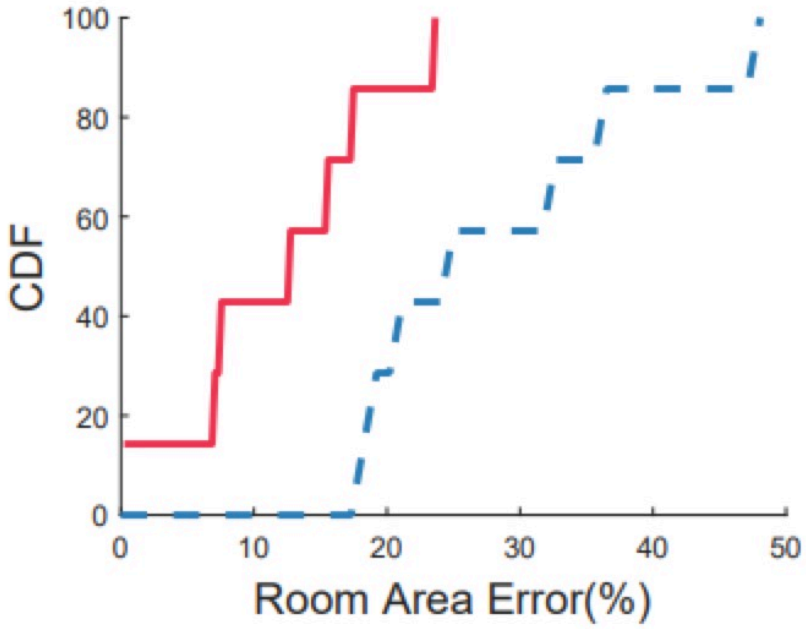
Evalution

- Room Area Estimation

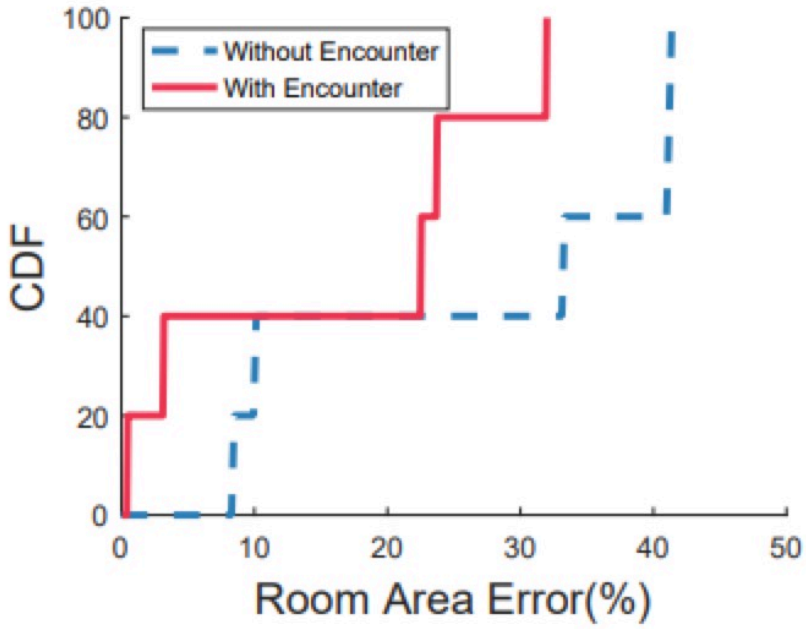
$$E_r = \frac{|S(R_{esti}) - S(R_{true})|}{S(R_{true})},$$



(a) Shopping mall 1



(b) Shopping mall 2



(c) Shopping mall 3

My opinion

- 通过用户的相遇自动构建地图还挺有意思的，实现方式直观好理解
- 跟别的方法对比，有种硬找优点的感觉
- 我学习了地图，PDR等内容