A Hidden Markov Model for Indoor Tracking Based on Bluetooth Fingerprinting and Grid Filtering

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Outline

- Background
- Introduction of Fingerprint-based location
- Methods and Algorithms
- Experiments
- Conclusion

Background

➢Indoor Pedestrian Navigation ：

- Oriented “human "services
- Indoor High similar pedestrian
- The Complexity of indoor environment
- High demand of real-time

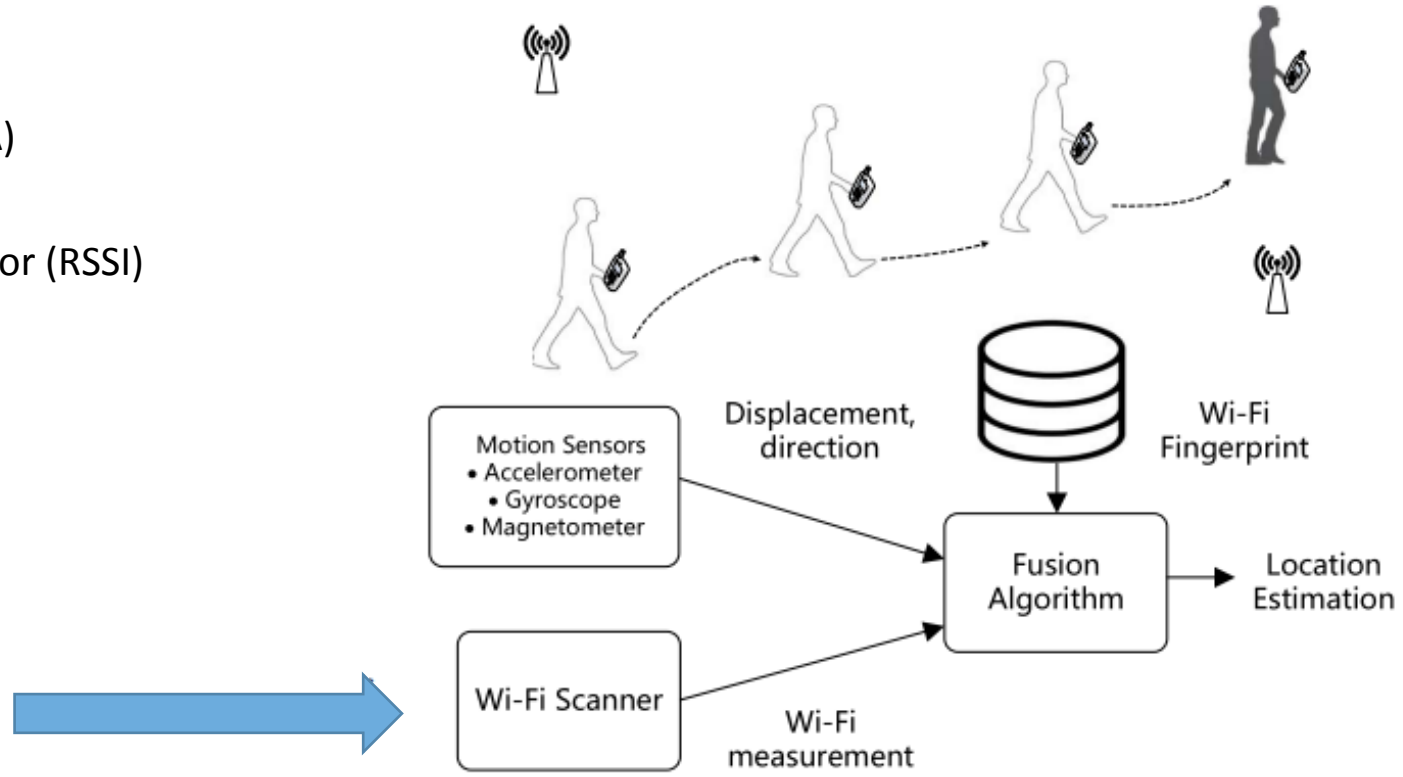
Train station

Museum

Tourist

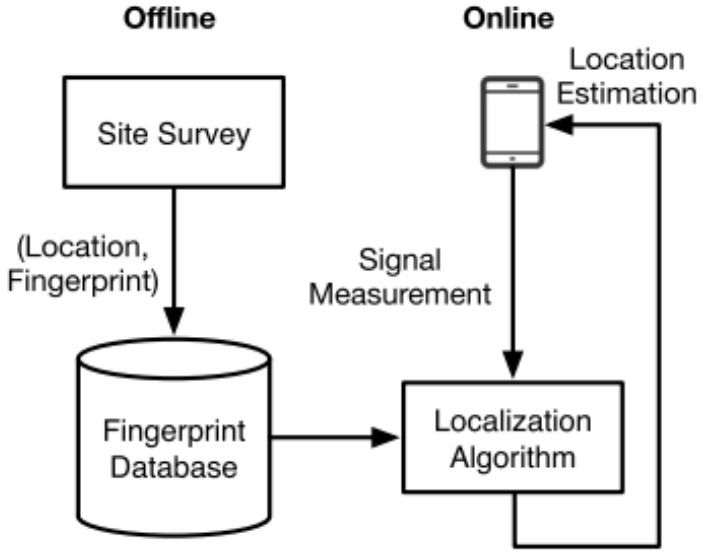
Techniques for Positioning/Location Tracking

- **Measurement types**
  - Time of arrival (ToA)
  - Time difference of arrival (TDoA)
  - Angle of arrival (AoA)
  - Received signal strength indicator (RSSI)
- **Location estimation methods**
  - Cell of origin (CoO)
  - Distance-based
    e.g., trilateration
  - Fingerprinting
    e.g pattern regnition



Challenge: the balance with the accuracy and efficiency

Introduction of Fingerprint-based Location



- Fingerprint method is RSS-based localization

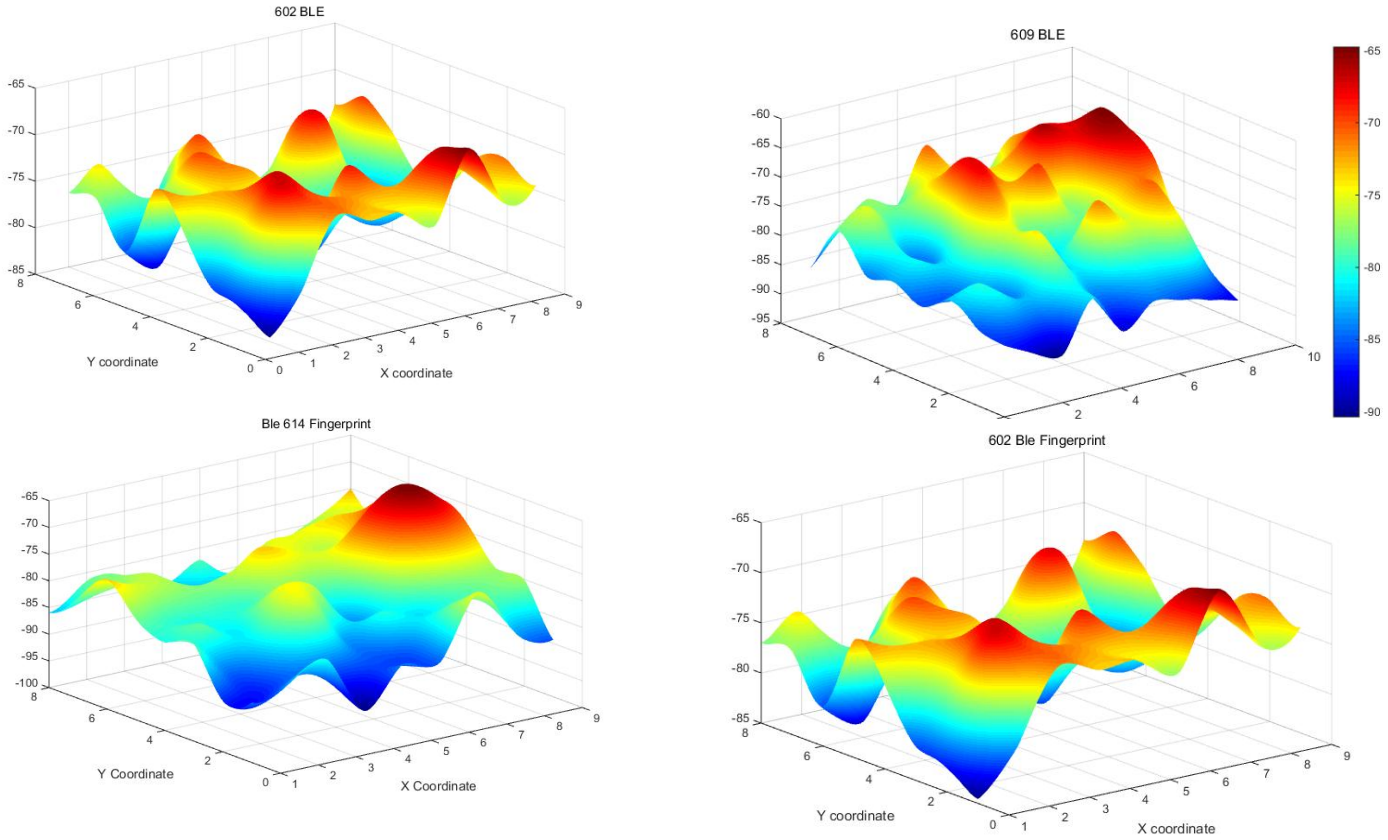
■**Probabilistic ,e.g.,**

➢ **Bayesian** $(x|y) = p(y|x)p(x)/p(y)$

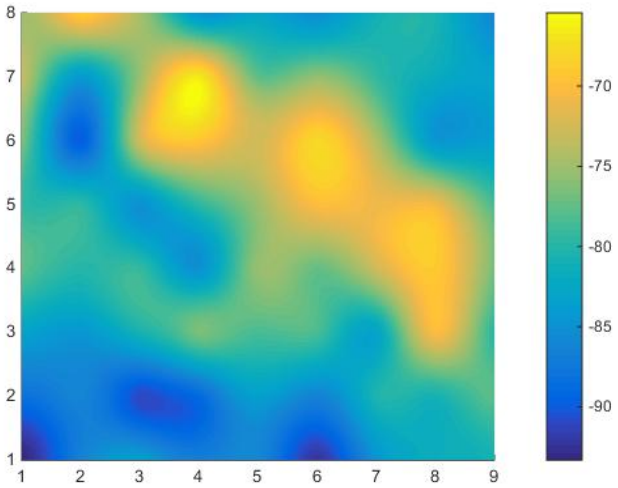
■**Deterministic, e.g.,**

➢ **Nearest Neighbor** $\text{Min } \delta = \sqrt{\sum_{i=1}^{n}(S_i - S_{mi})^2}$

Bluetooth Fingerprint similarity



Bluetooth Fingerprint



Signal similarity ➡ Spatial similarity

- Signals may has a high similarity in certain regions due to the refraction and diffraction of the signal

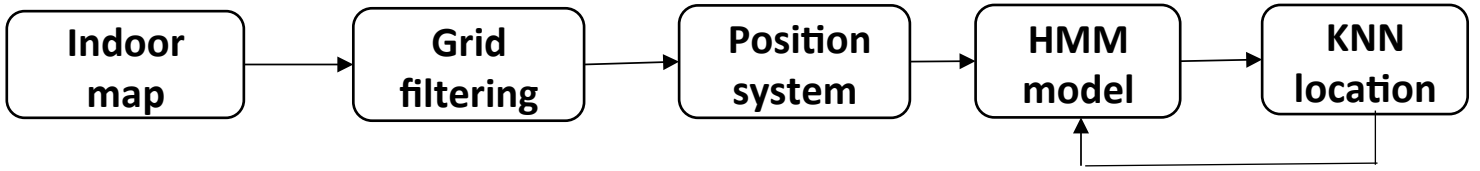
Brief review

Category	authors	Location Algorithm	Details
MOTION-ASSISTED	A. Rai, K. K. Chintalapudi(2012)	Particle Filter	Simple step detection can be based on peak detection or zero crossing of acceleration readings.
	W. Sun(2014)	Graph-fusion	Simplify the indoor map model ,get high accuracy for narrow corridors.
Temporal patterns	Y. Kim, H. Shin,(2012)	Walking direction	Use the Rssi peak in a temporal sequence get 2M accuracy in corridor.
	H. Wang *et al.*(2012)	Fingerprint	Through Wifi landmark
Fusion sensors	Z. Yang, X. Feng,(2014)	*Kalman filter*	some advanced and efficient models between wireless signals and motion to locate the target
Map information	Z. Xiao, H. Wen, A. Markham(2014)	Map Craft	Use the Step counts and heading direction, but rely on large training data
HMM	Jingbin Liu(2014)	Bayesian	Use the HMM and Viterbi to increase the accuracy in cooridors which is about 2M

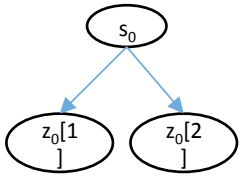
Our Approach for fingerprint

For improving location accuracy and reduce the calculating-time and complexity of fingerprinting

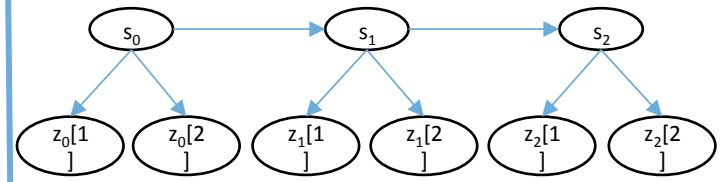
Combine the Bayesian and Nearest Neighbor ,Use the map information and grid filtering ,give map constrains and update the HMM model.



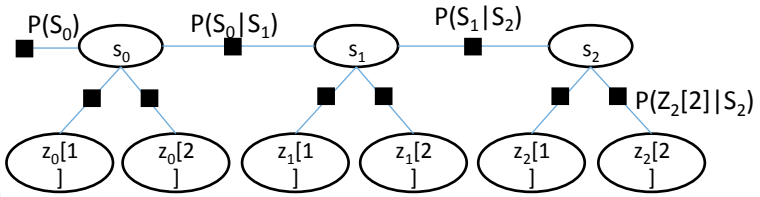
Bayes Model



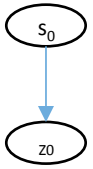
Hidden Markov Model



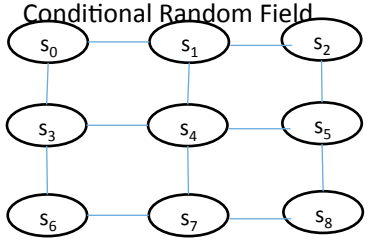
HMM Factor Graph



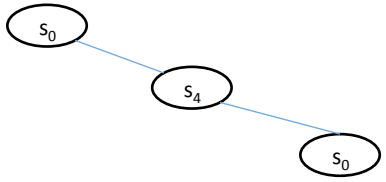
Constrain Min. Entropy Model



Grid Filtering Conditional Random Field

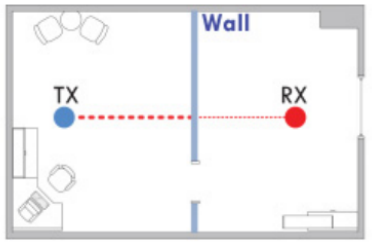


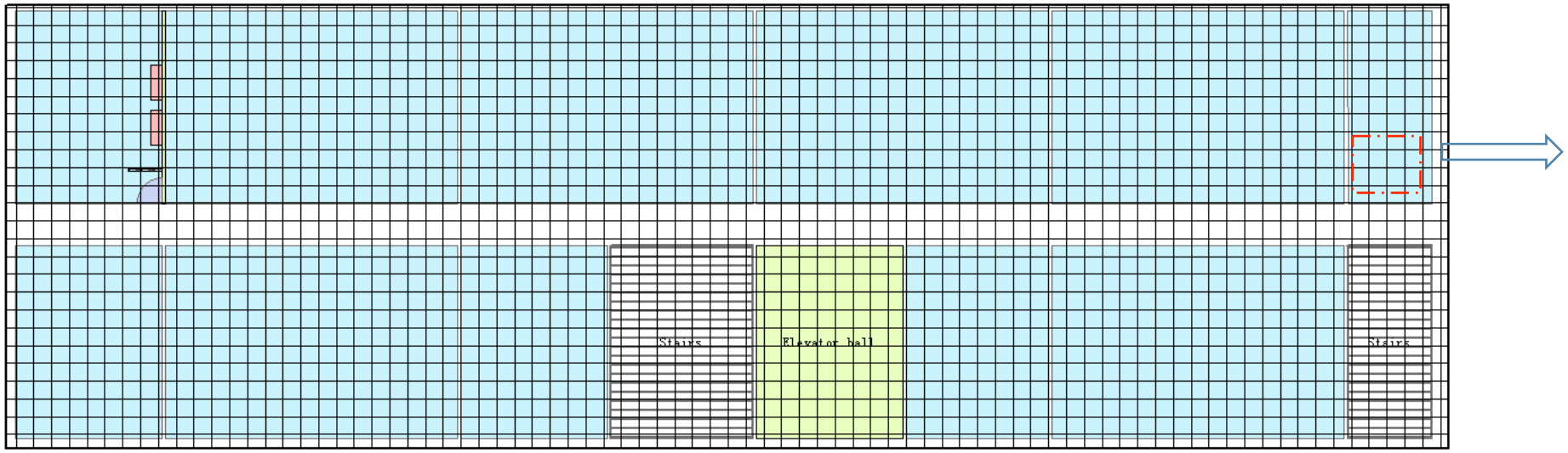
KNN constraint by Viterbi Algorithm



Principle of the New Algorithm (1)

- grid filitering
  - distance
  - accessibility
  - topology





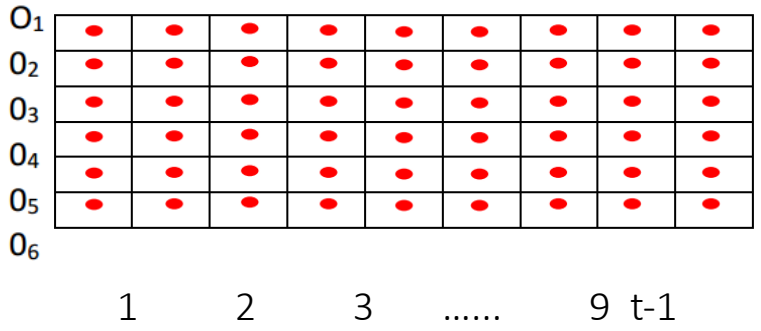
A1	A2	A3
A4	A0	A5
A6	A7	A8

Principle of the New Algorithm (2)

HMM characterized

1. $S = \{S_1, S_2, S_3, \ldots, S_N\}$,
2. $O = \{O_1, O_2, O_3 \ldots, O_T\}$
3. $A = a_{i,j} = P[q_{t+1} = S_j \mid q_t = S_i], 1 \ll i,j \ll N$ ⟶ $[\blacksquare a11 \& \cdots \& a1j @ \vdots \& \ddots \& \vdots @ ai$
4. $\pi = \{\pi_i\}\ \pi_i = P[q_1 = S_i]$. q=1
5. $V = \{v1, v2, v3, \ldots, vM\}$
6. $B = \{b_j(k) \text{at } t \mid q_t = S_j], 1 \le j \le N, 1 \le k \le M$.

- S is the set of possible state, is the set of possible states,where a state in grid.
- A is the state transition probability distribution between states i and j,
- O is a sequence of observations,
- π is the initial state probability distribution,
- V is the set of possible observation symbols,
- B is the observation symbol probability distribution in state j



Viterbi Algorithm

Viterbi Algorithm determining the most likely path.

1.Initialization

$$\delta_1(i)=\pi_i b_j(O_1),\ 1\ll i\ll N$$

$$\varphi_1(i)=0$$

2. Recursion

$$\delta_t(j)=\max_{1\ll j\ll N}[\delta_t(i)a_{i,j}]b_j(O_t) \qquad 1\ll t\ll T\ 1\ll i\ll N$$

$$\varphi_t(j)=arg\max_{1\ll j\ll N}[\delta_{t-1}(i)a_{i,j}] \qquad 2\ll t\ll T\ 1\ll i\ll N$$

$$\delta_t(j)=\min_{1\ll j\ll N}[\delta_t(i)a_{i,j}]b_j(O_t) \qquad 1\ll t\ll T\ 1\ll i\ll N$$

$$\varphi_t(j)=arg\min_{1\ll j\ll N}[\delta_{t-1}(i)a_{i,j}] \qquad 2\ll t\ll T\ 1\ll i\ll N$$

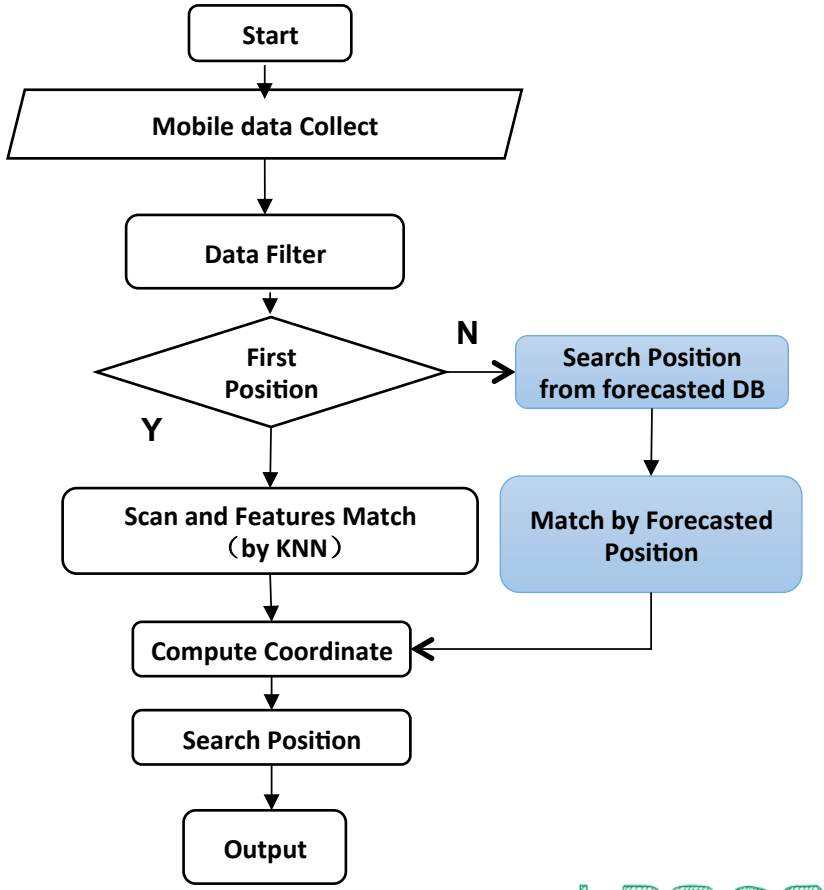
Principle of the New Algorithm (3)

1.According to the last point, query prediction point knowledge base,

2. Matching fingerprint database, get the positioning results.

N=Estimate.length,usually below 9.

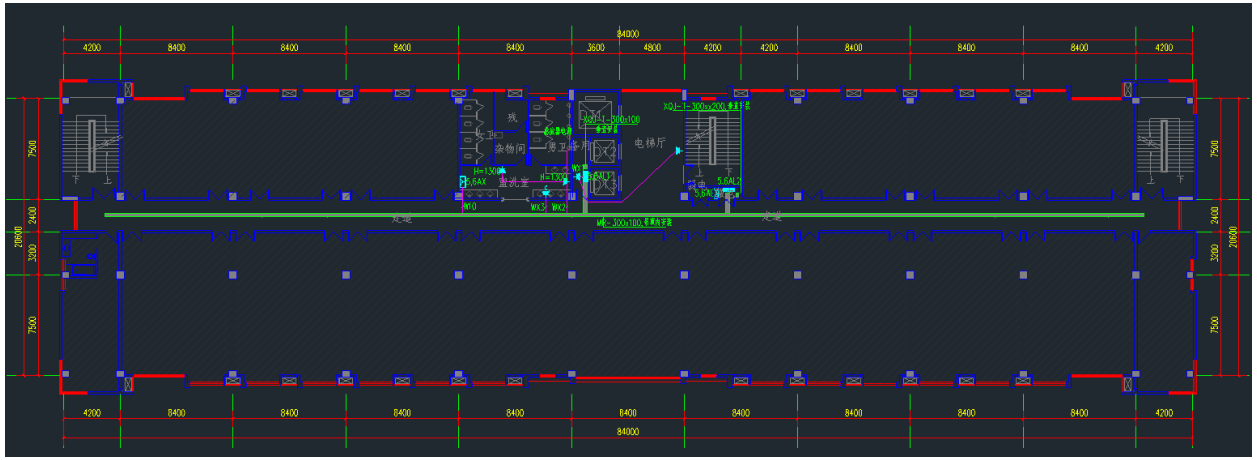
3.With the updata the position data,the HMM model would change



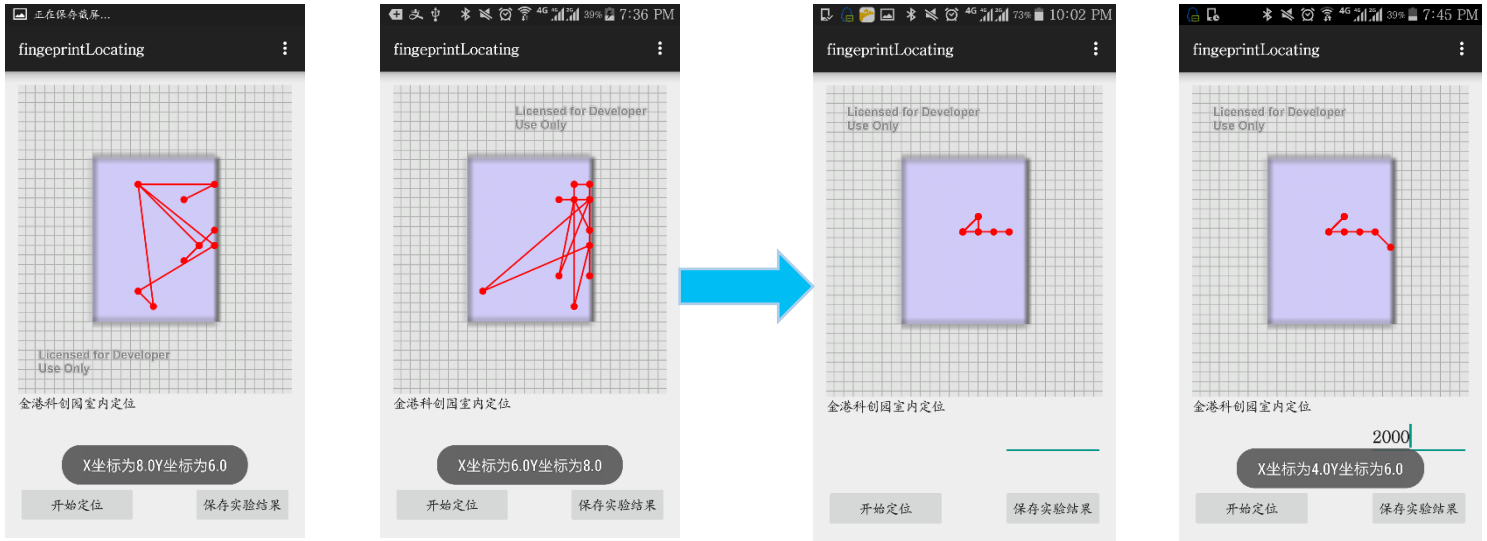
$$\text{argmin}_{\gamma\in\Omega}\left(l=1/n\ \sqrt{\sum i=l\uparrow n\ w\downarrow i\uparrow 2}\ (s\downarrow 0\uparrow -i-s\downarrow r\uparrow i)\uparrow 2\ \right)$$

Experiment

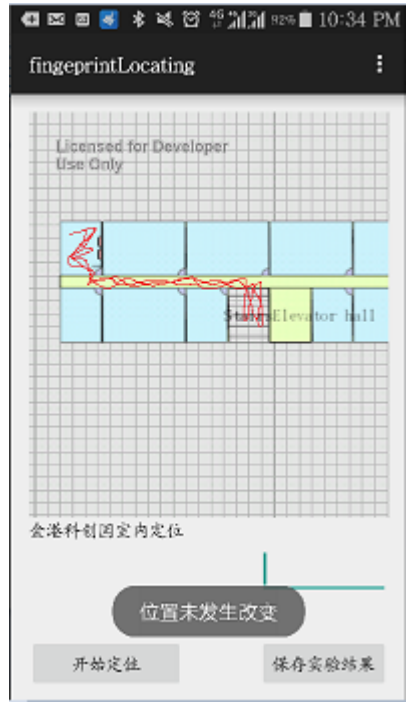
On 6 floor, at JinGang Science Park No. 4
Using mobile phone S5 and ibeacons equipment.
Plan one:
using KNN algorithm for open areas
Plan two:
Using HMM+Grid+KNN algorithm for rooms



Analysis of results



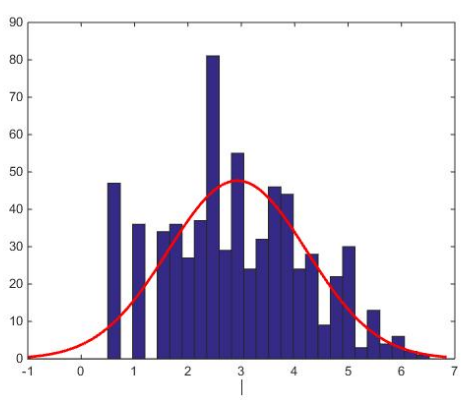
- KNN method

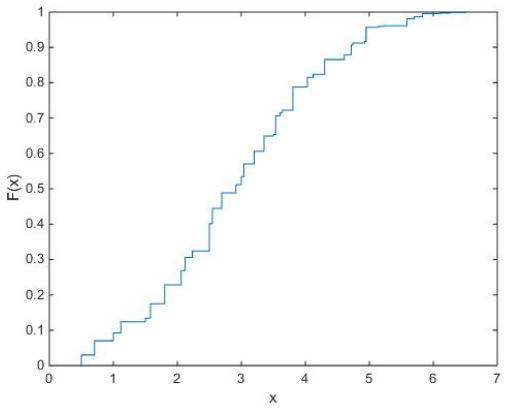


Our method

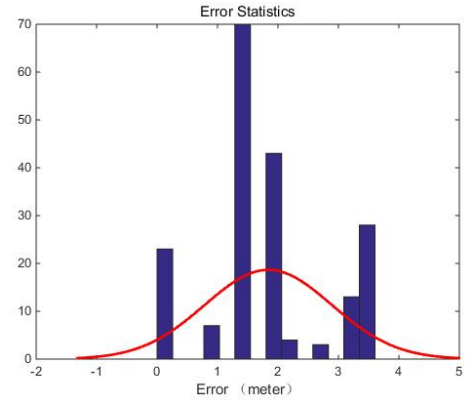
Analysis of results

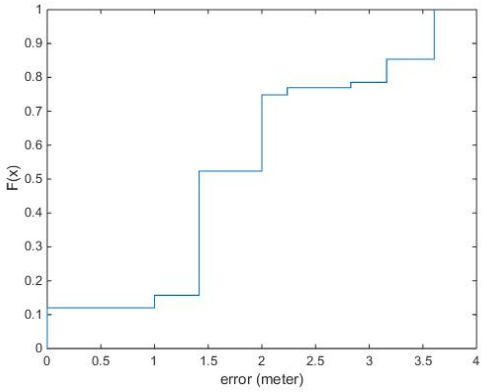
KNN accuracy error





Our approach accuracy error





Positioning Method	Accuracy/m	Time/s
KNN	2.95	3.1
HMM-grid-knn	2.15	1.1

Conclusions

- This paper proposes a Hidden Markov Model for indoor position with grid filitering that can use in the open area. The experiment proved the improvement of accuracy and stability on indoor location.
- The first point go wrong would not affect seriously. It would move toward the right direction.

Future work

- Need more tracks and big data to train the HMM.
- Use the combination of ibeacon and pdr algorithm.

Thank you!

Welcome question!

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