Reconstruct radio map for indoor localization

Part1: introduction

Part2: radio propagation model

Part3: model based approach for fingerprints reconstruction

Part4:simulation in MATLAB

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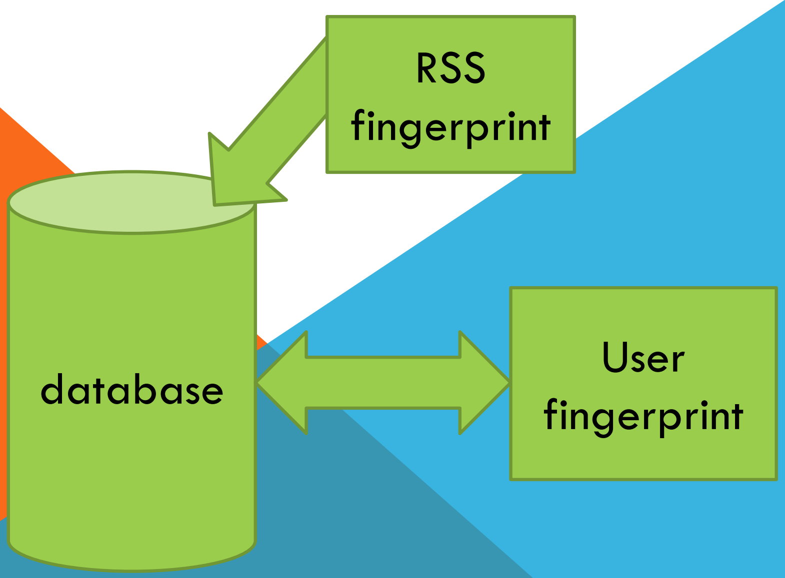
PART1: INTRODUCTION

- The main theory is based on the previous persons' work.
- Indoor localization has been under intensive investigations in recent years.
- The Wi-Fi fingerprints based approach is very popular.



MAIN PROBLEM

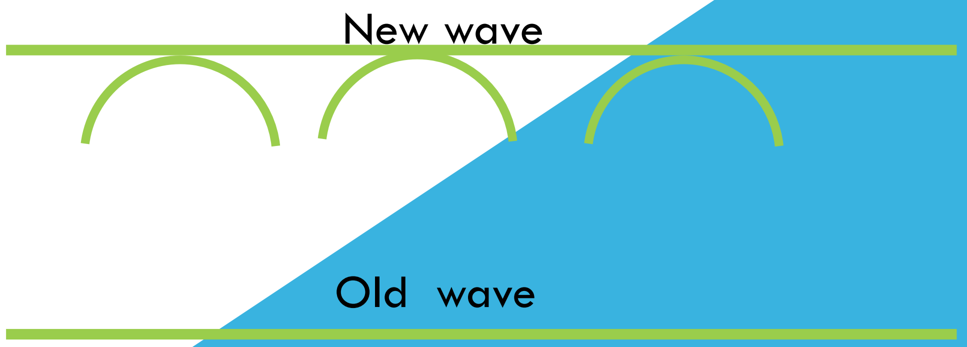
- How to get the RSS fingerprints efficiently.

Related work:

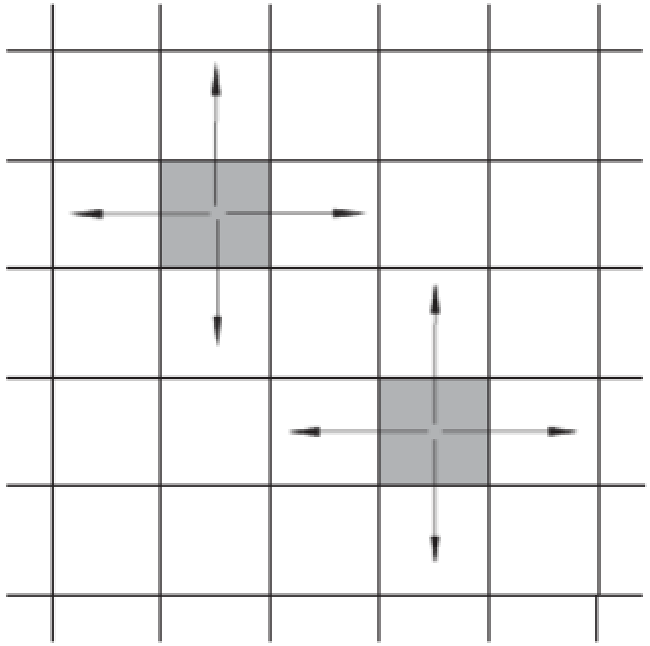
- Compressive Sensing
- Fingerprint based Indoor Localization
- Model based Approach

PART2: RADIO PROPAGATION MODEL

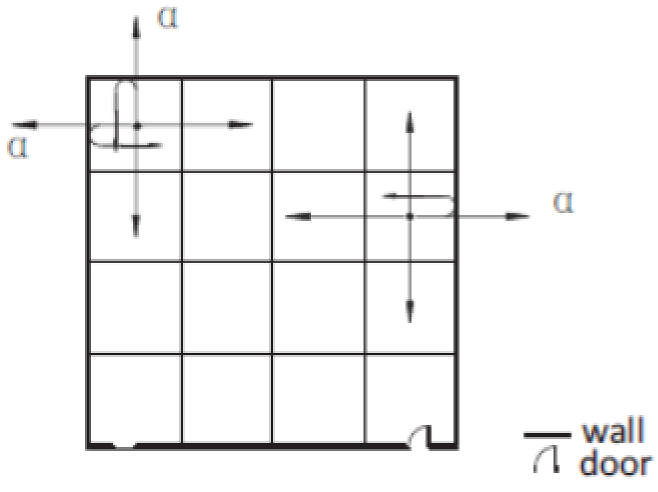
- Main theory : Huygens' principle



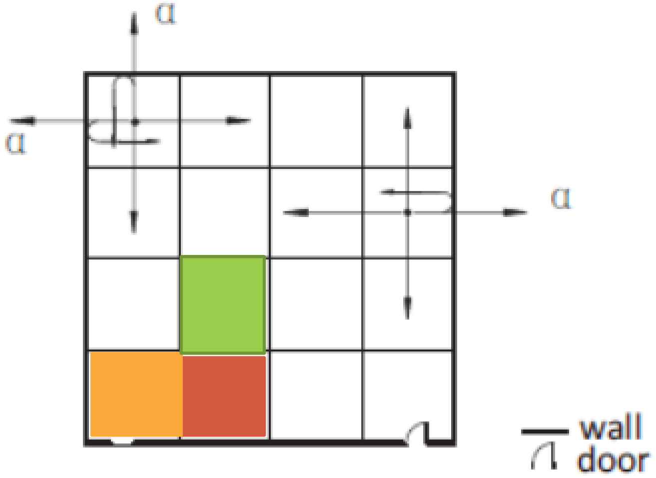
- Single-step radio propagation model



- The room is divided into n^2 parts with grid.

- Some assumption
- 1. x:the power level of the signal at the center of the square
- 2. y:the aggregate power level after the walls' effects
- 3. α the transmissivity of the wall ranging from 0 to 1
- We only consider the case where the signal can travel to the four neighboring cells for the simplicity of presentation.
- 

- Three kinds of cell:



- First kind: $y = \frac{1}{4}x + \frac{1}{2}x(1\text{-}\alpha)\frac{1}{2} = \frac{1}{2}x - \frac{1}{4}\alpha x;$
- Second kind: $y = \frac{1}{4}x + \frac{1}{4}x(1\text{-}\alpha)\frac{1}{3} = \frac{1}{3}x - \frac{1}{12}\alpha x;$
- Third kind: $y = \frac{1}{4}x.$

- As shown before, we can get the single-step matrix H.

  $H_{i,j}$:the radio signal changes after it arrives to $cell_j$ from $cell_i$ in power level

- Properties of H matrix:

  1) $H_{i,j} = H_{j,i}$

  2) for each roll in matrix H, there are at most four non-zero elements

PART3: MODEL BASED APPROACH FOR FINGERPRINTS RECONSTRUCTION

- T :the multi-hop radio propagation matrix
- $T_{ij} = \sum_{k=1}^{n^2} (H_{ij} + H_{ik}H_{kj} + \cdots + H_{ik}H_{km} \ldots H_{pq}H_{qj})$
- $H_{ik}H_{kj}$ describe the propagation process from $cell_i$ to $cell_j$ obeying Huygens' principle.
- Each elements of equation represents an independent channel form $cell_i$ to $cell_j$.

- $Tx = Hx + H^2x + H^3x + \ldots$
- $T = H + H^2 + H^3 + \ldots$
- $T = (E - H)^{-1}H$
- Get the H matrix through collected fingerprints at a limited number of locations.

Only $H_{i-1,j}$,$H_{i+1,j}$,$H_{i-n,j}$,$H_{i+n,j}$ are valid.

$$H_{i,i-1} = T_{i,i-1} - \sum_{k} H_{i,k}T_{k,i-1}$$

$$= T_{i,i-1} - H_{i,i-n}T_{i-n,i-1} - H_{i,i-1}T_{i-1,i-1} - H_{i,i+1}T_{i+1,i-1} - H_{i,i+n}T_{i+n,i-1}$$

- $$\begin{bmatrix} 1+T_{i-n,i-n} & T_{i-1,i-n} & T_{i+1,i-n} & T_{i+n,i-n} \\ T_{i-n,i-1} & 1+T_{i-1,i-1} & T_{i+1,i-1} & T_{i+n,i-1} \\ T_{i-n,i+1} & T_{i-1,i+1} & 1+T_{i+1,i+1} & T_{i+n,i+1} \\ T_{i-n,i+n} & T_{i-1,i+n} & T_{i+1,i+n} & 1+T_{i+n,i+n} \end{bmatrix} \begin{bmatrix} H_{i,i-n} \\ H_{i,i-1} \\ H_{i,i+1} \\ H_{i,i+n} \end{bmatrix} = \begin{bmatrix} T_{i,i-n} \\ T_{i,i-1} \\ T_{i,i+1} \\ T_{i,i+n} \end{bmatrix}$$
- As shown above: if x stand for the first subscript of T, and y stands for the second one. all we need is elements in matrix T that satisfy one of the equations as following: $\mathrm{y = x, y = x + n, y = x - n, y = x + 1, y = x + 1, y = x - 1, y = x + 2, y = x - 2, y = x - 2n, y = x + 2n, y = x + 1 + n, y = x + 1 - n, y = x - 1 + n, y = x - 1 - n}$.

Part4:simulation in MATLAB

Step 1: generate the H matrix

```
function [ H_matrix ] = genH(n, sigma)
```

Step 2: generate the T matrix

```
T= (E-H0)\H0;
```

Step 3: generate the T1 ,T2matrix

```
T1 = [1,2,3,4;5,6,7,8;9,10,11,12;13,14,15,16];
T2 = zeros(4, 1);
```

Step 4: generate the H1matrix

Step 5: compare H1matrix with the original H

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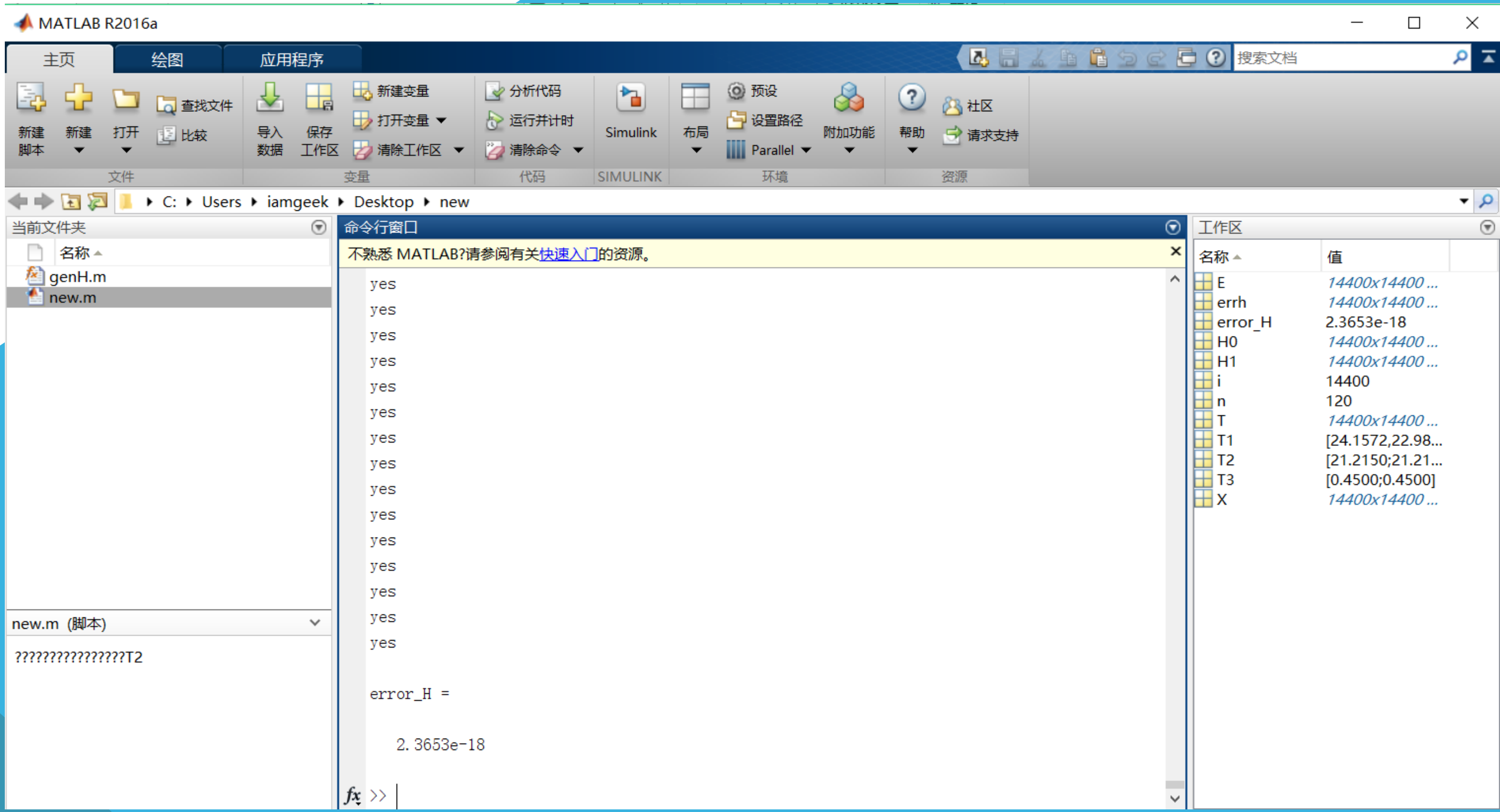
```
errh=(H1-H0)./(H0+0.0001);
error_H=sum(sum(errh)/(n*n*n*n));
```

Result:



- Further work:
- The simulation of the situation that there is an obstacle in the room