Research on Spatial and Temporal Dynamics of RSSI for Indoor Positioning

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目录 Contents

目录 Contents

Introduction

- Aim：RSSI-based indoor positioning technology
- Algorithms：RSSI —— Distance —— Location

- multipath, scattering, obstacles, electromagnetic interference
- Temporal Dynamics of RSSI
- Spatial Dynamics of RSSI

目录 Contents

Principle Analysis

- Analysis of Spatial Dynamics
  - Free space propagation model
  - Linear regression model
  - find the law how RSSI values change with locations or distances

Free space propagation model

$$p(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

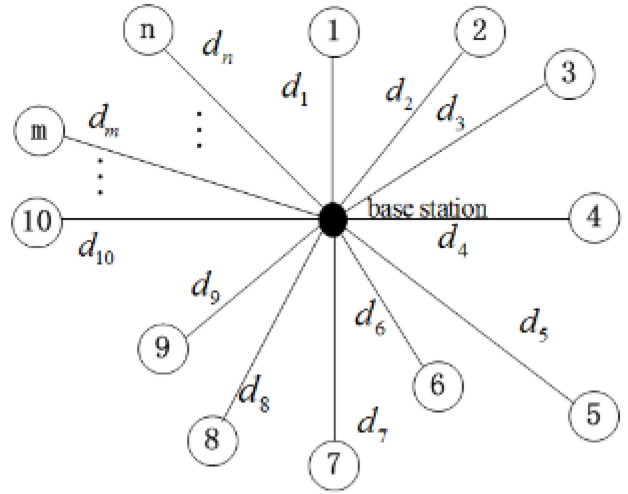
$$p(d) = p(d_0) - 10nlg\frac{d}{d_0}$$

$$RSSI = A - 10nlgd$$

$$d = 10^{|A-RSSI|/10n}$$

Linear regression model

- 2 environmental parameters: A & n
- N reference points



$$\bar{d} = \frac{1}{N}\sum_{i=1}^{N} d_i$$

$$\overline{RSSI} = \frac{1}{N}\sum_{i=1}^{N} RSSI_i$$

$$n = \frac{\sum_{i=1}^{N}(d_i - \bar{d})RSSI_i}{\sum_{i=1}^{N}(d_i - \bar{d})^2}$$

$$A = \overline{RSSI} - n\bar{d}$$

Principle Analysis

- Analysis of Temporal Dynamics
  - RSSI : unstable and great fluctuation
  - Mean Filtering
  - Gaussian Fitting Filtering

Mean Filtering

- most direct , easiest

$$RSSI_{op} = \overline{RSSI} = \frac{1}{N}\sum_{i=1}^{N} RSSI_i$$

Gaussian Fitting Filtering

- RSSI : Gaussian distribution

$$f_{(RSSI)} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(RSSI-\mu)^2}{2\sigma^2}}$$

$$\mu = \frac{1}{n}\sum_{k=1}^{n} RSSI_k$$

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{k=1}^{n}(RSSI_k - \mu)^2}$$

Gaussian Fitting Filtering

- high probability zone（$\mu-\sigma \leqslant RSSI < \mu+\sigma$)

$$P = F(\mu+\sigma) - F(\mu-\sigma) = \phi(1) - \phi(-1) = 0.6827$$

$$RSSI_{op} = \frac{1}{N}\sum_{k=1}^{N} RSSI_k, RSSI_k \in (\mu-\sigma, \mu+\sigma)$$

目录 Contents

Experiments and Data Analysis

- Environment 1:A big room with many desks and chairs(4-317)
- Environment 2:A small empty room(1-534)
- Environment 3:An open lawn

Environment 1

- 50 reference points
- 0m : 0.2m : 10m

$$n = \frac{\sum_{i=1}^{50} (d_i - \bar{d}) RSSI_i}{\sum_{i=1}^{50} (d_i - \bar{d})^2} = 1.8$$

$$A = \overline{RSSI} - n\bar{d} = -36$$

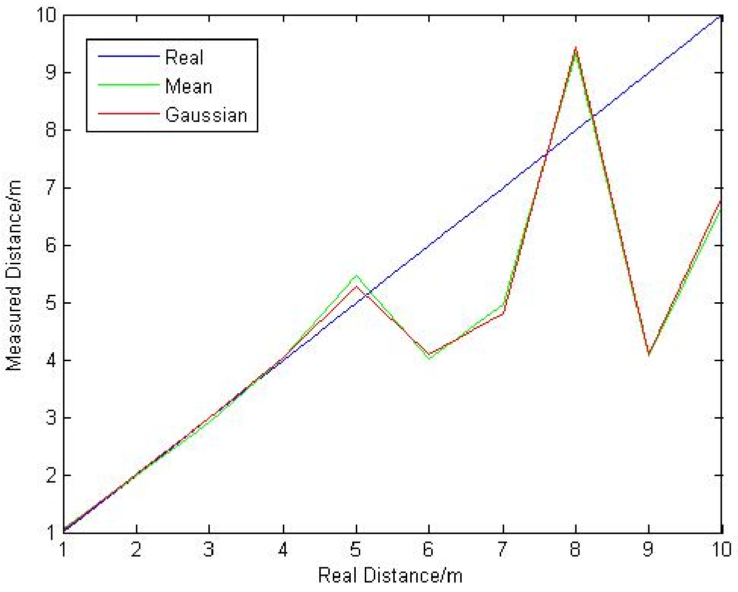
Environment 1

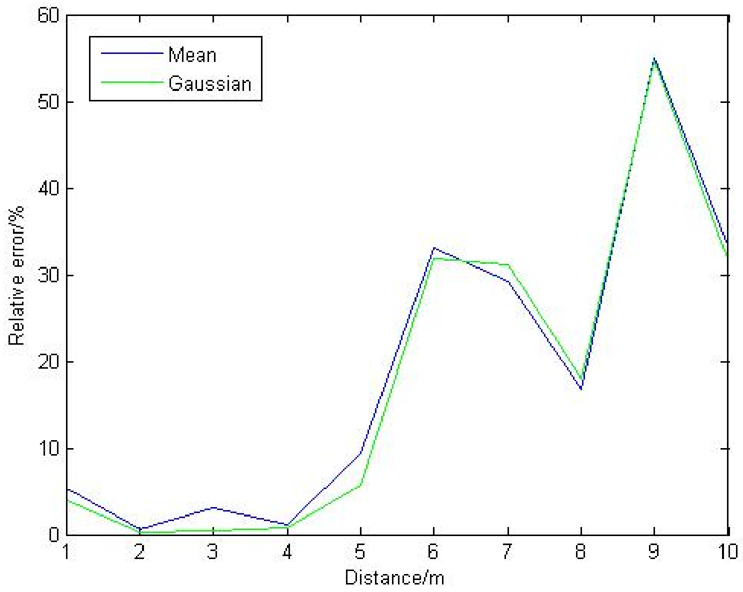
- 10 of the reference points
- 0m : 1m : 10m
- 100 more RSSI values each
- mean filtering and Gaussian Fitting Filtering

Environment 1

Real Distance(m)	Mean Filtering			Gaussian Fitting Filtering				
	Optimized RSSI(-dbm)	Measured Distance(m)	Relative Error(%)	μ(-dbm)	σ	Optimized RSSI(-dbm)	Measured Distance(m)	Relative Error(%)
1	36.41414141	1.05440597	5.440597	36.414	1.23726	36.30434783	1.0397004	3.97004
2	41.37373737	1.988570375	0.571481	41.374	1.20022	41.43396226	2.0039496	0.19748
3	44.34343434	2.907529503	3.08235	44.343	1.01178	44.55882353	2.9887542	0.37486
4	46.92929293	4.047463496	1.186587	46.929	1.09965	46.9010989	4.0328921	0.8223
5	49.28282828	5.469339781	9.386796	49.283	1.05017	49.01290323	5.2837112	5.67422
6	46.86868687	4.016205598	33.06324	46.869	0.81624	47	4.0842387	31.9294
7	48.51515152	4.957767946	29.17474	48.515	0.82516	48.28571429	4.8143724	31.2233
8	53.46464646	9.338091755	16.72615	53.465	0.62781	53.54347826	9.432736	17.9092
9	46.93939394	4.052696746	54.97004	46.939	0.7398	47	4.0842387	54.6196
10	50.81818182	6.656291353	33.43709	50.818	0.62863	51	6.8129207	31.8708

Environment 1





Environment 2

- 25 reference points
- 0m : 0.2m : 5m

$$n = \frac{\sum_{i=1}^{25} (d_i - \bar{d}) RSSI_i}{\sum_{i=1}^{25} (d_i - \bar{d})^2} = 0.8$$

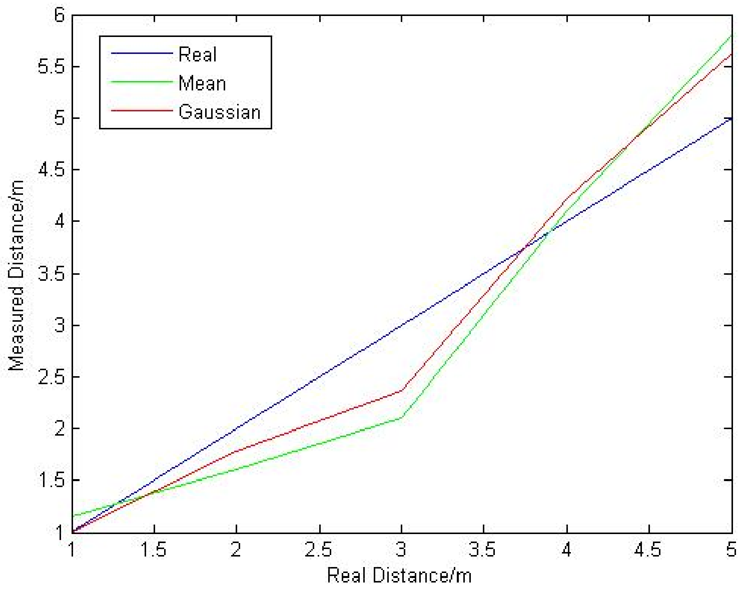
$$A = \overline{RSSI} - n\bar{d} = -31$$

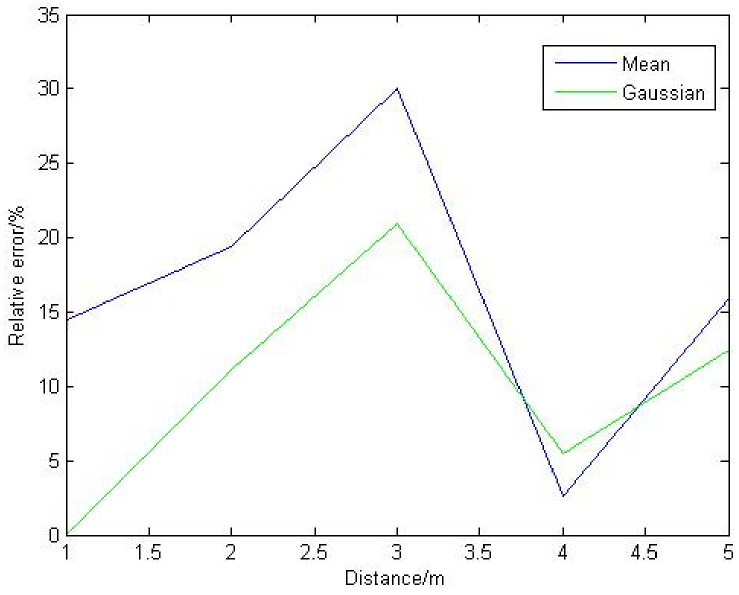
- 5 of the reference points
- 0m : 1m : 5m
- 200 more RSSI values each

Environment 2

Real Distance(m)	Mean Filtering			Gaussian Fitting Filtering				
	Optimized RSSI(-dbm)	Measured Distance(m)	Relative Error(%)	μ(-dbm)	σ	Optimized RSSI(-dbm)	Measured Distance(m)	Relative Error(%)
1	30.53	1.144853721	14.4853721	30.53	0.5	31	1	0
2	32.66	1.612501027	19.3749486	32.66	0.421	33	1.77827941	11.086029
3	33.575	2.098335847	30.0554718	33.58	0.496	34	2.371373706	20.95421
4	35.905	4.103221862	2.58054655	35.91	0.564	36	4.216965034	5.4241259
5	37.105	5.795954934	15.9190987	37.11	0.453	37	5.623413252	12.468265

Environment 2





Environment 3

- 45 reference points
- 0m : 0.2m : 9m

$$n = \frac{\sum_{i=1}^{45} (d_i - \bar{d}) RSSI_i}{\sum_{i=1}^{45} (d_i - \bar{d})^2} = 2.2$$

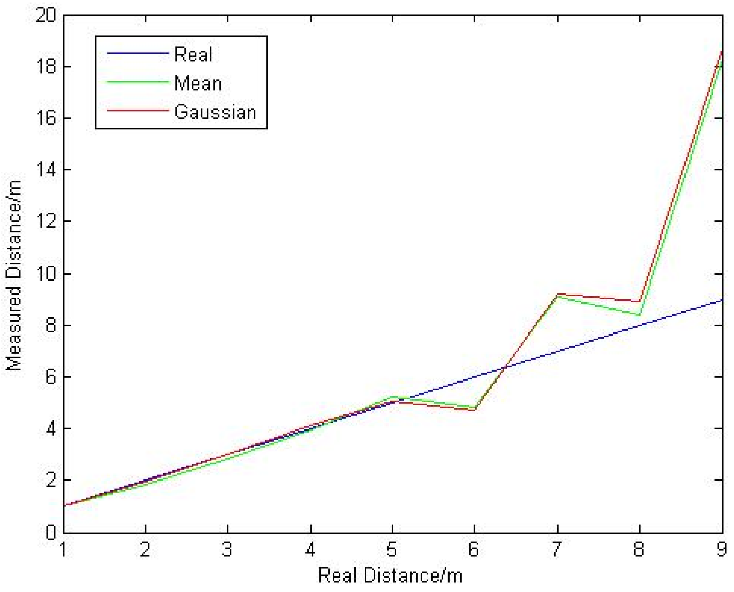
$$A = \overline{RSSI} - n\bar{d} = -40$$

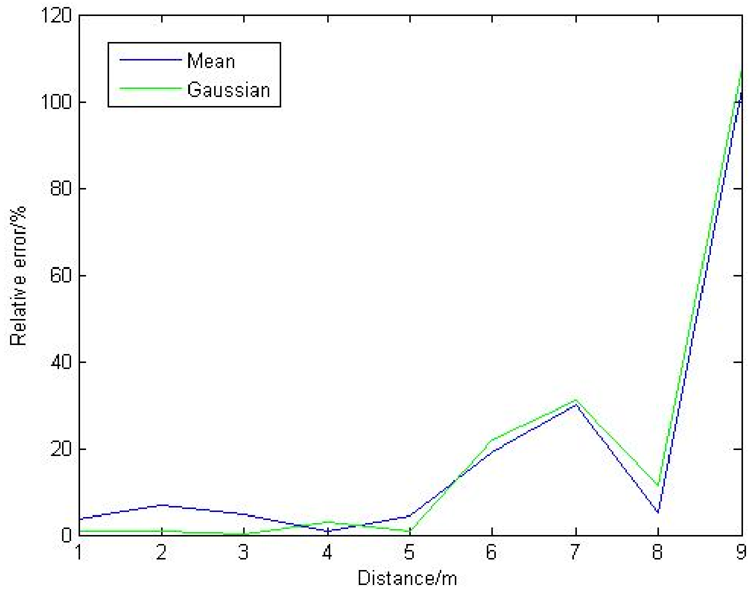
- 9 of the reference points
- 0m : 1m : 9m
- 100 more RSSI values each

Environment 3

Real Distance(m)	Mean Filtering			Gaussian Fitting Filtering				
	Optimized RSSI(-dbm)	Measured Distance(m)	Relative Error(%)	μ(-dbm)	σ	Optimized RSSI(-dbm)	Measured Distance(m)	Relative Error(%)
1	39.663265	1.035872068	3.587207	39.66327	2.19157	39.90411	1.010086705	1.00867
2	45.94898	1.863838006	6.8081	45.94898	3.18946	46.542857	1.983364782	0.83176
3	50.030612	2.857175518	4.760816	50.03061	2.48896	50.522388	3.008086817	0.26956
4	53.163265	3.96579482	0.855129	53.16327	2.07436	53.517241	4.115475899	2.8869
5	55.795918	5.223917257	4.478345	55.79592	1.91014	55.467742	5.047533138	0.95066
6	55.081633	4.847622103	19.2063	55.08163	1.73308	54.761905	4.688087091	21.8652
7	61.102041	9.10298178	30.0426	61.10204	2.13701	61.186667	9.183966757	31.1995
8	60.326531	8.393308955	4.916362	60.32653	2.10926	60.912281	8.923972303	11.5497
9	67.755102	18.26398523	102.9332	67.7551	2.65959	67.985075	18.70892555	107.877

Environment 3





目录 Contents

Conclusion

- perfrom generally well when the distance is smaller than 5 meters
- perform better when the environment is more open
- Gaussian Filtering is generally better than Mean filtering

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