Enhanced Location Estimation via Pattern Matching and Motion Modeling

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Outline

- Motivation
- Signal Power Level localization method
- Motion model
- Trial and Results
- Conclusions

Measurement Sites (GPS)

Area Type	Inaccuracy	Availability
“Ring”	<~23meter	~85%
“Downtown”	<~50meter	~57%

Power Level bases Loc. Methods

Localize handset by „unique“ RF pattern!

Extract feature vector:

Single position i:

$$\mathbf{f}^i = \left[\begin{array}{cccc} a_0^i & a_1^i & \ldots & a_6^i \end{array}\right]$$

a	… Cell ID
Index 0:	… Serving cell
Index 1 to 6:	… Neighboring cells

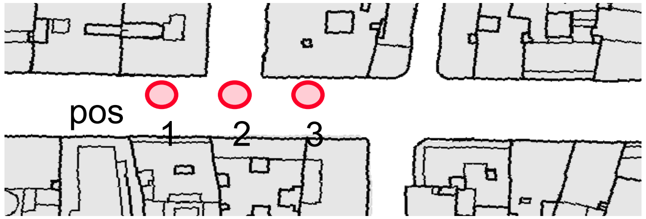
Compare with reference data:

Reference data: $\bar{\mathbf{d}}^1, \bar{\mathbf{d}}^2, \ldots, \bar{\mathbf{d}}^K$ with $\bar{\mathbf{d}}^i = [\bar{\mathbf{f}}_1^i, \ldots, \bar{\mathbf{f}}_M^i]$ M samples/pos

$\mathbf{f}^i$ → Location algorithm → Position estimate $\hat{i}$

Kplus Kompetenzzentren-Programm

Method continued



Assign model λ to every position:

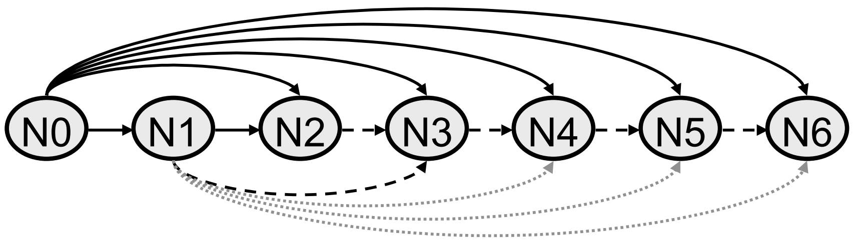
$$\lambda^i \Longleftrightarrow \text{pos } i$$

Model λ^i: represents all reference data d^i at position i

→ use non parametric models

→ Used prior information (of neighboring positions)

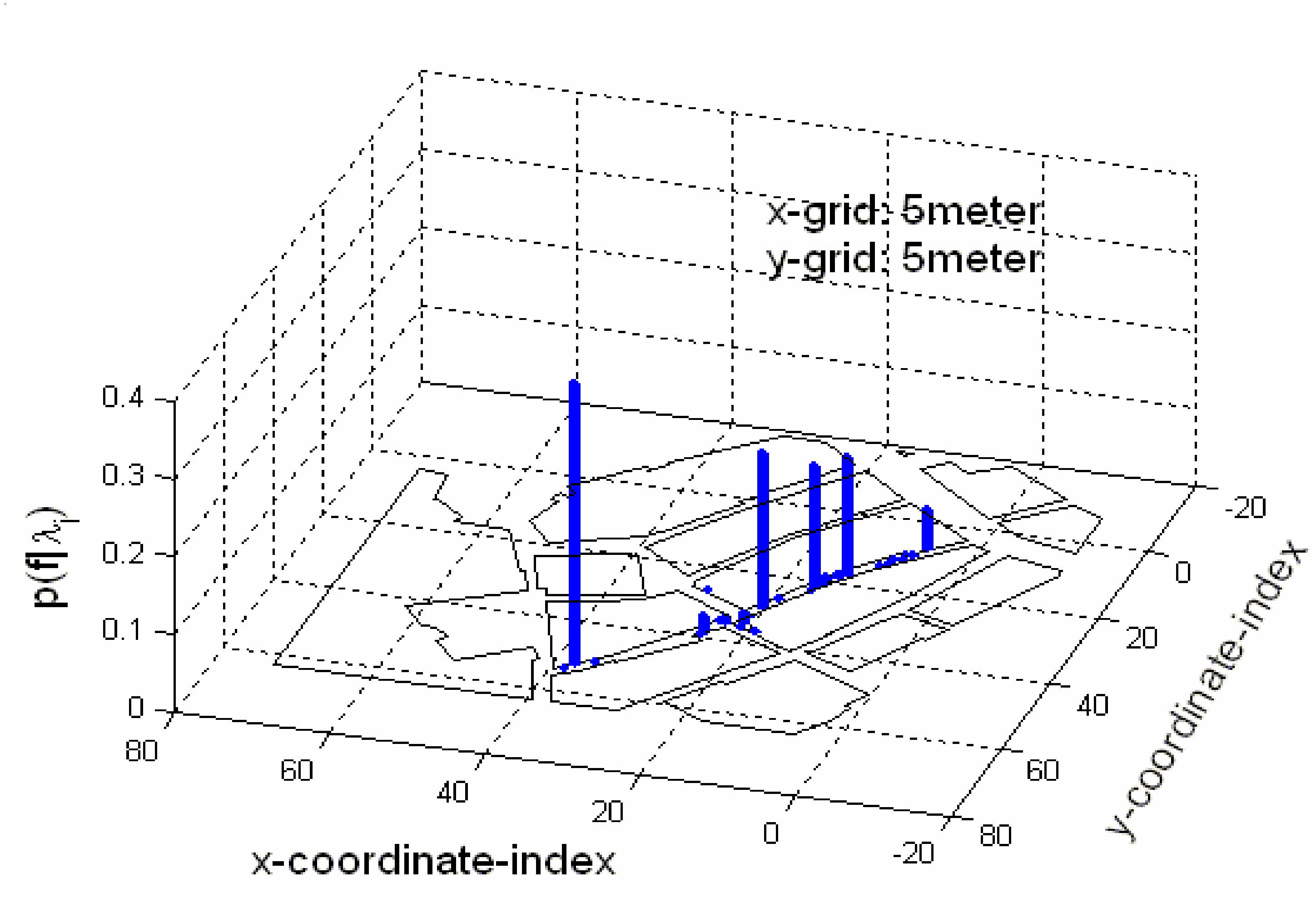
→ Use incomplete alphabet of nodes to decrease cardinality



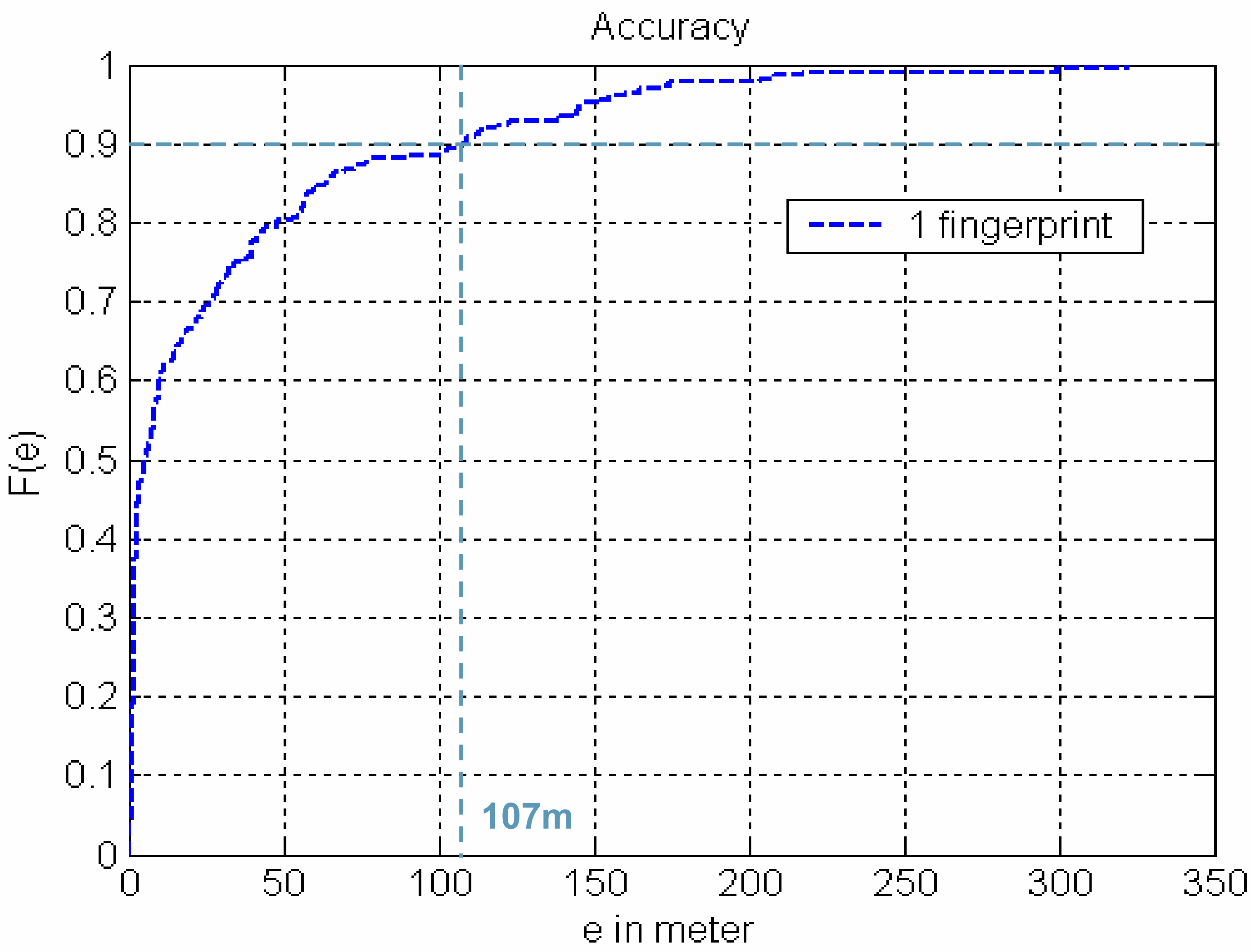
N0: Serving Cell
N1-N6: Neighboring cells

Likelihood of Position i

Localization: Find the model λ^i (and thus i) which emits most likely the measured fingerprint $\mathbf{f}^i$



Accuracy in Urban Areas



2800 test cases, uniformly distributed within target area

Utilization of Several Fingerprints

Step 1:

time t = k

Step 2:

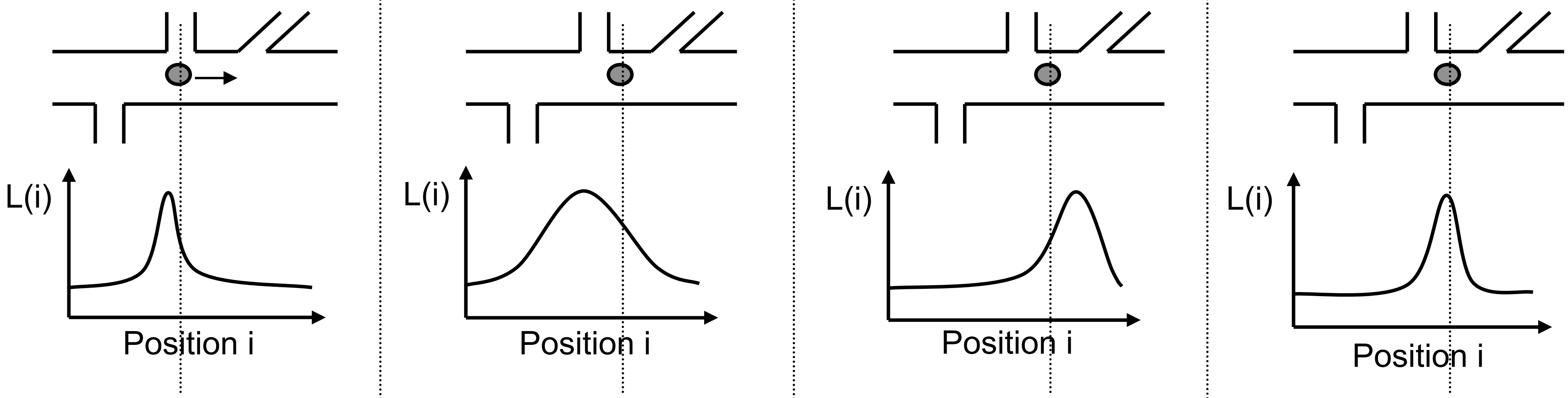
time t = k+1

Step 3:

time t = k+1

Step 4:

time t = k+1



First position estimate

Propagated position estimate

Second position estimate

Combined first and second position estimate

Motion Model (based on [1])

- Constant velocity for the time under consideration
- Obstacles are viewed as perturbations upon the constant velocity
- Users try to reestablish their constant velocity

Use state space model:

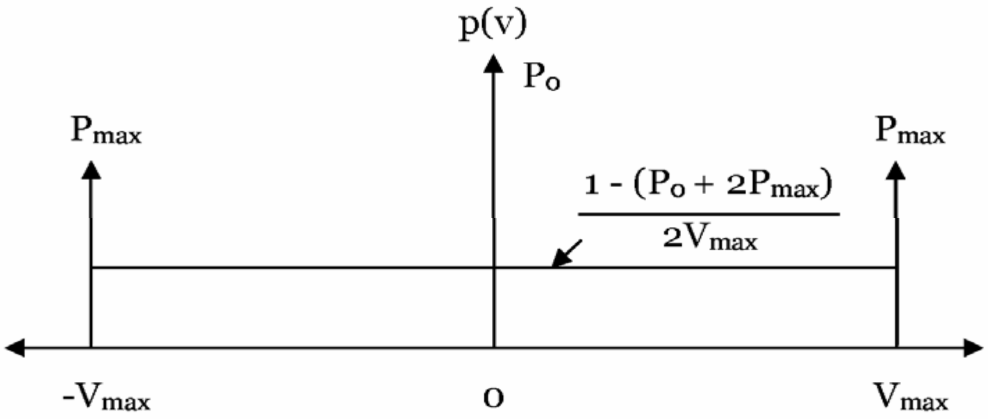
$$\begin{aligned} \dot{x}(t) &= v(t) + u(t) \\ \dot{v}(t) &= -\alpha v(t) + w(t) \end{aligned}$$

$x(t)$ ... covered distance
$v(t)$ ... user's velocity variation
$u(t)$ ... user's desired velocity
$w(t)$ ... white Gaussian noise
α ... reciprocal velocity time constant

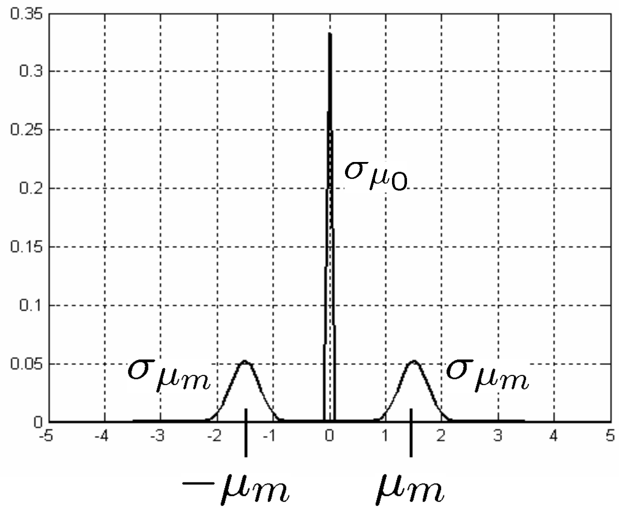
[1] D. Helbing, "A mathematical model for the behavior of pedestrians, "*Behavioral Science*, vol. 36, pp. 298–310, 1991.

Density Assumptions

Assumed probability density of velocity variation v



Assumed probability density of velocity u



V_{max} ... max. speed increase
P_0 ... probability of no perturbation
P_{max} ... probability of max. speed increase

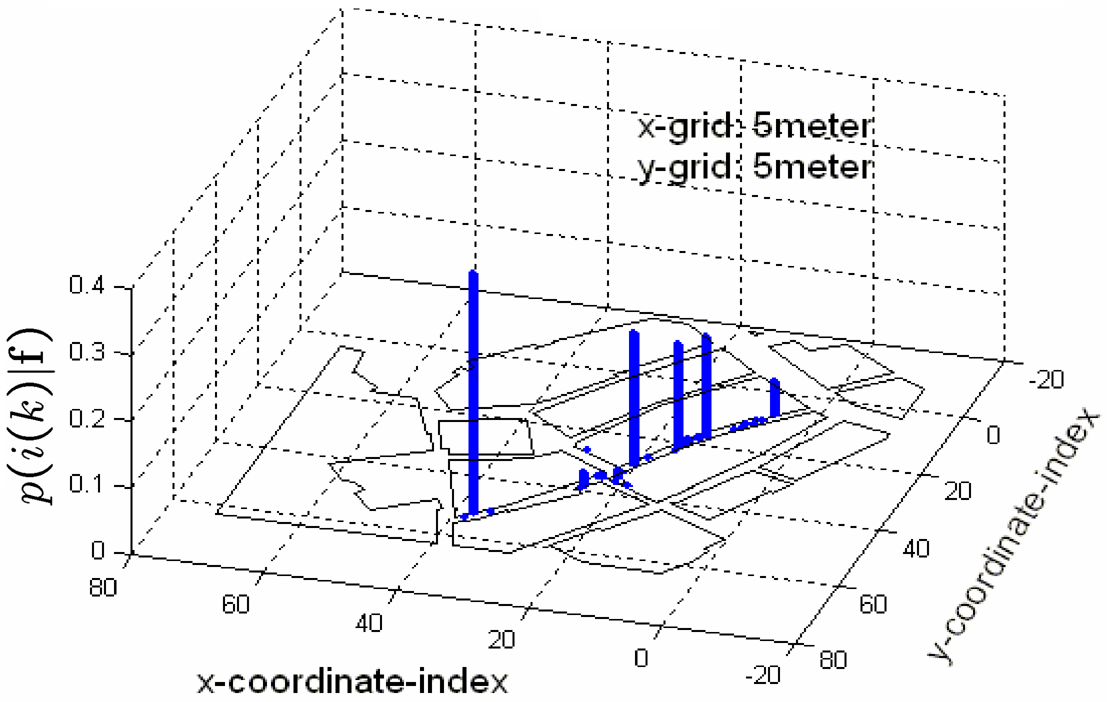
μ_m ... mean velocity of moving user
$\sigma^2_{\mu_m}$ ... variance of moving user
$\sigma^2_{\mu_0}$ ... variance of motionless user

Propagation of Position Estimate

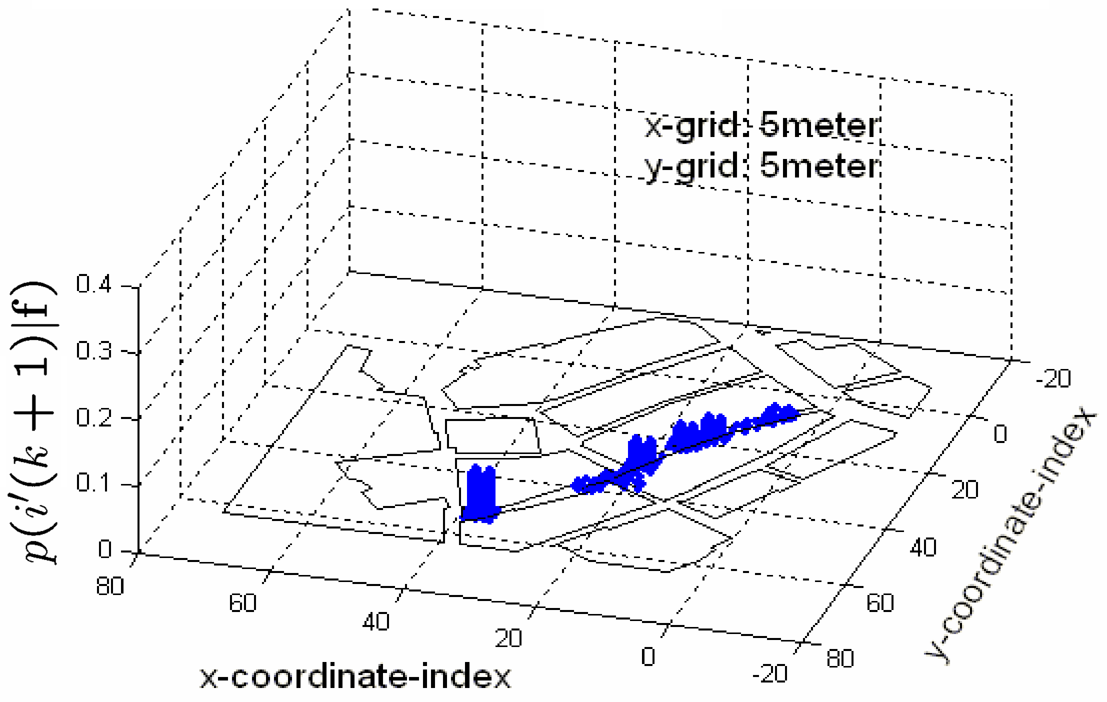
$\mathcal{L}(i) \propto p(i)$ ... if no prior belief about $p(\mathbf{f})$ and $p(i)$

$i'(k+1) = i(k) + x(k+1)$ ← motion model's contribution; ← position estimate at time k

Probability of being at position i at time k



Probability of being at position i' at time k+1



Combination of Position Estimates

$$\underbrace{i^*(k+1)}_{\text{new combined estimate}} = (I - K)\underbrace{i'(k+1)}_{\text{propagated estimate}} + K\underbrace{i(k+1)}_{\text{new estimate at time k+1}}$$

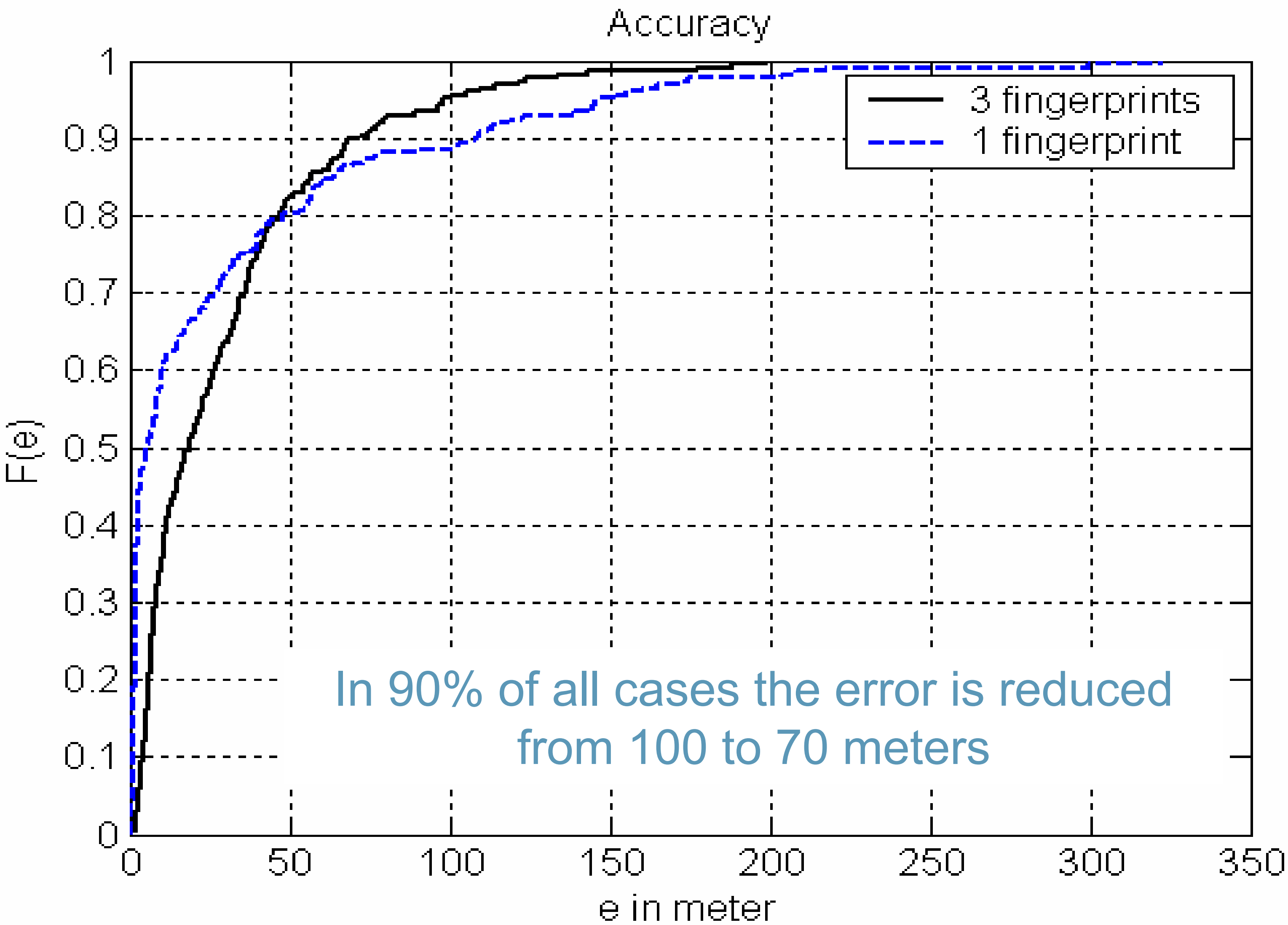
K ... Blending Factor

I ... Identity Matrix

- K is found by minimizing the variance of the estimator
- K can be computed in closed form

Test Area

Accuracy (3 Fingerprints)



2800 test cases, uniformly distributed within target area

Conclusions

Pro:
- → 100% availability (GPS less than 60% in downtown of Vienna)
- → Accuracy upper bounded by cell size.
- → Suitable for urban areas.

Con:
- → Reference data (still) necessary
- → Weak for indoor environments (but can be combined with other methods)

Thank you!