Cooperative indoor localization using multipath channel information

Josef Kulmer, Erik Leitinger, Paul Meissner, Stefan Hinteregger, and Klaus Witrisal

Graz, University of Technology

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Cooperative indoor localization using multi-path channel information

Motivation

- indoor positioning requires infrastructure, e.g. physical anchors
- omit physical anchors by employment of multipath propagation model and cooperation among agents
- reflective surfaces (e.g. wall segments, windows, . . .) act as physical anchors

Contribution

- indoor localization exploiting multipath propagation of radio frequency channels
- use floorplan information only

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1. Signal and multipath propagation model
2. Proposed algorithm
3. Results
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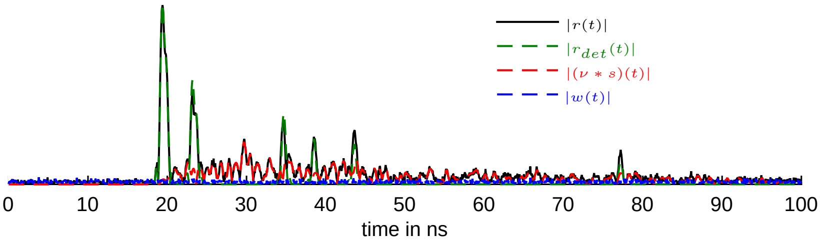
   - Sensitivity analysis
4. Conclusion

SIGNAL & CHANNEL MODEL

Received signal[1]

$$r(t) = \sum_{k=1}^{K} \alpha_k s(t - \tau_k) + (\nu * s)(t) + w(t)$$



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Signal & Channel Model

Received signal[2]

$$r(t) = \sum_{k=1}^{K} \alpha_k s(t - \tau_k) + \nu(t) * s(t) + w(t)$$

with delay τ_k denoted as

$$\tau_k = \frac{1}{c} \left\| \mathbf{p}^{(m)} - \mathbf{p}_k^{(m')} \right\|$$

with agent positions $\mathbf{p}^{(m)}$ and virtual anchor positions $\mathbf{p}_k^{(m')}$

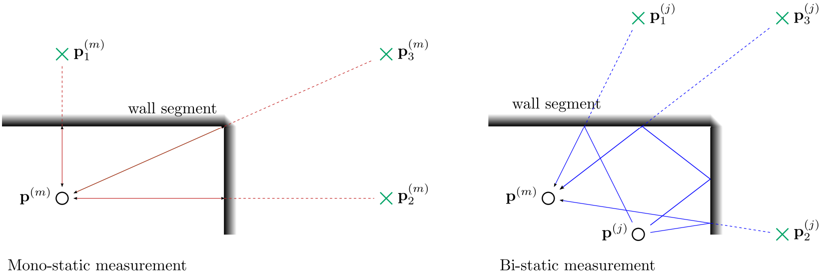
[2] K. Witrisal, P. Meissner: **'Performance Bounds for Multipath-assisted Indoor Navigation and Tracking (MINT),'** IEEE International Conference on Communications (ICC), 2012.

SIGNAL & CHANNEL MODEL

Measurement function

$$\tau_k = \frac{1}{c} \left\| \mathbf{p}^{(m)} - \mathbf{p}_k^{(m')} \right\|$$

Multipath propagation model



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[3] J. Kulmer, E. Leitinger, P. Meissner, K. Witrisal: Cooperative Multipath-Assisted Navigation and Tracking: A Low-Complexity Approach, Future Access Enablers of Ubiquitous and Intelligent Infrastructures. Springer 2015

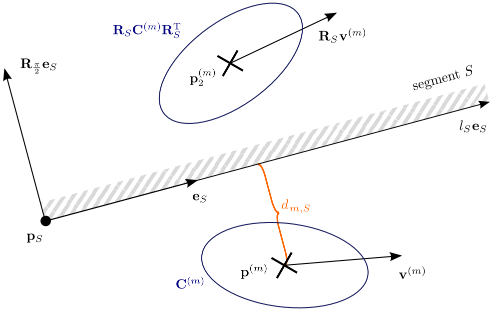
Multipath propagation model

Position uncertainty and velocity of agent m

- agent m's position described by $\mathcal{N}(\mathbf{p}^{(m)}, \mathbf{C}^{(m)})$
- and velocity $\mathbf{v}^{(m)}$

Relation to virtual anchors

- virtual anchor position, uncertainty and velocity are determined by reflector alignment $\mathbf{R}_S$



Proposed Algorithm

Linear state space model

$$
\begin{aligned}
\text{motion model:} \quad & \mathbf{x}_n = g(\mathbf{x}_{n-1}) + \mathbf{n}_{a,n} \\
\text{measurement model:} \quad & \mathbf{z}_n = h(\mathbf{x}_n) + \mathbf{n}_n
\end{aligned}
$$

Measurements

- self measurement
  - agent transmits and receives simultaneously (both antennas placed next to each other)
  - measurement results are independent on neighboring agents
- relative measurement
  - measurement between two agents (cooperative)
  - measurement results depend on both agent's positions

PROPOSED ALGORITHM

Extended Kalman Filter

- prediction step
  - linear constant-velocity model
- update step
  - measure impulse responses of each self and relative measurement
  - estimate channel parameters α_k and τ_k of each measurement
    - τ_k covers delay information
    - α_k covers reliability
  - predict deterministic delays
  - associate deterministic and measured delay
  - estimate agent positions by linearization of the multipath propagation model

Measurements

Setup

- two agents move along trajectories
- floorplan is known (34 reflectors: windows, doors, concrete walls)
- no additional physical anchors

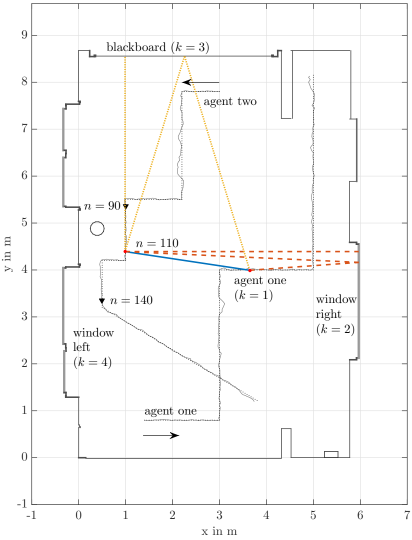
Channel measurements

- two self measurements
- one relative measurement
- impulse response shaped with raised cosine of 2 GHz bandwidth at 7 GHz carrier frequency

Measurements

Proof-of-concept

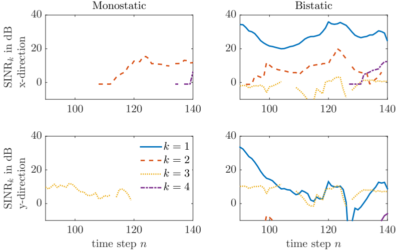
- estimated MPCs of agent two

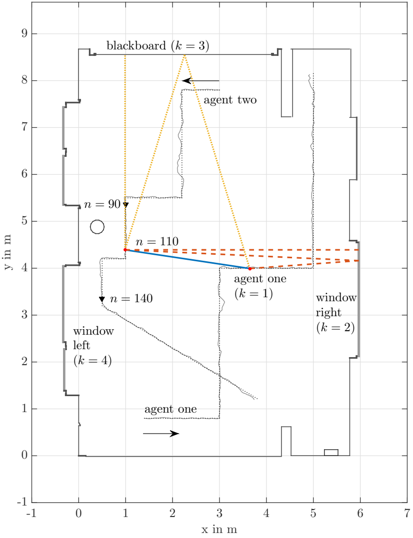


MEASUREMENTS

Proof-of-concept

- estimated MPCs of agent two
- reliability of MPCs





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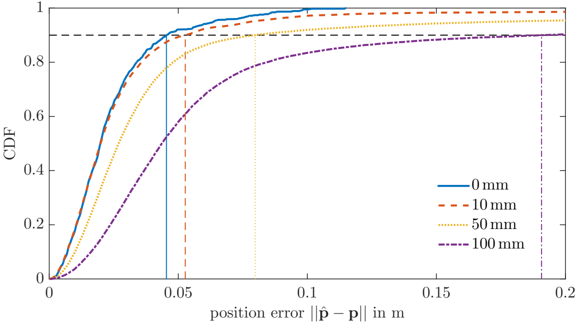
Measurements

Impact of floorplan accuracy

- virtual anchor positions rely on provided floorplan
- add uniform distributed noise to floorplan segment positions



Summary

Conclusion

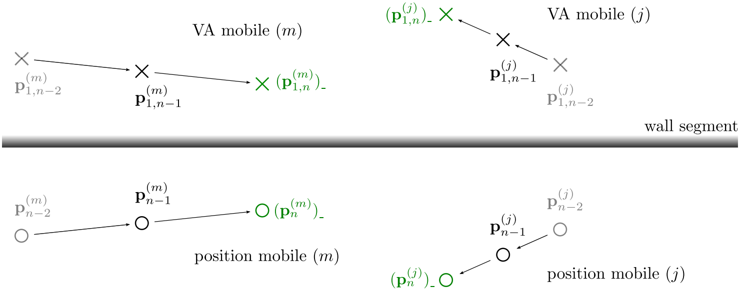
- Anchorless, cooperative localization using multipath components
- Focus on robustness and accuracy
- Assumptions
  - no external interference
  - perfect synchronization between agents
  - floorplan is provided with high accuracy

Future work

- Distributed localization
- Cognitive positioning

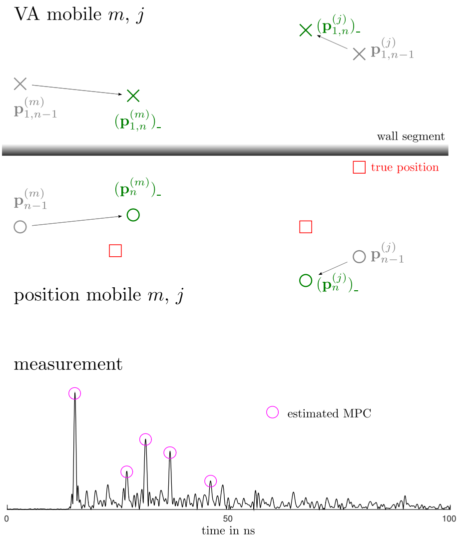
IMPLEMENTATION

- Prediction step
  - constant velocity motion model
  - virtual anchor (VA) movement dependent on the floor plan



IMPLEMENTATION

- Update Step
  - Perform measurements of each mobile
  - Estimate arrival time of multipath components
  - Compute expected delays given the virtual anchors
  - Data Association of estimated and expected set of MPCs
  - Perform EKF update step



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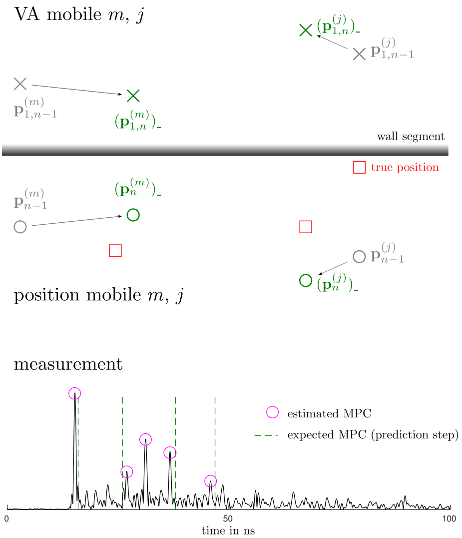

Implementation

- Update Step
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