Direct Localization: An Ising Model Approach

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Introduction

- With the emergence of location-based services, accurate knowledge of indoor location information has become important.
- Direct localization is an indoor positioning method in which the location of user is directly estimated from the received signal data in the base stations.

System Model

- 2D environment
- P receivers equipped with ULA with M elements
- The $M \times 1$ received signal vector at access point p:

$$\mathbf{y}_p = \mathbf{a}(\theta_p, \tau_p) s_p + \mathbf{n}_p$$

  - $s_p \in \mathbb{C}$: Complex signal amplitude
  - θ_p: Angle of arrival
  - τ_p: Time of flight
  - $\mathbf{n}_p \in \mathbb{C}^{M\times 1}$: Complex white Gaussian noise vector
  - $\mathbf{a}(\theta_p, \tau_p) \in \mathbb{C}^{M\times 1}$: Complex array manifold vector:

$$\mathbf{a}(\theta_p, \tau_p) = \left[\Omega_{\tau_p}, \Omega_{\tau_p}\Gamma_{\theta_p}, \cdots, \Omega_{\tau_p}\Gamma_{\theta_p}^{(M-1)}\right]^T$$

    * $\Gamma_{\theta_p} = e^{-j2\pi\frac{d}{\lambda}\sin(\theta_p) + j\frac{\pi d^2}{\lambda r_p}\cos^2(\theta_p)}$
    * $\Omega_{\tau_p} = e^{-j2\pi\Delta f \tau_p}$

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Methodology

- **Main Principles:** *Sparsity*
  - LoS path for all the base stations originates from a common location.
  - NLoS paths have a random nature.

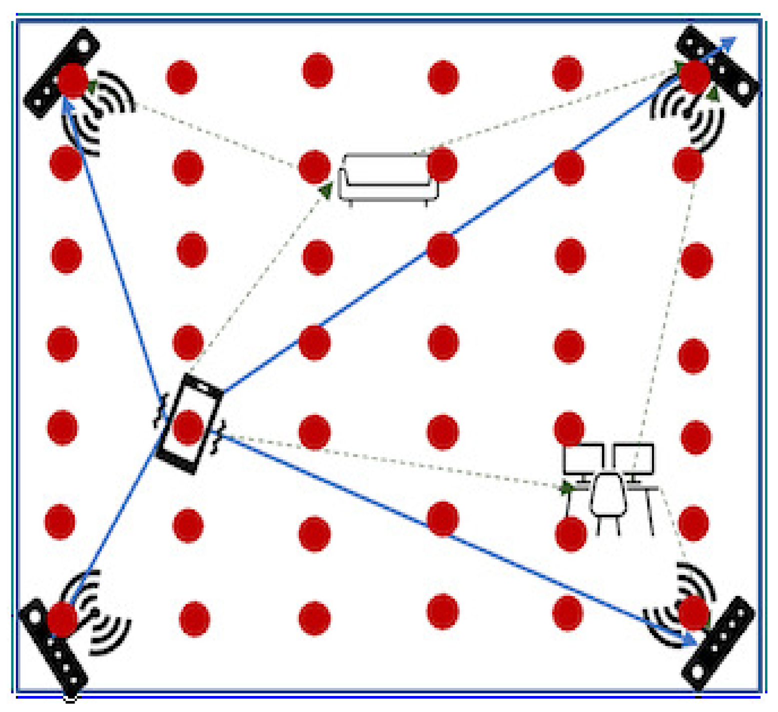


Figure 1: The 2D environment and the uniform grid

- **Procedure:**
  - Uniformly grid the environment
  - Form the over-complete array manifold for each access point:

$$\Psi_p = [\mathbf{a}(\theta_p^{(1)}, \tau_p^{(1)}), \mathbf{a}(\theta_p^{(2)}, \tau_p^{(2)}), \cdots, \mathbf{a}(\theta_p^{(G)}\theta_p^{(G)})]$$

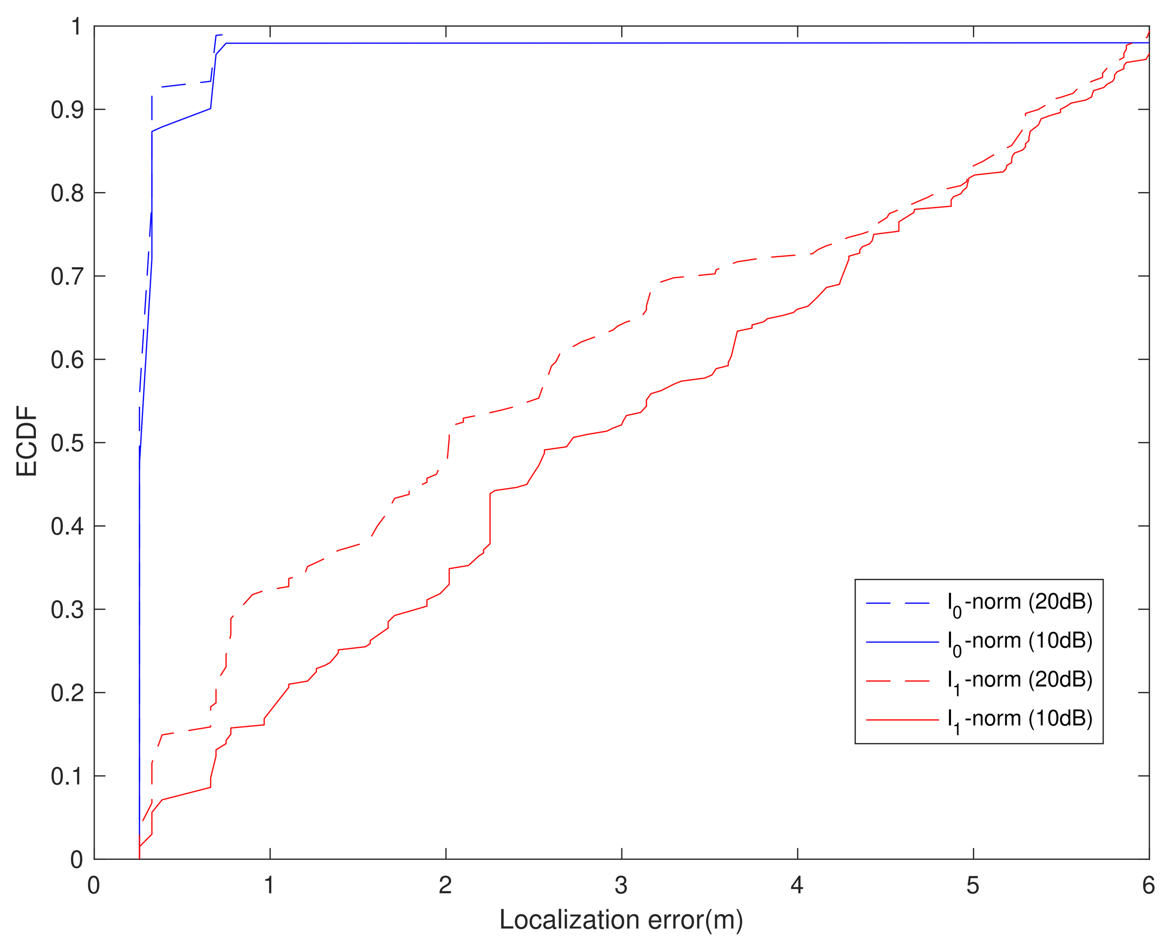
  - Form the approximate support recovery problem:

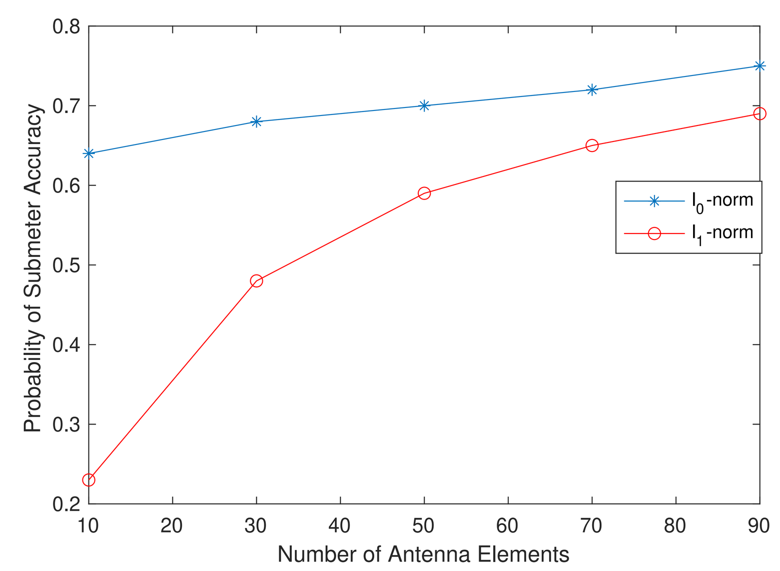
$$\min_{\mathbf{x}\in\{0,1\}^G} \quad ||\mathbf{x}||_0$$
$$\text{s.t.} \quad ||\mathbf{y}_p - \Psi_p \mathbf{x}||_2^2 < \epsilon, \quad p = 1, 2, \cdots, P$$

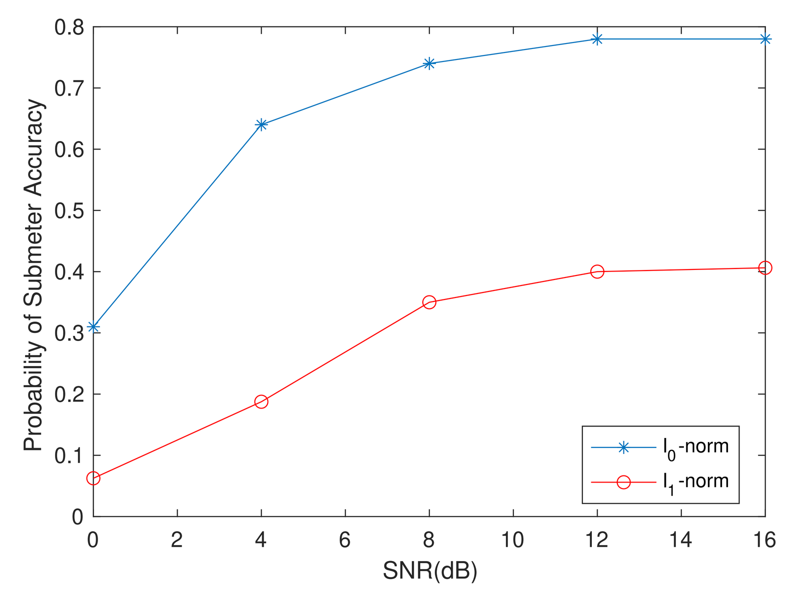
  - Restructure the regularized ℓ_0-norm minimization problem into Ising model formulation[1].
  - Solve the Ising model problem using digital annealer [2]

Results

- Used the WIM2 simulator[3] to generate the received signal.
- Compared the results for the proposed method and [4]







Conclusion

- We investigated a direct localization method in a multipath environment with an Ising energy model.
- We presented a method to co-process the received signal of all the access points to increase the accuracy of localization.
- The problem is formulated by the compressed sensing structure and is transformed to an Ising energy minimization problem.
- This NP-hard problem can be solved with Markov chain Monte-Carlo methods.
- Numerical results show that this method outperforms the existing methods in the literature.

References

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