Problem Formulation

This work addresses the source localization and association problem in a multipath propagation environment. The problem of source association (i.e., assigning a source to each detected path) is rarely considered by existing methods.

Methodology

1. Overcomplete Representation for Multiple Time Samples

We exploit the sparse characteristic of spatial signals and transform the location parameter estimation into sparse spectrum estimation. An overcomplete $M \times N$ dictionary is constructed such that

$$D_{jk} = \{a(\theta_{jk1}), \ldots, a(\theta_{jkl}), \ldots, a(\theta_{jkl})\} \quad (2)$$

where $(\theta_{jkl})$ denotes a sampling grid set with $N$ being the number of potential path directions.

With $D_{jk}$, (1) is then reformulated as

$$x(t) = D_j \psi(t) + n(t) \quad (3)$$

$r(t) \in \mathbb{C}^{M \times 1}$ denotes sparse (parameterized) coefficient vector with the $k$th element being

$$r_k(t) = \{r_{k, n_k1}, \ldots, r_{k, n_k1}, \ldots, r_{k, n_k1}\} \quad (4)$$

where $r_{k, n_k1}$ is the $k$th element of $r(t)$, $\theta_{jk} \in \mathbb{R}^{K \times 1}$, $\theta_{jk1} = [1, 2, \ldots, K]$, $p = 1, 2, \ldots, P_j$, $\theta_{jk2}$ is defined as

$$X = D_j \psi(t) + n(t) \quad (5)$$

2. Source Localization Based on Iterative Implementation with Semi-Unitary Constraint

The proposed source localization technique aims to estimate the $M \times N$ adaptive filter bank matrix $W$ and $N \times L$ parameterized matrix $R$ via

$$\begin{bmatrix} R & X \end{bmatrix} = \arg \min_{R, X} \{ \| R - W X \|_F^2 \text{ s.t. } WW^H = I_n \} \quad (6)$$

We introduce an iterative optimization strategy to solve (6)

1. updating $W$:

$$W_{st} = \arg \min_{R, X} \{ \| R - W_{st} X \|_F^2 \text{ s.t. } WW^H = I_n \} \quad (7)$$

2. Dictionary learning:

$$R_{st} = \min_{X} \text{ s.t. } WW^H = I_n$$

3. Source Association via Subspace Technique

Performing eigenvalue decomposition (EVD) on $R_{st}$ results in

$$X = E \{ \lambda_{1}, \ldots, \lambda_{M} \} U_{M \times M}^H U_{M \times M}^H$$

Since the signal-subspace and the noise-subspace are orthogonal to each other, we have

$$\begin{bmatrix} \lambda_k \end{bmatrix} = \begin{bmatrix} \lambda_k \end{bmatrix} \quad (8)$$

Non-full rank

The source vector is the $k$th source association set $G_k$, and $G_k = [1, 2, \ldots, K]$. $G$ is the number of possible combinations

$$Z_{G_k} = \text{corresponding number index vector}$$

The SA can be achieved by selecting one that minimizes $r_{k, n} = \sum_{z_k} z_k G_k$ among all the $G$ combinations.

Contributions

- We propose a joint source localization and association (JSLA) algorithm in the presence of multipath propagation environment.
- The initialization of path detection set, additional decorrelation preprocessing, and the prior information pertaining to multipath propagation scenario such as multipath channel parameters are not required in JSLA.
- It has no specific restrictions on the array manifold.

Simulation and experimental results

Radar System and Scenario Parameter

A 16-sensor uniform linear array (ULA) with half-wavelength element spacing is employed.

1. Simulation Results

Fig. 2: Variation of RMSE in terms of DOA estimate.

Fig. 3: The correct association probability versus SNR.

2. Measured Data Validation

Fig. 4: Target location parameter estimate result versus the observation time. (a) DOA estimate produced by different methods. (b) Estimate error of target DOA produced by different methods.

These results indicate that JSLA outperforms the baseline methods in terms of estimation accuracy and robustness.

References