論文の内容の要旨

Robust Microphone Array Signal Processing against Diffuse Noise
(拡散性雑音に頑健なマイクロフォンアレイ信号処理に関する研究)

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We consider the general problem of microphone array signal processing in diffuse noise environments. This has various applications epitomized by speech enhancement and robust Automatic Speech Recognition (ASR) for microphone arrays. Diffuse noise arriving from almost all directions is often encountered in the real world, and has been one of the major obstacles against successful application of existing noise suppression and Direction-Of-Arrival (DOA) estimation techniques. We operate in the time-frequency domain, where signal and noise are assumed to be zero-mean Gaussian and modeled by their respective covariance matrices.

Firstly, we introduce a general linear subspace model of the noise covariance matrix that extends three state-of-the-art models and propose a fourth more flexible real-valued noise covariance model.

Secondly, we apply this general model to the task of diffuse noise suppression with a known target steering vector. In the state-of-the-art Wiener post-filtering approach, it is essential to accurately estimate the short-time power spectrum of the target signal. Our algorithm estimates it based on denoising the observed covariance matrix by projecting this matrix onto the orthogonal complement of the linear subspace noise

model. The proposed method was validated through experiments with both synthetic and real-world noise.

Thirdly, we address the task of DOA estimation of multiple sources. The performance of the state-of-the-art MUltiple SIgnal Classification (MUSIC) algorithm is known to degrade in the presence of diffuse noise. In order to mitigate this effect, we estimate the signal covariance matrix and subsequently apply MUSIC to it. The estimation relies on the previously derived noise-free component of the observed covariance matrix and on the reconstruction of the remaining component via matrix completion techniques. We design two alternative algorithms based on low-rank matrix completion and trace-norm minimization that exploit the low-rankness and the positive semidefiniteness of the signal covariance matrix. The performance of the proposed methods and the models were compared with a large database we created.

Finally, we present a technique for diffuse noise suppression with an unknown target steering vector. The steering vector and the power spectrogram of the target signal are jointly estimated using the noise-free component of the observation covariance matrix. The derived algorithm updates the steering vector and the power spectrogram alternatively. In the real-world validation, the proposed method outperformed a state-of-the-art blind algorithm called Independent Vector Analysis (IVA); the proposed method gave an output Signal-to-Noise Ratio (SNR) higher by approximately 7dB.