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Rank Estimation and Redundancy Reduction of High-Dimensional Noisy Signals with Preservation of Rare Vectors

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Abstract

In this paper, we address the problem of redundancy-reduction of high-dimensional noisy signals that may contain anomaly (rare) vectors, which we wish to preserve. For example, when applying redundancy reduction techniques to hyperspectral images, it is essential to preserve anomaly pixels for target detection purposes. Since rare-vectors contribute weakly to the ℓ_2-norm of the signal as compared to the noise, ℓ_2-based criteria are unsatisfactory for obtaining a good representation of these vectors. The proposed approach combines ℓ_2 and ℓ_∞ norms for both signal-subspace and rank determination and considers two aspects: One aspect deals with signal-subspace estimation aiming to minimize the *maximum* of data-residual ℓ_2-norms, denoted as $\ell_{2,\infty}$, for a given rank conjecture. The other determines whether the rank conjecture is valid for the obtained signal-subspace by applying Extreme Value Theory results to model the distribution of the noise $\ell_{2,\infty}$-norm. These two operations are performed alternately using a suboptimal greedy algorithm, which makes the proposed approach practically plausible. The algorithm was applied on both synthetically simulated data and on a real hyperspectral image producing better results than common ℓ_2-based methods.

Index Terms

Signal-subspace rank, singular value decomposition (SVD), minimum description length (MDL), anomaly detection, dimensionality reduction, redundancy reduction, hyperspectral images.