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Structured Sparse Representation with Low-Rank Interference – Algorithms and Applications

Dissertation Defense by
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Abstract

Nowadays, many modern applications in signal processing, machine learning or computer vision involve representations of multiple correlated signals where data sampling is performed simultaneously from multiple co-located sources, yet within a small time frame, recording the same physical events. This scenario allows exploitation of complementary features within related signals to improve signal recovery and guide successful decision making. One powerful tool to efficiently incorporate multiple related measurements is sparse representation. A sparse signal representation allows us to capture the hidden simplified structure often present in the data jungle, and thus minimizes the harmful effects of noise in practical settings. However, current sparsity-based approaches are limited due to several critical drawbacks: (i) the lack of capability to effectively deal with very large noise/interference; (ii) most existing methods require the prior knowledge of interfered signals, while in real-world problems such information is often unknown; and (iii) rich spatio-temporal correlation structures often existing in natural signals have not been fully incorporated.

This dissertation presents new theoretical ideas and mathematical frameworks on structured sparse data representations in the presence of low-rank interference. We provide various novel models for the representation of multiple measurements where signals exhibit a high level of correlation over a proper dictionary but are severely corrupted by some interference which can be signals from external sources, underlying background, or any pattern noise that remains stationary during signal collection. Under the assumption that the interference component forms a low-rank structure, the proposed models minimize the rank of the interference to exclude it from the representation of multivariate sparse representation. We demonstrate that this is particularly essential in a multi-sensor problem since sensor co-location ensures that interference noise patterns are very similar, hence justifying the low-rank assumption. Fast and efficient algorithms based on alternative direction method are proposed where the convergence to optimal solutions is guaranteed. Extensive experiments are conducted on various practical applications: (i) synthetic aperture radar image recovery; (ii) hyperspectral chemical plume detection and classification; (iii) robust speech recognition in noisy environments; (iv) video-based facial expression recognition; and (v) multi-sensor classification on automatic border patrol control to verify the effectiveness of the proposed methods.

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