A new concept for compressive radio-interferometric imaging: the modulated rank-one projection model

O. Leblanc(1) C. S. Chu(2), L. Jacques(1), and Y. Wiaux*(2)
(1) ISPGroup, INMA/ICTEAM, UCLouvain, 1348 Louvain-la-Neuve, Belgium
(2) Institute of Sensors, Signals and Systems, Heriot-Watt University, Edinburgh, EH14 4AS, UK

The emerging generation of radio-interferometric (RI) arrays, such as the upcoming Square Kilometre Array (SKA), are set to observe the sky with unprecedented angular resolution and sensitivity. This ambition leads to the requirement of arrays with a large number of antennas. As an array with Q antennas acquires noisy Fourier samples of the field of view of interest in the form of a $Q \times Q$ covariance matrix at each of B short-time integration intervals, or batches, data volumes scale as $\mathscr{O}(Q^2 B)$. As a result, an array such as SKA is to generate Exabyte-scale data volumes for each observation, calling for efficient data dimensionality reduction techniques.

We discuss here recent work [1, 2] proposing a new approach to data compression during acquisition, coined the **M**odulated **R**ank-**O**ne **P**rojection model. **MROP** compresses the covariance matrix associated with each batch into a smaller number of rank-one projections, and compresses across time by trading the number of batches for a smaller number of Bernoulli modulations of the ROP measurement vectors. Firstly, our work introduces a dual perspective on the acquisition of MROPs, which can either be understood as random beamforming, or as a post-correlation compression. Secondly, theoretical image recovery guarantees are discussed, establishing that the sample complexities of MROP scale with the image sparsity. Thirdly, the expected efficiency of the scheme is studied via a detailed analysis of the memory and computational cost requirements throughout the data acquisition and image reconstruction stages, with comparison to state-of-the-art dimensionality reduction approaches. Finally, extensive numerical experiments are proposed to validate the MROP model on simulated MeerKAT observations, with comparison to the classical and baseline-dependent averaging (BDA) [3] models, and using the uSARA optimisation algorithm for image formation [4].

Additional experiments, as part of ongoing investigations, will also be discussed, aiming to validate the MROP model for reconstruction with the deep-learning based image formation algorithms AIRI [4] and R2D2 [5].

References

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