URSI GASS 2022, Gran Canaria, Spain, 29 May -3 June 2022

AI for Regularization in Radio-Interferometric Imaging (AIRI)

M. Terris(1), A. Dabbech(1), C. Tang(1)(2), A. Wilber(1), A. Jackson(2), and Y. Wiaux(1)
(1) Institute of Sensors, Signals and Systems, Heriot-Watt University, Edinburgh EH14 4AS, UK
(2) EPCC, University of Edinburgh, Edinburgh EH8 9BT, United Kingdom

Radio interferometric (RI) imaging consists in recovering an image from noisy and undersampled Fourier data probed by an array of antennas, yielding an ill-posed inverse problem towards image formation. Inspired by plug-and-play algorithms, we propose a new class of iterative algorithms for scalable precision radio-interferometric imaging, at the interface of convex optimization and deep learning. The approach entails learning a prior image model by training a deep neural network (DNN) as a denoiser, and substituting it for the proximal regularization operator of an optimization algorithm for image reconstruction. AIRI, standing for "AI for Regularization in Radio-Interferometric Imaging", inherits the robustness and interpretability of optimization approaches, and the learning power and speed of networks, while avoiding generalizability limitations of end-to-end networks for which training involves the details of the measurement model. We have developed a first AIRI algorithm capable of imaging complex structures with diffuse and faint emissions by (i) designing, from optical images, a realistic but low dynamic range database for supervised training, (ii) training a denoiser at a noise level inferred from the signal-to-noise ratio of the data, with a carefully tailored training loss to ensure algorithm convergence [1], and including on-the-fly database dynamic range enhancement via exponentiation, (iii) plugging the DNN into the forward-backward optimization algorithm, resulting in a simple iterative structure alternating a denoising step with a gradient-descent data-fidelity step. Simulations show that AIRI is superior to the advanced optimization algorithms of the SARA family in imaging quality (well beyond CLEAN), while providing significant acceleration (though still remaining slower than CLEAN). We further show that the method generalises well on real RI data. Using a faceted version of AIRI where the DNN is applied in parallel across patches of the image, we have shown that we can reconstruct the full field of view for sub-band observations made with the Australian SKA pathfinder (ASKAP) up to a resolution of 2.2 arcsec, with outstanding reconstruction quality. This abstract summarises work from two full papers in preparation [2, 3].

References

[1] Pesquet et al, "Learning maximally monotone operators for image recovery." SIAM Journal on Imaging Sciences 14.3 (2021): 1206-1237.

[2] Terris et al, "Radio-interferometric imaging with learned denoisers (AIRI)", 2022, in preparation (https://researchportal.hw.ac.uk ID 51886679).

[3] Wilber et al, "AI for Regularization in Radio-Interferometric Imaging (AIRI) validated on ASKAP data", 2022, in preparation.