Aperture Domain Model Image Reconstruction with Hyperbolic Regularization

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Background, Motivation, and Objective

The degradation of biomedical ultrasonic image quality has typically been attributed to two primary sources, aberration and reverberation. The resulting undesired echoes that cause fill-in and loss of contrast are referred to as clutter. Aperture Domain Model Image REconstruction (ADMIRE) (B.Byram 2015) is a model-based approach recently developed to suppress clutter.

ADMIRE relies on estimating spatial-frequential maps indicating which of the multiple considered reflection paths describe the image content and which just add to clutter. To do so, a penalized least-square criterion is minimized. Ideally, we expect the penalization to favor maps containing many small values (similar to white noise with small variance) letting large amplitude values have a sparse pattern.

The current penalization choice of ADMIRE is inspired by elastic-net regression, which linearly combines L1 and L2 penalties. While the L1 norm enforces many amplitudes to be zero, the large amplitude values will be strongly penalized by the L2 potential, leading to an underestimation (bias).

In this situation, a better penalization choice is Huber-like hyperbolic potential functions, as they provide a good tradeoff between sparsity and convexity (D.-H.Pham 2021). The objective of this work is to verify the potential improvement of data estimation and image quality when replacing the elastic-net penalty with the hyperbolic one in the ADMIRE declutter algorithm.

Statement of Methods

The optimization problem with the hyperbolic penalty is solved by the limited memory variation of the Broyden–Fletcher–Goldfarb–Shanno (L-BFGS) algorithm. The code for applying ADMIRE is open-source on Github.

The performance is evaluated by the generalized Contrast-Noise-Ratio (gCNR), Lag-One-Coherence (LOC) factor, and Speckle Signal-Noise-Ratio (SSNR) of the reconstructed Field II simulated images.

Results/Discussion

Fig. 1 illustrates the potential improvements of hyperbolic penalization. Future work includes the fine-tuning of parameters and the test on realistic datasets.

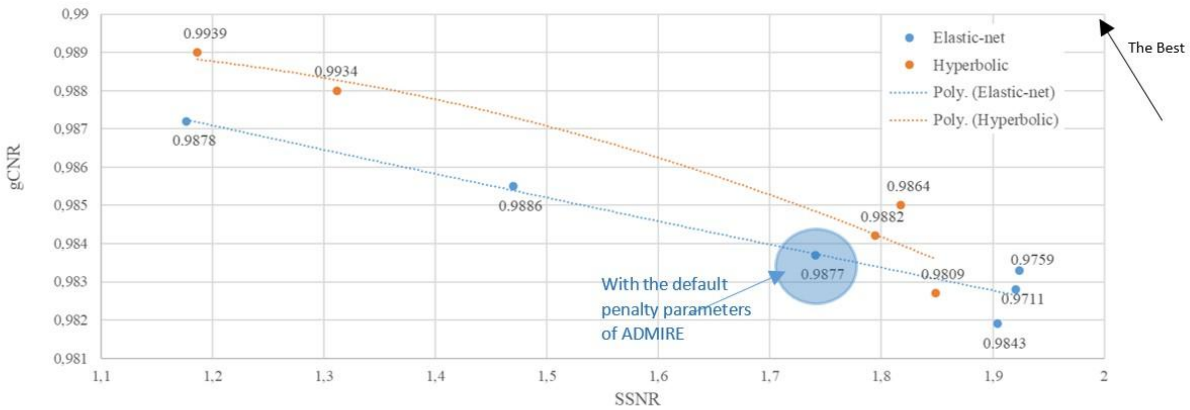

Fig. 1. Evaluation Results on a simulated dataset. Points correspond to different regularization coefficients. Dashed lines are fitted curves to the points of each method: elastic-net (blue) and hyperbolic (orange). Data labels are the LOC values.