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Deep greedy unfolding: sorting out the argsort operator in greedy sparse recovery algorithms

Recent years have seen a growing interest in "unrolled neural networks" for various signal processing applications. These networks provide model-based architectures that mimic the iterations of an iterative algorithm and, when properly designed, admit recovery guarantees. However, there has been limited work on unrolling greedy and thresholding-based sparse recovery algorithms, such as Orthogonal Matching Pursuit (OMP) and Iterative Hard Thresholding (IHT), and existing efforts often lack full neural network compatibility. The primary challenge arises from the non-differentiable (discontinuous) argsort operator within their iterations, which obstructs gradient-based optimization during training. To address this issue, we approximate argsort operator by a continuous relaxation of it using a proxy called "softsort". We then demonstrate, both theoretically and numerically, that the differentiable versions of OMP and IHT—termed "Soft-OMP" and "Soft-IHT"—serve as reliable approximations of their original counterparts, with minimal error under suitable conditions on the softsort temperature parameter and the gap between elements in the sorted vector. Finally, implementing these algorithms on neural networks, with weights as trainable parameters, reveals that unrolled Soft-OMP and Soft-IHT effectively capture hidden structures in data, establishing a connection between our approach and weighted sparse recovery.