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Orthogonal Matching Pursuit with Replacement

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(Submitted on 14 Jun 2011)

In this paper, we consider the problem of compressed sensing where the goal is to recover almost all the sparse vectors using a small number of fixed linear measurements. For this problem, we propose a novel partial hard-thresholding operator that leads to a general family of iterative algorithms. While one extreme of the family yields well known hard thresholding algorithms like ITI (Iterative Thresholding with Inversion) and HTP (Hard Thresholding Pursuit), the other end of the spectrum leads to a novel algorithm that we call Orthogonal Matching Pursuit with Replacement (OMPR). OMPR, like the classic greedy algorithm OMP, adds exactly one coordinate to the support at each iteration, based on the correlation with the current residual. However, unlike OMP, OMPR also removes one coordinate from the support. This simple change allows us to prove that OMPR has the best known guarantees for sparse recovery in terms of the Restricted Isometry Property (a condition on the measurement matrix). In contrast, OMP is known to have very weak performance guarantees under RIP. Given its simple structure, we are able to extend OMPR using locality sensitive hashing to get OMPR-Hash, the first provably sub-linear (in dimensionality) algorithm for sparse recovery. Our proof techniques are novel and flexible enough to also permit the tightest known analysis of popular iterative algorithms such as CoSaMP and Subspace Pursuit. We provide experimental results on large problems providing recovery for vectors of size up to million dimensions. We demonstrate that for large-scale problems our proposed methods are more robust and faster than existing methods.

Subjects: **Information Theory (cs.IT)**; Machine Learning (stat.ML)
Cite as: **arXiv:1106.2774v1 [cs.IT]**

Submission history

From: Ambuj Tewari [view email]
[v1] Tue, 14 Jun 2011 18:13:40 GMT (58kb)

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