

Adaptive Submodular Dictionary Selection for Sparse Representation Modeling with Application to Image Super-Resolution

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This paper proposes an adaptive dictionary learning approach based on submodular optimization. With the low-frequency components by the analytic DCT atoms, high-resolution dictionaries can be inferred through online learning to make efficient approximation with rapid convergence. It is formulated as a combinatorial optimization for approximate submodularity, which is suitable for sparse representation based on dictionaries with arbitrary structures. With application to single-image super-resolution, the proposed scheme has been demonstrated to outperform the double sparsity dictionary in reconstruction quality and operate faster than standard K-SVD.

Given a collection of training examples $\mathbf{Y} = \{y_1, \dots, y_N\}$, a dictionary \mathbf{D} is constructed by selecting atoms from the combination of the trained and analytic dictionaries. DCT dictionary with a fast computation is adopted as the analytic component, while online dictionary learning based on stochastic approximation is employed to improve computational efficiency. Both the selection of dictionary columns and the sparse representation of signals are formulated as a combinatorial optimization problem

$$\begin{aligned} L_s(\mathbf{A}) &= \min_w \{ \|y_s - \mathbf{A}w\|_2^2 \}, \\ F(\mathbf{D}) &= \frac{1}{N} \sum_{s=1}^N \left\{ L_s(\emptyset) - \min_{\mathbf{A} \subseteq \mathbf{D}, |\mathbf{A}| \leq T} L_s(\mathbf{A}) \right\}, \end{aligned} \quad (1)$$

where $y_s \in \mathbf{Y}$ is a fixed signal and \mathbf{A} is the corresponding dictionary columns for sparse representation with a sparsity constrain T . An simple greedy algorithm, which starts with an empty set and at every iteration adds a new element to maximize a submodular function as a close approximation of the original objective is introduced with a guaranteed near-optimal solution [1].

Experimental results show that reconstruction performance (PSNR and SSIM) of the proposed scheme consistently outperforms the double sparsity dictionary based on Sparse K-SVD algorithm as well as the existing learning-based super-resolution algorithm. Compared to the standard K-SVD, the proposed algorithm can achieve comparable performance while significantly reducing the computational overhead .

Reference

[1] V. Cevher and A. Krause, "Greedy dictionary selection for sparse representation," *IEEE Journal of Selected Topics in Signal Processing*, vol. 5, no. 5, pp. 979-988, Sep. 2011.

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