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Replica Analysis of the Performance of Compressed Sensing for Image Processing

Compressed sensing is one of the most effective signal processing methods based on the sparse representation of inferred data, in which dictionary matrices play an essential role as a set of overcomplete basis vectors. They are learned from data by feature extraction methods such as K-SVD ones. Therefore, in general, it requires a considerable amount of computational cost to construct a dictionary matrix.

In this work, we analytically evaluate the performance of compressed sensing for image processing, utilizing the replica method of statistical physics. For this purpose, we have derived the expression of the probability distribution followed by a dictionary matrix for image processing, assuming that grey scale images are generated by the Gaussian model [1]. Also, we have adopted the framework of replica analysis by Kabashima et. al. to analytically evaluate the performance of compressed sensing based on Lp-norm minimization [2].

Our analysis has made clear, for example, the scaling relation between the complexity of images and the optimal size of dictionary matrices, which has been addressed not in an analytical way but only in a numerical one.

[1] Y. Ashida and T. Aida, "Probability Distribution of an Image Dictionary for Compressed Sensing," Proceedings of 2016 16th International Conference on Control, Automation and Systems, pp. 1377-1380, 2016.

[2] Y. Kabashima, T. Wadayama and T. Tanaka, "A typical reconstruction limit for compressed sensing based on Lp-norm minimization," Journal of Statistical Mechanics: Theory and Experiment, (2009) L09003.