Efficient variational inference in large-scale Bayesian compressed sensing

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We study linear models under heavy-tailed priors from a probabilistic viewpoint. Instead of computing a single sparse most probable (MAP) solution as in standard deterministic approaches, the focus in the Bayesian compressed sensing framework shifts towards capturing the full posterior distribution on the latent variables, which allows quantifying the estimation uncertainty and learning model parameters using maximum likelihood. The exact posterior distribution under the sparse linear model is intractable and we concentrate on variational Bayesian techniques to approximate it. Repeatedly computing Gaussian variances turns out to be a key requisite and constitutes the main computational bottleneck in applying variational techniques in large-scale problems. We leverage on the recently proposed Perturb-and-MAP algorithm for drawing exact samples from Gaussian Markov random fields (GMRF). The main technical contribution of our paper is to show that estimating Gaussian variances using a relatively small number of such efficiently drawn random samples is much more effective than alternative general-purpose variance estimation techniques. By reducing the problem of variance estimation to standard optimization primitives, the resulting variational algorithms are fully scalable and parallelizable, allowing Bayesian computations in extremely large-scale problems with the same memory and time complexity requirements as conventional point estimation techniques. We illustrate these ideas with experiments in image deblurring.

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