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An adaptive Monte-Carlo Markov chain algorithm for counting muons in Auger water Cherenkov detector signals

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Adaptive Metropolis (AM) is a powerful recent algorithmic tool in numerical Bayesian data analysis. AM builds on a well-known Markov Chain Monte Carlo (MCMC) algorithm but optimizes the rate of convergence to the target distribution by automatically tuning the design parameters of the algorithm on the fly. In our data analysis problem of counting muons in the water Cherenkov signal of the surface detectors in the Pierre Auger Experiment, the signal is modeled by a mixture distribution. Label switching is a major problem in inference on such models because of the invariance to symmetries. The simplest (non-adaptive) solution is to modify the prior in order to make it select a single permutation of the variables, introducing an identifiability constraint. This solution is known to cause artificial biases by not respecting the topology of the posterior. In this paper we descibe a new online relabeling procedure which can be incorporated into the AM algorithm. We state the convergence of the algorithm and identify the link between its modified target measure and the original posterior distribution of interest.

Our long-term goal in the Pierre Auger Experiment is to develop a comprehensive generative model for the surface detector signal and use MCMC techniques to estimate the parameters. The first step of this program is the development of a generative model of the response of an Auger water tank and an adaptive reversible jump MCMC algorithm that can deal with the unknown number of muonic components in the signal. In the second part of this paper we discuss the algorithmic and computational issues of implementing MCMC techniques for large-scale data analysis.

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