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Riemann manifold Langevin and Hamiltonian Monte Carlo methods. With discussion and authors' reply. (English) Zbl 1411.62071

J. R. Stat. Soc., Ser. B, Stat. Methodol. 73, No. 2, 123-214 (2011).

Summary: The paper proposes Metropolis adjusted Langevin and Hamiltonian Monte Carlo sampling methods defined on the Riemann manifold to resolve the shortcomings of existing Monte Carlo algorithms when sampling from target densities that may be high dimensional and exhibit strong correlations. The methods provide fully automated adaptation mechanisms that circumvent the costly pilot runs that are required to tune proposal densities for Metropolis-Hastings or indeed Hamiltonian Monte Carlo and Metropolis adjusted Langevin algorithms. This allows for highly efficient sampling even in very high dimensions where different scalings may be required for the transient and stationary phases of the Markov chain. The methodology proposed exploits the Riemann geometry of the parameter space of statistical models and thus automatically adapts to the local structure when simulating paths across this manifold, providing highly efficient convergence and exploration of the target density. The performance of these Riemann manifold Monte Carlo methods is rigorously assessed by performing inference on logistic regression models, log-Gaussian Cox point processes, stochastic volatility models and Bayesian estimation of dynamic systems described by non-linear differential equations. Substantial improvements in the time-normalized effective sample size are reported when compared with alternative sampling approaches. MATLAB code that is available from http://www.ucl.ac.uk/statistics/research/rmhmc allows replication of all the results reported.

MSC:

62F15	Bayesian inference
62H11	Directional data; spatial statistics
65C60	Computational problems in statistics (MSC2010)
65C05	Monte Carlo methods
62-02	Research exposition (monographs, survey articles) pertaining to statistics

Keywords:

Bayesian inference; geometry in statistics; Hamiltonian Monte Carlo methods; Langevin diffusion; Markov chain Monte Carlo methods; Riemann manifolds

Software:

Matlab

Full Text: DOI