IEICE The Institute of Electronics, Information and Communication Engineers

IEICE Proceeding Series

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Vol. 2 pp. 345-345
Publication Date: 2014/03/18
Online ISSN: 2188-5079

Inference in nonlinear dynamical systems using transport maps

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Abstract—We present a new approach to Bayesian inference that entirely avoids Markov chain simulation or sequential importance resampling, by constructing a map that pushes forward the prior measure to the posterior measure [1]. Existence and uniqueness of a suitable measure-preserving map is established by formulating the problem in the context of optimal transportation [2]. The map is computed efficiently through the solution of a stochastic optimization problem, using a sample-average approximation approach. Advantages of a map-based representation include analytical expressions for posterior moments and the ability to generate arbitrary numbers of independent and uniformly-weighted posterior samples without additional evaluations of the dynamical model.

We then focus on various means of explicitly parameterizing the map in order to take advantage of low-dimensional structure present in many problems of parameter inference and state estimation. Numerical demonstrations include large-scale inverse problems involving partial differential equations and sequential data assimilation (filtering) in nonlinear and chaotic dynamical systems of increasing complexity.

References

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