TRANS-DIMENSIONAL TREES FOR PARSIMONIOUS GEOPHYSICAL INVERSION

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Geophysical inversion consists of choosing a model parameterization and a function that quantifies the fit of data predictions to observations. Within such framework, inferences of the Earth can be obtained from optimal parameter estimates and uncertainties[1]. In classical approaches, model parameterization is fixed at the outset and optimization is performed using a minimization of some combination of norms that attempt to balance the inherent trade off between model complexity and the spatial resolving power of the observations. Uncertainties are then estimated from linearized approximations from the optimization process. The initial choice of some fixed model parameterization has dramatic effects on the resulting inferences and equally on the estimated uncertainty.

In contrast, sampling based approaches using Markov chain Monte Carlo (McMC) techniques offer a way to obtain robust uncertainty estimates through numerically approximating the posterior probability density with large ensembles of solutions that are consistent with data and prior information. While computationally expensive, these approaches require no linearization assumptions. With advances in McMC techniques [2, 3] that allow the model parameterization to change, called reversible jump or trans-dimensional sampling in the literature, model parameterization can remain a variable whose complexity is data driven rather than subjectively fixed from the outset.

We have developed a novel Bayesian trans-dimensional approach which, at its core[4], uses an abstract tree to subdivide any space (e.g. 2D, 3D, spherical, Cartesian, temporal), allowing the model parameterization to vary spatially or temporally to better suit the problem at hand. Compared to previous work[5], our approach is more flexible in terms of the problem geometry and the ease with which various basis functions can be used. In our initial synthetic experiments with the new formalism, we have used simple functions such as box-car, triangle, and Lanczos functions, as well as many families of wavelets.

We present two recent applications of our new approach with wavelet parameterizations to geophysical inversion problems. First, we show the results of the inversion of ambient noise tomography data for the Iceland region. Second, we highlight the generality of the approach with a non-linear tsunami-source inversion to determine the spatio-temporal evolution of the sea surface displacement after the great 2011 Japan tsunami.

Recent experiments into truncated polynomial representations show great promise in the solution of geophysical imaging problems due to their greater utility. We demonstrate these through some early simulated and real data examples. These include large scale seismic tomography inversions using Finite Frequency kernels, and small scale inversions using full-waveform simulations. These may provide a template for Bayesian full waveform and joint inversions which will become more feasible as computational power increases.

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