Bayesian inversion in a trans-dimensional framework for subsurface stratification

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Abstract

Subsurface stratification from Cone Penetration Test (CPT) data to delineate different soil layers and their layer boundaries is an important task in soil investigation exercises in agricultural, geotechnical and geological engineering. The stratification parameters are: the number of soil layers, the layer interface depths and the soil spatial random field parameters. Seeing that the number of layers is unknown apriori and that the other two parameters are dependent on the number of layers, the problem assumes a trans-dimensional characteristic where the dimension of the parameter space can change. Using a Bayesian formulation, a simple proposal density is designed that satisfies the reversibility criteria in the Reversible Jump Markov Chain Monte Carlo (RJMCMC) framework. The proposal density enables jumping between parameter spaces of different dimensions and forms part of the first sampling block in a three-block MCMC algorithm. The other two blocks involve sampling of the spatial random field parameters. RJMCMC algorithms typically display poor acceptance rates necessitating the development of efficient samplers. The particular blocking strategy described allows for the development of a formulation that primarily involves computationally inexpensive tasks such as sampling from truncated normal and Inv-Gamma distributions and evaluation of general normal densities. The algorithm is validated using synthetic and real world CPT data. A standard normality check of the decorrelated residuals is seen as a useful measure to test algorithm performance.