THE UNIVERSITY OF CHICAGO

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DISSERTATION PRESENTATION AND DEFENSE

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Residual Likelihood Analysis for Spatial Mixed Linear Models

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ABSTRACT

In this thesis, we present a new matrix-free residual maximum likelihood (REML) analysis for spatial mixed linear models where spatial observations usually represent average values over non-null regions. The REML analysis is obtained after embedding the sampling locations in a fine scale rectangular lattice, treating unobserved sites as missing data. The spatial random fields considered here are the intrinsic autoregression processes or are based on fractional Laplacian differencing on the lattice. Here, using the h-likelihood method, we derive REML estimating equations that allow for singular precision matrices, estimation of covariate effects, prediction of unobserved spatial effects and REML estimation of precision parameters as a solution to explicit gamma regression models.

Furthermore, we devise a sophisticated computational algorithm that enables us to achieve fast matrix-free statistical computations. In particular, these matrix-free computations include the use of (1) the two-dimensional discrete cosine transformation that arises in the spectral decomposition of the precision matrix of our spatial random fields and that allows fast matrix-free matrix-vector multiplication, (2) a matrix-free preconditioned Lanczos algorithm that solves non-sparse matrix equations with linear constraints, (3) a matrix-free Hutchinson's trace estimator that stochastically approximates the trace of a matrix, and (4) a robust trust region method that always finds a local maximum of the non-concave residual log-likelihood function. Keeping various inferential problems in mind, we exploit these computational algorithms to develop a matrix-free method of conditional simulation and also obtain precise stochastic approximations to the log likelihood functions.

We provide extensive applications on agriculture variety trials, precision agriculture trials on large arrays and mapping ground water arsenic concentration in Bangladesh. These applications bring forward various new aspects of spatial modeling on regular lattice such as numeric consistency of results and robustness of statistical inference to changes of lattice spacing.

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