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Stochastic Local Interaction Models for Processing Spatiotemporal Datasets

Dionissios Hristopulos, Vasiliki Agou, Andreas Pavlides, and Panagiota Gkafa
Technical University of Crete, Mineral Resources Engineering, Chania, Greece (dionisi@mred.tuc.gr)

We present recent advances related to Stochastic Local Interaction (SLI) models. These probabilistic models capture local correlations by means of suitably constructed precision matrices which are inferred from the available data. SLI models share features with Gaussian Markov random fields, and they can be used to complete spatial and spatiotemporal datasets with missing data. SLI models are applicable to data sampled on both regular and irregular space-time grids. The SLI models can also incorporate space-time trend functions. The degree of localization provided by SLI models is determined by means of kernel functions and appropriate bandwidths that adaptively determine local neighborhoods around each point of interest (including points in the sampling set and the map grid). The local neighborhoods lead to sparse precision (inverse covariance) matrices and also to explicit, semi-analytical relations for predictions, which are based on the conditional mean and the conditional variance.

We focus on a simple SLI model whose parameter set involves amplitude and rigidity coefficients as well as a characteristic length scale. The SLI precision matrix is expressed explicitly in terms of the model parameter and the kernel function. The parameter estimation is based on the method of maximum likelihood estimation (MLE). However, covariance matrix inversion is not required, since the precision matrix is known conditionally on the model parameters. In addition, the calculation of the precision matrix determinant can be efficiently performed computationally given the sparsity of the precision matrix. Typical values of the sparsity index obtained by analyzing various environmental datasets are less than 1%.

We discuss the results of SLI predictive performance with both real and simulated data sets. We find that in terms of cross validation measures the performance of the method is similar to ordinary kriging while the computations are faster. Overall, the SLI model takes advantage of sparse precision matrix structure to reduce the computational memory and time required for the processing of large spatiotemporal datasets.

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