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Title:

Multi-Resolution Spatial Random-Effects Models for Automatic Fixed-Rank Kriging

Abstract:

The spatial random-effects model is flexible in modelling spatial covariance functions, and is computationally efficient for spatial prediction via fixed rank kriging. However, the model depends on a class of basis functions, which if not selected properly may result in unstable or undesirable results. Additionally, the maximum likelihood (ML) estimates of the model parameters are commonly computed using an expectation-maximization (EM) algorithm, which further limits its applicability when a large number of basis functions are required. In this research, we propose a class of basis functions extracted from thin-plate splines. The functions are ordered in terms of their degrees of smoothness with higher-order functions corresponding to larger-scale features and lower-order ones corresponding to smaller-scale details, leading to a parsimonious representation of a (nonstationary) spatial covariance function with the number of basis functions playing the role of spatial resolution. The proposed class of basis functions avoids the knot-allocation or scale-selection problem. In addition, we discovered that the ML estimates of random-effects covariance matrix can be expressed in simple closed forms, and hence the resulting fixed-rank kriging can accommodate a large number of basis functions without suffering numerical instability. Finally, we proposed to select the number of basis functions using Akaike's information criterion, which also possesses a simple closed-form expression. The whole procedure, which is automatically adaptive to a spatial resolution, is efficient to compute, easy to program, and applicable to massive amounts of spatial data even when they are observed at sparse and irregularly spaced locations.