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Title:

Fast variational estimation of a Cox process model for spatial point patterns using spatial random effects

Abstract:
Records of the locations where a species was observed constitute a spatial point pattern. The log-Gaussian Cox process (LGCP) is a kind of spatial point process model that combines a linear fixed-effect term with a Gaussian random field to describe the log-density of points at any location. Estimating the parameters of an LGCP by the method of maximum likelihood requires integrating the log-density surface, which is not analytically tractable. Representing the Gaussian random field as a linear combination of spatial random effects makes the LGCP analogous to a generalised linear mixed-effect regression model, and facilitates maximising the log-likelihood via the variational approximation. The resulting coefficient estimates for the fixed effects are consistent and asymptotically normal.

Two example analyses are presented to illustrate the method. In the first, the point locations are where Eucalyptus sparsifolia trees have been observed within 100 km of the Blue Mountains World Heritage Area. I demonstrate how to fit a model that estimates how the density of Eucalyptus sparsifolia is affected by environmental covariates like elevation, the average annual rainfall, and the number of fires since 1950. Apparently, the Gaussian random field is confounded with the covariates, which leads to uncertainty in how to apportion explanatory power between the fixed effects and the random effects. A simple projection of the spatial random effects allows us to avoid this spatial confounding.

In the second example, the points are locations along a river network in the US state of Wyoming where trout were observed. I show how to estimate the parameters of an LGCP along a stream network, by adapting spatial basis functions to the stream network setting.