An informative background for a semi-parametric Hawkes process. Application to french probabilistic seismic hazard analysis

Ibrahim Seydi[†,1,2], Sophie Donnet[§,2], Merlin Keller[§,1], Joseph Muré[§,1], Julien Stoehr[§,2,3]

[†] PhD student (presenting author). [§] PhD supervisor
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[1] Électricité de France, EDF R&D Lab Chatou
first.last@edf.fr

[2] MIA Paris-Saclay, Université Paris-Saclay, AgroParisTech, INRAE
first.last@agroparistech.fr ; first.last@inrae.fr

[3] CEREMADE, Université Paris Dauphine-PSL, CNRS
last@ceremade.dauphine.fr

Abstract

We introduce iB-ETAS, a fully Bayesian spatio-temporal Hawkes process model for earthquake catalog analysis that jointly estimates a nonparametric background seismicity rate and parametric aftershock triggering dynamics. The background intensity is modeled by a Spatially Structured sigmoidal Gaussian Cox process (SSGC), which factorizes the spatial rate into the product of a spatially structured piecewise-constant baseline — encoding prior geological knowledge via a partition with a correlated Gaussian prior on zonal log-intensities — and a sigmoidal zero-mean Gaussian Process (GP) capturing local residual fluctuations. The triggering component follows a standard parametric seismological parametrization.

Posterior inference over all model components is made tractable by a two-stage data augmentation strategy : a latent branching structure decouples background and triggering contributions to the likelihood, while Pólya–Gamma and latent marked Poisson process augmentations yield closed-form Gaussian conditional posteriors for the GP. To scale inference to large seismic catalogs, the GP is approximated using an Hilbert Space Gaussian Process (HSGP) method as developed in [2]. The resulting Gibbs sampler alternates between exact conjugate updates for the HSGP coefficients and branching variables, a Metropolis–Adjusted Langevin Algorithm (MALA) step for the zonal baseline parameters, and Metropolis–Hastings updates for the triggering kernel parameters.

First numerical experiments on synthetic catalogs demonstrate that iB-ETAS achieves superior background intensity recovery over SGCP [1] and kernel density baselines across a range of spatial contrast profiles and latent field configurations, while maintaining well-calibrated posterior uncertainty and satisfactory MCMC convergence diagnostics. Others experiments study robustness under prior misspecifications and sensibility of key hyperparameters.

References

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