Earthquake forecasting

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Session: 1

Even though prediction of individual earthquakes is an elusive unsolved problem, by combining geophysical insight with statistical modelling, it is possible to construct probabilistic forecasts of earthquake activity. When constructed for specific regions, such models may, for example, include information about geological structures, historical information about seismic activity, and a stochastic model for how "mainshocks" can generate an "aftershock sequence". A classic statistical tool for modelling temporal and spatial point data (in this case times, locations, and magnitudes of earthquakes) is the Poisson process model, where points are assumed to be independent, conditionally on an intensity process. For earthquakes with aftershocks, we need to extend this to model dependent points, via a Hawkes process model, that allows the intensity of future earthquakes depend on the occurrence of previous earthquakes.

A fundamental question for all forecasting models is how good they are at forecasting the future, and how much, and what type, of data is needed to reliably estimate the needed model parameters. The aim of this project is to investigate some aspects of this problem, for some models developed at the University of Edinburgh. To investigate this, simulated data may be used, to compare different scenarios where the true models are known. In a purely temporal setting, one can for example generate predefined mainshocks and stochastic aftershock sequences, and compare model estimates and forecasts under different settings. A more challenging, but also potentially more rewarding case is to investigate how fully spatio-temporal forecasts depend on known covariates that influence the spatial pattern of seismic activity. This more advanced sub-problem would require working more closely with the R code for constructing the Hawkes process likelihood.

Software for specifying and estimating the models is available in R, built on top of the INLA and inlabru packages. For forecast assessment, R can be used as well, but there's also a possibility of using the pyCSEP Python package for this purpose.

Useful courses: Generalised Regression Models, Bayesian Data Analysis, R skills needed, and optionally some Python knowledge

References:

[1] Approximation of Bayesian Hawkes process models with inlabru, https://arxiv.org/abs/2206.13360

[2] Bayesian modelling of the temporal evolution of seismicity using the ETAS.inlabru R-package https://arxiv.org/abs/2212.06077