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Sequence-based Parameter Estimation for an Epidemiological Temporal Aftershock Forecasting Model using Markov Chain Monte Carlo Simulation

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Introduction

The first few days elapsed after the occurrence of a strong earthquake and in the presence of an ongoing aftershock sequence are quite critical for emergency decision-making purposes. Epidemic Type Aftershock Sequence (ETAS) models are used frequently for forecasting the spatio-temporal evolution of seismicity in the short-term (Ogata, 1988). The ETAS models are epidemic stochastic point process models in which every earthquake is a potential triggering event for subsequent earthquakes. The ETAS model parameters are usually calibrated a priori and based on a set of events that do not belong to the on-going seismic sequence (Marzocchi and Lombardi 2009). However, adaptive model parameter estimation, based on the events in the on-going sequence, may have several advantages such as, tuning the model to the specific sequence characteristics, and capturing possible variations in time of the model parameters.

Simulation-based methods can be employed in order to provide a *robust* estimate for the spatio-temporal seismicity forecasts in a prescribed forecasting time interval (i.e., a day) within a post-main shock environment. This robust estimate takes into account the uncertainty in the model parameters expressed as the posterior joint probability distribution for the model parameters conditioned on the events that have already occurred (i.e., before the beginning of the forecasting interval) in the on-going seismic sequence. The Markov Chain Monte Carlo simulation scheme is used herein in order to sample directly from the posterior probability distribution for ETAS model parameters. Moreover, the sequence of events that is going to occur during the forecasting interval (and hence affecting the seismicity in an epidemic type model like ETAS) is also generated through a stochastic procedure. The procedure leads to two spatio-temporal outcomes: (1) the probability distribution for the forecasted number of events, and (2) the uncertainty in estimating the probability of exceeding a certain number of events, both with a magnitude greater than a prescribed threshold. The robust ETAS forecasts can be directly implemented in adaptive daily aftershock hazard and risk assessment procedures (see Jalayer *et al*. 2011, Ebrahimian *et al*. 2014).

Numerical example

As the numerical example, the L'Aquila 2009 (central Italy) aftershock sequence is used herein. The methodology described in the previous section is applied in order to perform robust forecasting for the spatio-temporal distribution of number of events within the first few days elapsed after the main-shock.

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