Progress in Signal-Based Bayesian Monitoring
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Introduction

• Global seismic monitoring for the Comprehensive Nuclear-Test-Ban Treaty (CTBT) aims to recover the time, location, depth, and magnitude for all seismic events in the megaton range of interest. Data from the International Monitoring System (IMS) are processed in real time at the International Data Centre (IDC) in Vienna, the goal is to improve the sensitivity and accuracy of automated processing at IDC.

Signal-Enhancement-Based Detection Methods

• The current automated system (DELS) detects 80% of real events and creates twice as many spurious events, which are filtered out by manual checks. The IDC can correct existing ones, throw out spurious events, and generate LID (“signal of interest”). 

• DELS/DECS is a detection system that incorporates threshold-based and time-series-based detections algorithms used in the IDC processing. It misses about 2.2 times fewer events than DELS.

• SIG-VISA, a signal-based system, uses generative models that span the range from events to waveform traces. This approach has several qualitative advantages over DELS/VISA, with the potential for significantly improved sensitivity and localization performance.

Basics of Bayesian Detection

• The model signal encodes a distribution over waveform envelopes at each station given parameters for all hypothesized events.

• Each observed envelope is modeled with a shaped template combined with a stochastic model of signal generation for each waveform phase, and a background noise process at each station.”

Bayesian Signal Modeling

• The signal model encodes a distribution over waveform envelopes at each station for given parameters for all hypothesized events.

• Each observed envelope is modeled with a shaped template combined with a stochastic model of signal generation for each waveform phase, and a background noise process at each station.

• Observed envelopes are modeled via a mixture of Gaussian distributions. An event detection is confirmed if the data posterior density exceeds a threshold.

• Station noise is estimated by an autoregressive process, retrieved hourly at each station to capture regional and temporal variation in background noise properties.

Signal-Enhancement-Based Detection Methods

• Observed signals are modeled independently across a range of narrow frequency bands, automatically learning spectral characteristics and frequency-specific decay rates.

• Amplitude for each phase within each frequency band is predicted using a physics-based source model (Brune, 1970; Mercier, 1981; and a path-specific learned transfer function (next column).

Bayesian Signal Modeling

• We model these effects empirically using a nonparametric spatial Gaussian Process regression (GP) model, which learns for each seismic station a probability distribution over template parameters for events at every point on the Earth.

• We also use a GP-based Bayesian signal modeling system whose detection-based inference is 89% of real events and creates twice as many spurious events.

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