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Design of real-time processing for estimation of earthquake source parameters and generation of Shake Maps in Iceland.

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As a part of the Icelandic Meteorological Office participation in the SAFER project, we are implementing tools for the estimation of earthquake source parameters and the generation of Shake Maps. A necessary component in any process for seismic early warning is processing seismograms in real- or near real-time. Two of the most computationally intensive operations are filtering and detection.

In order to represent the bulk of the spectral energy of earthquakes ranging in size from M 2.5 to M 6.5 spectral information from 0.1 to 50 Hz must be preserved. If it is desired to extend this down to events of magnitude 0.5, frequencies up to 500 Hz must be recorded, which implies a sample-rate of 1000 samples per second. Currently data is only recored at 100 samples per second, but with the methods presented here, 1000 samples per second could be processed.

In order to optimize the signal to noise ratio, energy outside the frequency band generated by any one earthquake must be removed by filtering. In a real-time system, this requires parallel filtering in different frequency bands, so that waves from earthquakes of different magnitudes can be detected and processed.

The computational cost of using a finite impulse response (FIR) filter, is proportional to the sample rate squared. Infinite impulse response, (IIR), recursive filters, on the other hand require much fewer operations, and the number of operations increases only in proportion to the sample rate. When designing recursive filters, care must be taken to insure stability. In the present work, filters are constructed using minimum phase components, which guaranties that the filters are stable; stable inverse filters exist, the filters are causal and the delay caused by the filter is minimized for the desired spectral amplitude of the filter.

Many kinds of real time detectors can be constructed by applying some linear filters to the data, followed by the calculation of some metric that often includes non-linear operations. A detection takes place when the metric reaches a local maximum value, above some threshold. A simple example is a detector for Shake Maps, where data is filtered to yield both ground velocity and ground acceleration, and maximum values are reported, inside a window of some length. A slightly more complex example is a detector where the ratio between long and short term averages of signal amplitude is used as the basis for event detection.

In order to reduce the number of duplicate detections, it is important to use a window of appropriate length. If straightforward algorithms are used, the computational cost becomes proportional to the product of sample rate and window length in samples. By making use of the heap data structure and associated algorithms, the cost can be reduced to something proportional to the sample rate times the logarithm of window length in samples.