Multistage adaptive spectral subtraction of seismic signals

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The detection of microearthquakes is an important task in various seismological applications as volcano seismology, induced seismicity, and mining safety. In this work we have developed a novel technique in order to improve the quality and efficiency of STA/LTA based detection of microearthquakes. This technique consists of different stages of filtering employing an adaptive spectral subtraction method, which allows greatly improving the signal/noise ratio.

The implemented technique consists in a preliminary band-pass filtering of the signal followed by different stages of an adaptive spectral subtraction. The spectral subtraction technique is a non-linear filtering which allows taking into account the actual noise spectrum shape. It allows achieving a good filtering even in cases where the signal and noise spectrum overlaps. In order to take into account of the temporal variation in the background noise spectrum, we designed an adaptive technique. We first divide the incoming signals into short temporal windows. Each window is classified as “noise only” or “meaningful signal” (which can be either a microearthquake or any other relevant transient signal) using different features as the signal energy and the zero-crossing rate. Windows classified as “noise only” are continuously accumulated in a dynamic buffer which allows the average noise spectrum to be estimated and updated in an adaptive manner. This technique can be applied on subsequent stages to further improve the signal/noise ratio. This technique has been implemented in Python for the automatic detection of the microearthquakes on both off-line and near-real time data.

In order to check the efficiency of the results, we compared the results of an STA/LTA based automatic detection on the initial band-pass filtered signal and on the spectral subtracted signals after different stages of filtering. A notable improvement of the quality of the detection process is observed when repeated spectral subtraction stages are applied.

We applied this procedure to seismic data recorded by Red Sísmica Canaria, managed by Instituto Volcánologico de Canarias (INVOLCAN), on Tenerife (Canary Islands), comparing results from the proposed detection algorithm with standard approaches as well as with manual detections. We present an extensive statistical analysis of the results, determining the percentage of correct detections, novel detections, false positives and false negatives after each stage of filtering. First results have shown that this technique is also able to detect automatically microearthquakes...
which went undetected after a manual analysis.