Detecting Small Seismic Events by Applying Image Processing Techniques to Transportable Array Data

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The near-regular station spacing and high-quality seismic data of the EarthScope USArray Transportable Array (TA) provide a unique opportunity for development of novel methods for array processing of recorded seismic data. We are developing methods for automated detection of small seismic events occurring within the footprint of the TA using 2-dimensional filtering techniques borrowed from the field of image processing.

We select a select a time slice duration (initially 15 seconds), and for each station in the array during that time slice we filter over a 1-8Hz passband and integrate under the envelope of the signal. We compare this resulting value (which we term Integrated Ground Motion, or IGM) to a rolling longer-term average to find the equivalent of a short-term/long-term average (STA/LTA) for each station and time slice (Figure 1).

We convert the resulting values for all stations in the array to an image for that time slice by creating an image file with1-km pixel resolution sized to correspond to the geographical area being studied and treating each station as a 70X70 pixel box within that image (Figure 2). This approach introduces sharp edges, which we subsequently smooth using a 2D Gaussian filter (Figure 3). We convert this smoothed image to the frequency domain using a 2D Fourier transform. We apply a spatial bandpass filter to remove features larger than those expected for a small event (e.g., signals from out-of-area teleseisms) and features from high IGM ratios at a single station (due to local cultural noise, etc.). We apply an inverse 2D Fourier transform to the filtered image and set any pixels below a threshold value to zero (Figure 4). Following these image processing steps, we use a simple cluster detection algorithm to find the resulting regions of non-zero values, and store the center point, radius, and date/time for each cluster.

The detected region for a local seismic event starts small and increases in diameter over one or more subsequent time slices before falling below the detection threshold. We are currently working on fine-tuning a post-processing stage to eliminate clusters not following this pattern, which will remove spurious signals and retain only those from small local seismic events. Because the spatial filtering approach minimizes the effects of large-area perturbations such as those from teleseismic events, this method has the potential to detect small-magnitude events even when occurring within the coda of large teleseismic signals. Besides providing a new approach to small event searching within dense arrays such as the TA, this method will be useful for other investigations such as event triggering from remote teleseisms and those requiring statistical analysis of seismic events within an area.

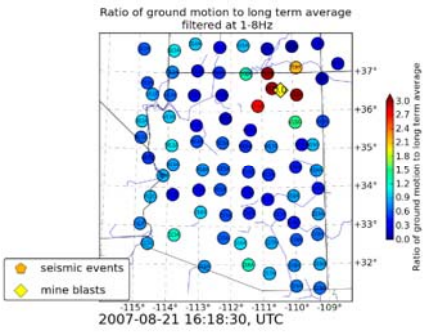

Figure 1: Map of TA stations in Arizona showing Integrated Ground Motion (IGM) ratios and previously detected seismic event for a 15-second time slice in August of 2007.

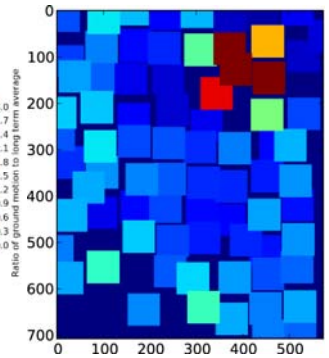

Figure 2: IGM ratios at individual stations as 70km squares on an image with 1km/pixel resolution.

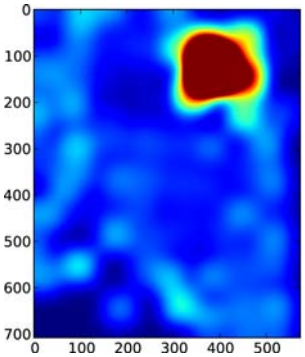

Figure 3: Image from Figure 2 after application of 2D Gaussian smoothing filter.

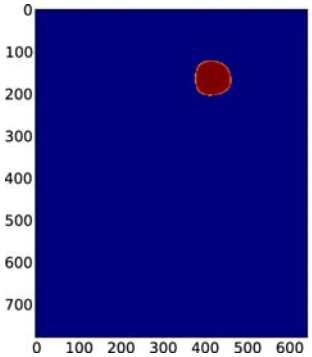

Figure 4: Spatially filtered image from Figure 3 after application of threshold, showing an event detected in NE Arizona.