Similarity-Based Earthquake Detection

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Current Practice in Seismic Monitoring

Detection of signal on individual sensors followed by association of detections across a monitoring network.

Process is automated, but current practice bears the signature of ancient traditions.
Waveform Similarity

39 repeating earthquakes

Template matching

Used to understand that newly discovered kind of seismic signal was due to a swarm of thousands of very small, slow earthquakes.

 Revealed 11x more aftershocks of the M 6 Parkfield earthquake than were found with standard processing – improved understanding of aftershock mechanics.

 Led to discovery of over 500,000 small, weak earthquakes under the San Andreas - all deeper than any previously known SAF events, and more than doubled the known population of earthquakes in N California.
Waveform Similarity

Nearby earthquakes have highly similar waveforms.

Can be used for detection even if we don’t know what we’re looking for by comparing everything with everything else (all times with all other times).

Naïve approach scales poorly (10 years seismic network data requires $\sim 10^{26}$ FLOPs to search).

This problem has been solved in other contexts – web, audio, image search.
Data Rates

Global earthquake monitoring
  0.5 Terabytes/day

Reservoir monitoring
  1-10 Terabytes/day

Emerging inexpensive sensors mean these numbers are set to skyrocket - we’re not prepared to take full advantage of that.
Attributes of “Big Seismology” Project

Local-to-global-scale earthquake monitoring
  High profile – earthquakes get people’s attention
  New imaging based on recording unaliased wavefields.
  New kinds of signals – what’s out there?

Energy options
  Managing oil and gas fields
  Geothermal power production
  Hydrocarbon reservoir stimulation
  Managing induced seismicity
  CO2 Sequestration

Test-ban treaty verification

Should map to many other applications – multi-disciplinary