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# Earthquake Monitoring with Deep Learning

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Earthquake monitoring requires the analysis of continuous seismic waveforms for events that represent seismic waves generated by sudden deformation transients. Diverse algorithms have been developed for efficient and effective earthquake detection, signal processing, phase association, location, and characterization. Now that seismological data centers are routinely storing continuous seismic waveform data from increasingly large seismic networks, we have the opportunity to mine these continuous wavefields to develop more comprehensive earthquake catalogs. Waveform similarity search, based on the premise that adjacent earthquakes generate similar waveforms, has become a widely and effectively used method to detect earthquakes too small to appear routinely in earthquake catalogs. Template matching, the simplest form of informed search, has proven effective in diverse settings. More recently, several methods have been developed to exploit waveform similarity without prior knowledge of waveform signatures. In this talk, we demonstrate that we can use machine learning to generalize similarity search from strict waveform similarity to more permissive forms that capture similar waveform characteristics. We have used convolutional and hybrid convolutional-recurrent networks for the tasks denoising, detection, and arrival time measurement. In each case deep learning improves the performance substantially relative to traditional approaches. In our presentation we demonstrate the performance of deep learning applied to seismic signals for each of these tasks.