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Deep learning to predict time to failure of lab foreshocks and earthquakes from fault zone raw acoustic emissions

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Earthquake forecasting and prediction are going through achievements in short-term early warning systems, hazard assessment of natural and human-induced seismicity, and prediction of laboratory earthquakes.

In laboratory settings, frictional stick-slip events serve as an analog for the complete seismic cycle. These experiments have been pivotal in comprehending the initiation of failure and the dynamics of earthquake rupture. Additionally, lab earthquakes present optimal opportunities for the application of machine learning (ML) techniques, as they can be generated in long sequences and with variable seismic cycles under controlled conditions. Indeed, recent ML studies demonstrate the predictability of labquakes through acoustic emissions (AE). In particular, Time to Failure (TTF) (defined as the time remaining before the next main labquake and retrieved from recorded shear stress) has been predicted for the main lab-event considering simple AE features as the variance.

A step forward in the state of the art is the prediction of Time To Failure (TTF) by using raw AE waveforms. Here we use deep learning (DL) to predict not only the TTF of the mainshock with raw AE time series but also the TTF of all the labquakes, foreshocks or aftershocks, above a certain amplitude. This is a great finding for several reasons, mainly: 1) we can predict TTF by using traces that don't contain EQ (but only noise); 2) we can improve our knowledge of seismic cycle predicting also TTF of foreshocks and aftershocks.

This work is promising and opens new opportunities for the study of natural earthquakes just by analyzing the continuous raw seismogram. In general laboratory data studies underscore the significance of subtle deformation signals and intricate patterns emanating from slipping and/or locked faults before major earthquakes. Insights gained from laboratory experiments, coupled with the exponential growth in seismic data recordings worldwide, are diving into a new era of earthquake comprehension.