LABORATORY EARTHQUAKE ANALYSIS

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Abstract. We apply machine learning to data set, that comes from a classic laboratory earthquake experiment, that has been studied in depth as a tabletop analog of seismogenic faults for decades. Our goal is to find the pattern of seismic signals that precede earthquakes. Here we show that by listening to the acoustic signal emitted by a laboratory fault, machine learning can predict the time remaining before it fails with a good accuracy. These predictions are based solely on the instantaneous physical characteristics of the acoustical signal and do not make use of its history. Los Alamos' initial work [1] showed that the prediction of laboratory earthquakes from continuous seismic data is possible in the case of quasi-periodic laboratory seismic cycles. In this work we use a much more challenging dataset with considerably more aperiodic earthquake failures with more realistic behavior.

1 INTRODUCTION

A traditional way to determine that an earthquake may take place is based on the recurrence interval for characteristic earthquakes, that repeat periodically. But the earthquake recurrence is not constant for a given fault, event occurrence can only be inferred within large error bounds. Over the last 15 years, there has been renewed hope that progress can be made regarding forecasting owing to tremendous advances in instrumentation quality and density. These advances have led to exciting discoveries of previously unidentified slip processes that include slow slip, low frequency earthquakes and Earth tremor, that occur deep in faults. These discoveries form a new understanding of fault slip and may lead to advances in predicting.[1]

In August 2017 Los Alamos National Laboratory (LANL) conducted an experiment [1], that illuminate the mechanics of slow-slip phenomena. They predicted the remaining time until laboratory earthquakes occur with 89% accuracy. In this paper we use acoustic data, that was provided by LANL in January 2019, as part of Kaggle project, which also represent laboratory slow-slips. Data from this experiment exhibits a very aperiodic and more realistic behavior compared to the data they studied earlier, with earthquakes occurring very irregularly.[2] The results of this experiment are potentially applicable to the field of real world earthquakes. Other potential applications include avalanche prediction or failure of machine parts. "If this challenge is solved and the physics are ultimately shown to scale from the laboratory to the field, researchers will have the potential to improve earthquake hazard assessments that could save lives and billions of dollars in infrastructure.[2]" Given seismic signal data with considerably more a-periodic laboratory earthquake failures and modern computing hardware; we find the pattern of acoustic signals to determine when laboratory earthquakes will occur.

2 TUTORIAL MATERIAL

We hear about earthquakes mostly via news media when there is a large seismic event which is noticeable, causes death and destruction. These are stick–slip events that radiate seismic energy along the seams (fault lines) between tectonic plates. In this study we refer to these as Regular Earthquakes. Regular earthquakes are caused by a sudden slip on a fault. Tectonic plates are always slowly moving, but they get stuck at their edges due to friction. When the stress on the edge overcomes the friction, there is an earthquake that releases energy in waves that travel through the earth's crust and cause the shaking that we feel.[5]

Another type of earthquake we refer to in this study is a Slow Slip Earthquake (SSE). SSE's are fault behaviors that occur slowly enough to make them undetectable without instrumentation. They do not shake the ground and cause widespread destruction like regular earthquakes do. They occur near the boundaries of large earthquake rupture zones[3]. There is evidence to suggest that there is a relationship between slow slip earthquakes and more noticeable regular earthquakes[4].

LANL researchers discovered a way to successfully predict SSE in a laboratory experiment that simulates natural conditions. In 2017, this team discovered a way to train a computer to pinpoint and analyze seismic and acoustic signals emitted during the movements along the fault to predict an earthquake. They processed massive amounts of data and identified a particular sound pattern previously thought to be noise that precedes an earthquake. The team was able to characterize the time remaining before a laboratory earthquake at all times.[6]

In the lab, the team imitated a real earthquake using steel blocks interacting with rocky material (fault gouge) to induce slipping that emitted seismic sounds. An accelerometer recorded the acoustic emission emanating from the sheared layers.[6] For the first time, researchers discovered a pattern that accurately predicted when a quake would occur. The team acknowledges that the physical traits of the lab experiment (such as shear stresses and thermal properties) differ from the real world but the application of the analysis to real earthquakes to validate their results is ongoing. This method can also be applied outside of seismology to support materials' failure research in many fields such as aerospace and energy.[6] The team's lab results reveal that the fault does not fail randomly but in a highly predictable manner. The observations also demonstrate that the fault's critical stress state, which indicates when it might slip, can be determined using exclusively an equation of state.[6] So far seismologists and Earth scientists have relied exclusively on catalogues of historical data to try to characterize the state of faults. These catalogues contain a minute fraction of seismic data, and remaining seismic data is discarded during analysis as useless noise. The authors discovered that hidden in this noiselike data there are signals emitted by the fault that inform them of the state of the fault much more precisely than catalogues.[6] "Our work shows that machine learning can be used to extract new meaningful physics from a very well studied system," said Bertrand Rouet-Leduc, Los Alamos Earth and Environmental Sciences Division scientist and the paper's lead author. "It also shows that seismogenic faults are continuously broadcasting a signal that precisely informs us of their physical state and how close they are to rupture, at least in the laboratory."

3 DATA

Must have section that defines data Use tables and figures to illustrate data attributes

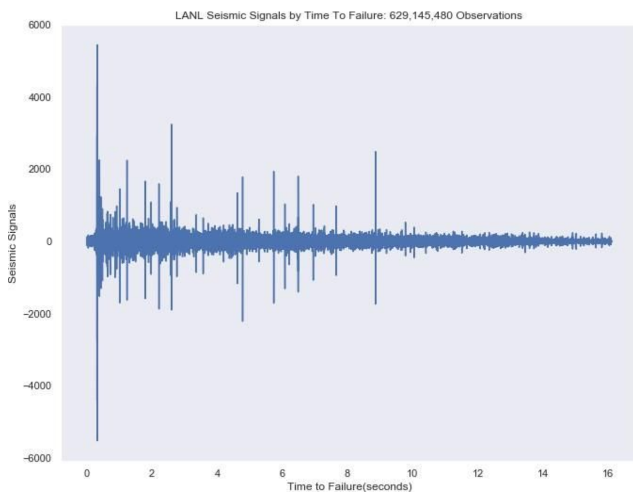

Fig. 1.

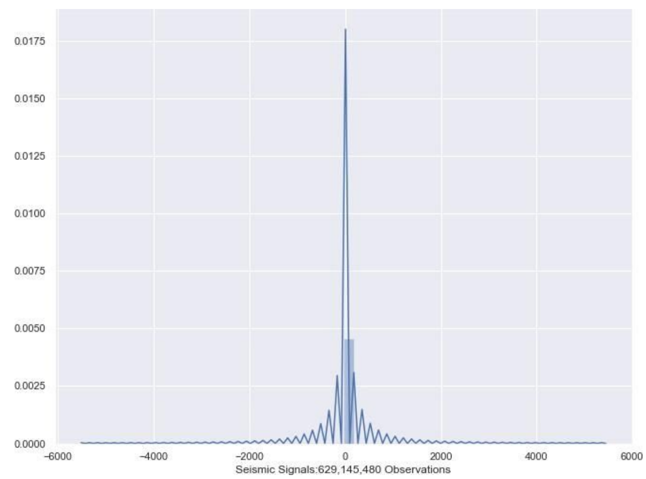

Fig. 2. Distribution of Seismic Signal Measurements by LANL

4 METHODS AND EXPERIMENTS

Define algorithms, methods and eperiments DO NOT give play by play of every- thing we did Dont put code in paper; if anything put in appendix. Put versions of software but no one cares about how to use technology; just state what we did.

5 RESULTS

Results of experiments Use tables and graphs Use tables and graphs Use tables and graphs Don't forget explanations

6 ANALYSIS

Analyze results. These are NOT conclusions.

7 ETHICS

If people believe us and we are wrong; bad things can happen. If people believe us and we are right; good and bad things can happen.

8 CONCLUSION

Draw conclusionS (plural, more than one conclusion- minimum of 3) This is NOT a summary section.

References

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4. Baptiste Rousset, Roland Burgmann, M.C.: Slow slip events in the roots of the san andreas fault