ARMA Future Leader Webinar Series

Every Two Weeks on Fridays 9-10 am MT (11 am – 12 pm ET)

From understanding energy release organization to developing graph neural network encoder for fracture behavior prediction

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https://stonybrook.zoom.us/j/9539339965?omn=96069259795

Abstract

Energy releases from rocks contain valuable information for various disciplines, including seismology, geothermal engineering, hydraulic fracturing, and laboratory rock mechanics. These energy releases exhibit scale-invariant features, meaning observations at different scales can inform each other. Recent studies have discovered complex organizational patterns in seismicity, micro-seismicity, and laboratory acoustic emissions, though identifying the causations of these patterns remains challenging. The rapid advancement of bio-inspired machine learning (ML) techniques, which bypass conventional logical reasoning, has shown promise in predicting behaviors in complex systems, such as those involved in image recognition, natural language processing, and seismic signal analysis.

In this talk, we explore an approach that leverages discoveries and advancements from two perspectives: understanding the organization of energy releases and applying machine learning techniques to predict factors of interest in the aforementioned disciplines.

First, we will demonstrate the extensive existence of energy release organizations from a series of studies. These studies cover topics such as remote triggering, the temporal decay of energy releases, and correlations in the magnitudes and focal mechanism features of these events. The data sets discussed include various types: natural earthquakes, induced seismicity from hydraulic fracturing and wastewater disposal, and laboratory tests. Specifically, we will discuss a rapidly evolving technique for constructing energy release networks based on spatial-temporal features. This technique, whose proposal has just passed its first decade, has apparently facilitated the research regarding stress orientation, geological settings, and volcanic activity.

Building on the understanding that seemingly discrete energy releases can be modeled as structured data, we introduce Graph Neural Networks (GNNs) to harness the advantages of structured data and bio-inspired ML. Such GNN architecture consists of an encoder of sequential graph convolutional layers for outputting the learned embeddings, followed by multilayer perceptron for prediction output. As the "training and learning" is on structured data, this approach reduces the data quantity requirements for deep learning models. We will demonstrate that even with a training set of just 490 graph-label tuples, GNNs can yield promising predictions about rock fracture behavior.

Biography

Qiquan Xiong is a postdoc researcher at Los Alamos National Lab (LANL). Before join LANL, Xiong is a research scientist in the GeoD (Geomechanics and Damage) group at the University of Wisconsin-Madison. Xiong's work addresses issues in induced seismicity, petroleum, and geological engineering. He uses extensive experimental techniques: Acoustic Emission, Digital Image Correlation, and Distributed Fiber Sensing to understanding the rock behaviors, and integrates advanced data science techniques into experimental data analyses. His research has been published in prestigious journals including Nature Communications, Journal of Geophysical Research: Solid Earth (JGR), Rock Mechanics and Rock Engineering (RMRE), etc.

As an ARMA Future Leader, Xiong has served ARMA in many roles, including as reviewer/meta-reviewer and as session chair/co-chair. He is currently serving as the track lead for the interdisciplinary track for ARMA 2025 in Santa Fe, NM, and is also organizing the ARMA Future Leader webinar series. Additionally, he served as the committee chair for selecting the ARMA Early Career Keynote Speaker for ARMA 2023 and as a committee member for selecting ARMA Future Leaders for the class of 2024, where Nicholas Espinoza was selected as the Early Career Keynote Speaker for ARMA 2023, and five new colleagues were selected as ARMA Future Leaders for the class of 2024.