Theory meets application: Machine learning techniques for geothermal exploration

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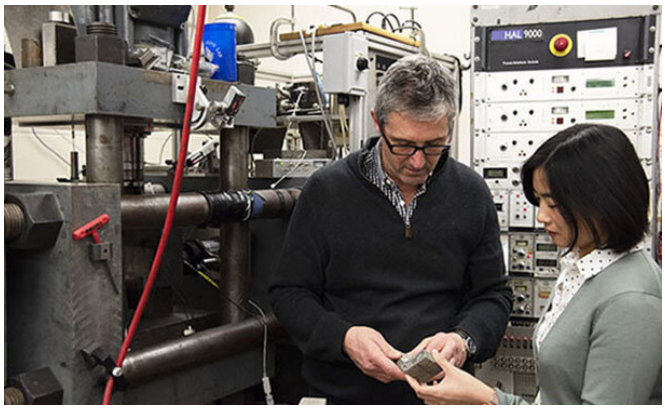

Credit: Penn State

When Jing Yang, assistant professor of electrical engineering, began looking for practical applications to her machine learning research, partnering with Chris Marone, professor of geosciences, for his work on safe and efficient geothermal exploration and energy production, was a perfect fit.

Yang and Marone were recently awarded a 2019 Penn State Multidisciplinary Seed Grant for their collaborative research "Machine learning approaches for safe geothermal exploration."

"I've been working on machine learning for a number of years," said Yang. "My research is more on the theoretical side, and I want to show how theory can be related to practice. Energy-related applications could be the place where machine learning techniques can manifest a great impact."

The work aims to use machine learning both to better predict seismic activity during geothermal exploration and to optimize geothermal energy production.

Geothermal systems require the creation of fractures through hydraulic stimulation. This fracture formation and stimulation is associated with microearthquakes (MEQs) that can damage buildings and other surface structures. Marone and Yang hope that by using Yang's machine learning (ML) algorithms they will be able to forecast and predict seismic events such as MEQs.

"We are very interested in whether certain precursors exist for microearthquakes so that we can predict when a major seismic activity is going to happen in the near future, upon which some immediate actions can be taken before anything destructive happens," said Yang.

A critical component to this research is the ability of ML algorithms to predict this seismic activity on a large scale. The researchers currently have had success with gathering data and forecasting seismic activity in the lab, but they need to ensure that they can make these predictions at field scale.

"If you have thousands of sensors generating measurements in a streaming fashion, analyzing the data streams in real-time is extremely challenging. The problem becomes even more complicated when many microevents happen at the same time," said Yang. "So [the question is] how could we locate or more accurately infer those events happening beneath the surface from streaming data."

The second goal of the project is to safely extract the optimal amount of geothermal energy in the hydraulic fracturing process.

"We want to carefully control the amount of fluid injected into the ground so that we can achieve high production of geothermal energy, and at the same time ensure that it doesn't cause damage to the site, the surface structures and so on," said Yang.

To do this, Yang and Marone will develop a safe

reinforcement learning framework. This will entail creating scalable algorithms to handle unknown environments and that will be able to be transferred from the lab to field use.

Marone and Yang plan to use results from this preliminary effort to develop a larger funded project and to extend this work beyond geothermal energy production into other areas.

"The safe reinforcement learning techniques that I'm developing allow a learning agent to maximize production while ensuring safety. But safety isn't just an issue for geothermal exploration," said Yang. "Safe reinforcement learning can have very important applications in other domains like autonomous driving. For example, we want a car to automatically learn the environment and continuously adapt its motion accordingly. At the same time, we want to ensure that the car does not make reckless decisions in the face of uncertainties in the predicted consequences.

"So safety during learning is definitely a very important issue there," Yang added. "And the techniques developed here can potentially be modified and adapted to ensure safety with autonomous driving and other situations."

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