What's shaking at Yale? A Raspberry Shake has some answers

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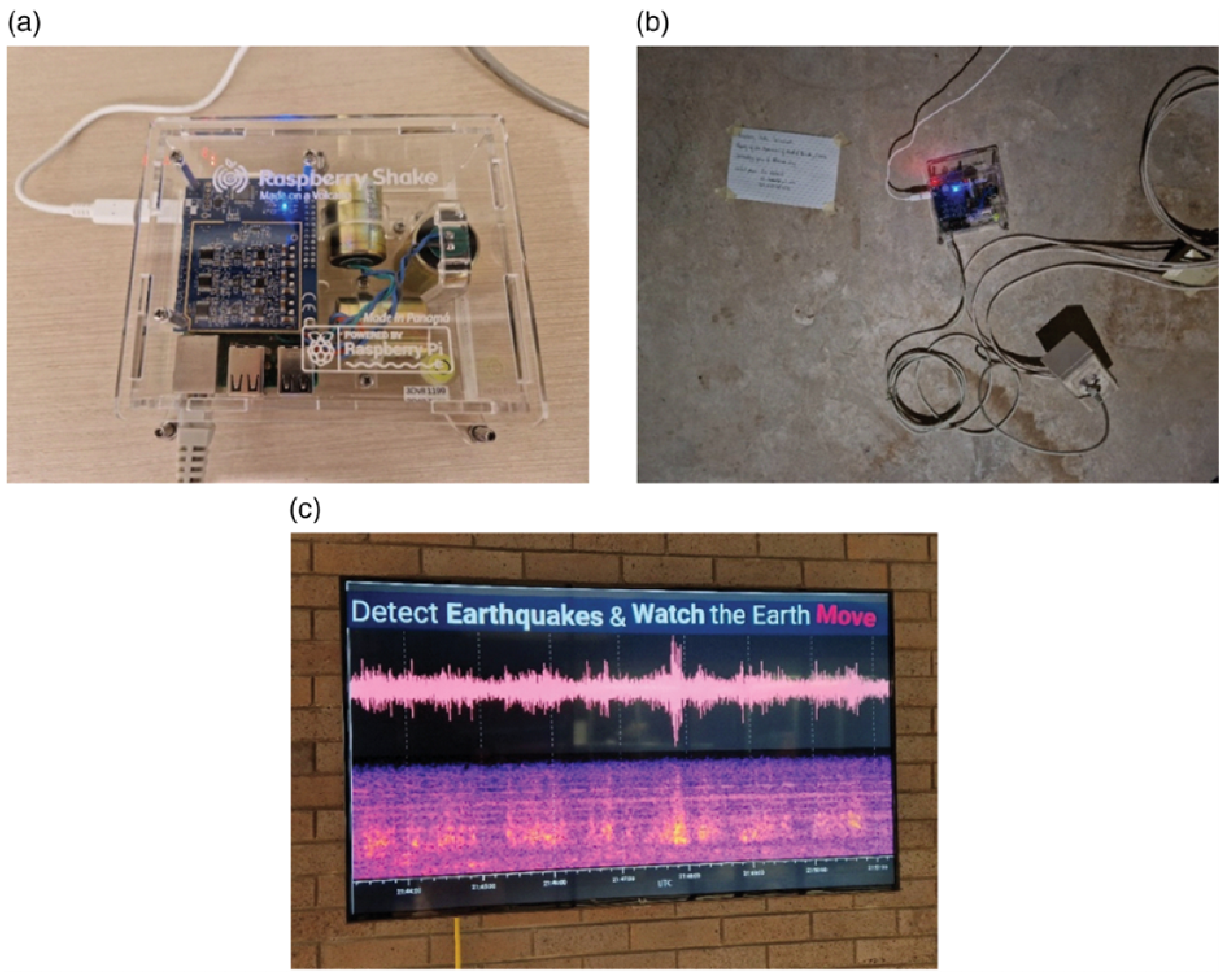
Earthquakes—both fascinating and dangerous—capture the imagination of the general public. Consider the entertainingly inaccurate box-office success, San Andreas, starring many a geologist's favorite actor, The Rock.

Yet, teaching the concepts of seismology in Earth science classrooms can be difficult. Seismic waves propagating through Earth are invisible. Most students haven't been affected by major earthquakes. Many teaching institutions are far from active faults, so even small shakes are uncommon and thus unfamiliar.

Teaching students to work with seismic data could be vividly illustrated by examining signals emanating from their own campus. Such signals contain information about their source, natural or not. For instance, an explosion distinguishes itself from an earthquake via its seismic wave characteristics (with respect to both frequency and time), allowing scientists to tell the difference between the two.

Unfortunately, research-grade seismic sensors are typically deployed in remote regions and can cost over tens of thousands of dollars with installation. On the other hand, Raspberry Shakes—lower-cost and easy-to-install seismometers with tools for easy data viewing—enable educators and students to explore locally measured seismic waves. Because citizen scientists install these instruments in private households, classrooms, and beyond, students can become part of a global network of Shakers, an informal term that hobbyists use to describe themselves.

Yale University has its own three-component Raspberry Shake, located in the Earth and Planetary Sciences department building since 2022. The unit picks up local, regional, and distant earthquakes, as well as seismic noise of all flavors. In a new paper published in Seismological Research Letters, Yale seismologists Eric Löberich and Maureen Long discuss how they plan to incorporate Raspberry Shake data into Yale's undergraduate seismology curriculum based on preexisting ObsPy computer codes by outlining a series of exercises that build upon one another.



Photos of the Yale Raspberry Shake (R3547) installation. (a) The Raspberry Shake 3D sensor is built upon a Raspberry Pi computer that is connected to power and ethernet, with attached geophones in three orientations. (b) R3547 installed on the concrete floor in the basement of Yale's Kline Geology Laboratory. (c) Unfiltered "live stream" from the Raspberry Shake Station View, displayed in the lobby of Kline Geology Laboratory. (Credit: Löberich and Long, 2024)

Installation and data collection

Because Raspberry Shakes are both inexpensive and simple to use, they've been employed in a variety of projects beyond studying earthquakes. They've recorded icequakes and rockfalls, and even documented elephants stomping about and vocalizing with one another.

The three-component Raspberry Shake (so named because they're built using Raspberry Pi minicomputers) contains three orthogonally aligned geophones (a type of seismic sensor) that measure ground vibrations along the north-south, east-west, and Z (or vertical) directions. Proper installation is key to collecting these data.

At Yale, the Raspberry Shake, dubbed R3547, was installed in a room in the basement that has a concrete floor, which ensures good coupling with the ground. When seismometers are installed, they must be leveled and oriented properly. Raspberry Shakes come with a bubble level for the former. Installers must use their own compass for the latter when installing a three-component seismograph. However, because compasses behave poorly in buildings with metal, secondary methods (discussed below) can help check alignment.

R3547's sensors continuously record ground velocity data. The rate at which velocity is recorded (the sampling rate) is 100 samples per second. Those data are saved locally on R3547 for seven days, and are transferred via ethernet to a server maintained by Raspberry Shake. "Everyone can access [the data], even in real-time within an app," Löberich says.

Earthquakes!

Exploring earthquakes is perhaps the most obvious use of R3547. Löberich and Long created four classroom earthquake-related exercises, the first of which focuses on the locations of recorded earthquakes, the geometry of the host faults and the location and type of tectonic plate boundaries. "The first exercise is really for beginners, so they will have a look at the map, which shows them where the earthquakes that we recorded occurred, in which depth range, how strong these events were and which mechanism they had," Löberich says. The term "mechanism" generally refers to how the fault moved.

The second exercise will teach students to use ObsPy routines for data processing. "ObsPy is a well-documented, open-source Python framework that offers predefined functions, which simplify handling seismic data," Löberich explains. These routines, for example, enhance the quality of the data via tools like filtering. This exercise is designed to teach students the characteristics of different seismic wave phases as they arrive—first the P-wave, then the S-wave, and the subsequent surface waves. The students can also learn to estimate the seismic wave velocity of each incoming phase. The exercise uses data collected by R3547 from a strong, distant earthquake that occurred in Mexico.

The third exercise hearkens back to installation orientation. In this exercise, students will learn to correct for sensor misorientation (should it exist) by exploring P-waves, which should be polarized toward the direction of an earthquake's origin. Seismologists rely on correctly oriented sensors. "This skill is very useful and particularly important if the sensor orientation is completely unknown, as it might be the case for ocean-bottom seismometers," Löberich says. The students will determine whether R3547 was installed correctly in spite of above-mentioned compass difficulties (spoiler alert: it was).

The fourth and final earthquake exercise focuses on smaller regional events detected by R3547 that occurred in the states of New York and Maine. Using what they learned from the previous exercises, students should be able to recognize how records of these nearby earthquakes differ from distant ones.

Sensing noise

A seismometer, however, doesn't just record earthquakes. It will detect all ground motions at that location, including those lumped into a category called seismic noise. Some noise sources are natural, like the constant sloshing of the ocean. Other noise comes from humans, like the tromping of students to and from class, construction of a new building, or even public events like concerts and football games. As it turns out, Swiftquakes are a real phenomenon!

The team presented three exercises to explore the seismic noise that R3547 detects on campus. In the first exercise, students will learn to evaluate the quality of records at a given station and explore the limits of the geophones. The exercise asks students to create a visualization of the distribution of seismic energy recorded over a few months and compare it with high- and low-noise models of Earth, Löberich explains. With the visualization, the students can, for example, also explore daily and weekly noise variations.

In the second exercise, students will learn about the secondary microseism caused by waves in the ocean, which can be linked to local or regional weather conditions. Students can compare data from RS3547 with nearby meteorologic, oceanic buoy data to find correlations between the two. With this exercise, "students might get a feeling for Earth as a system," Löberich says. "Analyzing the microseism[s] might be a fascinating entrance point to seismology for students in regions that might not be subject to earthquakes."

The final exercise helps students see how humans create ground motions. In the first year of RS3547's deployment, an adjacent building was being renovated. Not only did RS3547 detect noise increases correlated with construction activities, but it also recorded a minor explosion in a nearby steam tunnel. With this exercise, students will discover how seismologists can differentiate between sources of noise, including explosions, jackhammers, and other heavy machinery. Moreover, students will compare these human-caused seismic signals with the earthquake signals they've analyzed in the previous exercises.

Hands-on teaching tool

With exercises like these, educators can facilitate hands-on experience, particularly for upper-level seismology students. The level of detail will vary depending upon the level of the class. For instance, Löberich explains that in an introductory geology course, they'll likely show the data and discuss earthquake distributions and their relation to fault zones. "On a more advanced level, we might... let [students] try a bit by themselves." The more advanced the class, the more advanced the exercises can become. Accessing and processing data recorded on their own campus will allow students to dive into not just earthquakes, but also broader questions of hazards, plate tectonics, ambient noise, forensic seismology, and more. If you're interested, you can view the data from Yale's station in real time here.