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rsudp: A Python package for real-time seismic monitoring with Raspberry Shake instruments

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Software

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Statement of Need

The uses of low-cost seismographs in science and education are becoming more widely known as these devices become more popular (Anthony et al., 2018; Diaz et al., 2020; Lecocq et al., 2020; Subedi et al., 2020; Walter et al., 2019; Winter et al., 2021). Raspberry Shake seismographs are commonly used in schools, by Shake community members, and other individuals having no formal training in seismology. The existence of this class of instruments highlighted the need for easy-to-use visualization and notification software to complement these devices. Because all Raspberry Shake instruments are able to forward data as user datagram protocol (UDP) packets, taking the opportunity to exploit the existence of this streaming data was obvious.

While the plotting may be the centerpiece of the program, perhaps the most useful aspect of `rsudp` for researchers is its ability to monitor sudden motion and trigger various actions when events are detected. This software's ability to monitor data and trigger alerts with little processing overhead could be critical to monitoring units in the field. Additionally, `rsudp` was designed for extensibility, meaning that it leaves room for users to add their own code to be run when events are detected. The demands of real-time seismic processing require that calculations must be made quickly and remain stable for weeks or months without user intervention. `rsudp` aims to achieve both of these things, maintaining a codebase lean enough to run on Raspberry Pi but intuitive enough that users can learn the theory of real time continuous data processing and contribute code of their own. Programs that do similar tasks are usually not as fully-featured, cost money, are unmaintained, are difficult to fork and customize, or are complex to set up and run. We have tried to keep dependencies to a minimum, the code base understandable, and installation simple across multiple platforms.

Similar JAVA programs, including Swarm (United States Geolgical Survey, 2020), jAmaSeis (http://www.iris.edu/hq/jamaseis/), and SeisGram2K (http://alomax.free.fr/seisgram/SeisGram2K.html) have broader scope but less extensibility, and while they can all be set up to run with the Rasbperry Shake, they can not read Raspberry Shake UDP format. Therefore, accessing near-realtime data will necessarily use more bandwidth and place processing load on the Shake itself. More powerful network processing suites like Earthworm (http://www.earthwormcentral.org/) are difficult to set up and do not easily produce kiosk-ready live visualizations. SeisComP4 (https://www.seiscomp.de), while arguably the industry standard for network processing, requires a license for full functionality, and is typically meant for high-level seismological institutions.

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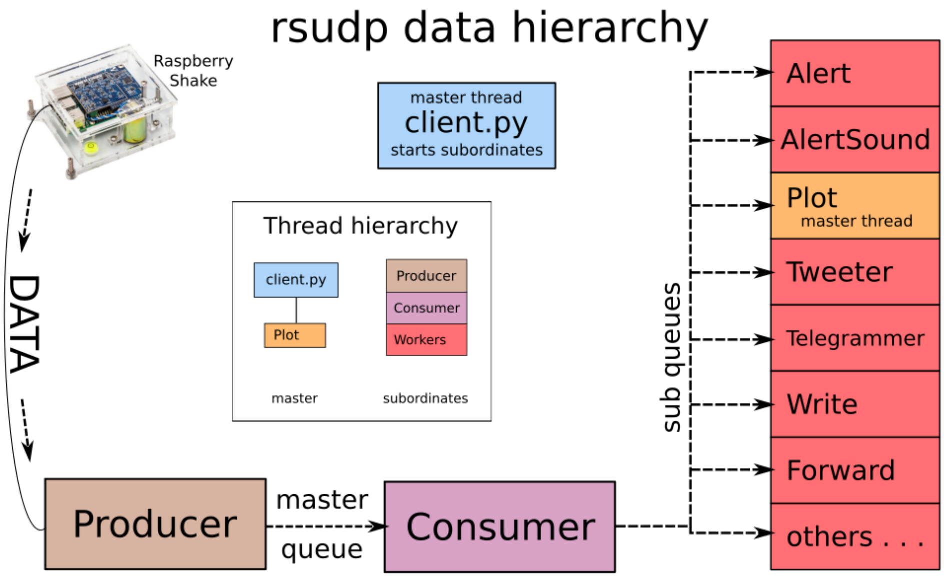

Figure 1: Chart of producer and consumer threads and the organization of data flow in `rsudp`. In order to maximize computational efficiency, features are broken into modules—each module constituting a thread—and data is passed to each module through an asynchronous queue. Inset: thread hierarchy and ownership chart, color-coded by function. Note that the Plot module is owned by the main thread, since `matplotlib` objects can only be created and destroyed by the main thread.

Summary

`rsudp` is a multi-featured, continuous monitoring tool for both Raspberry Shake seismographs, used to record both weak and strong ground motion—and Raspberry Boom pressure transducer instruments, used to record infrasound waves. To encourage hands-on community involvement, `rsudp` is open-source, written in Python, and utilizes easy-to-use tools common to the seismology community, including `matplotlib` visualizations (Hunter, 2007) and the `obspy` seismic framework for Python (Beyreuther et al., 2010; Krischer et al., 2015; Megies et al., 2011). `rsudp` is multi-threaded and architected according to a modular producer-consumer data-flow paradigm (Figure 1). The detection algorithm employs a recursive short-term/long-term average ratio (STA/LTA) computation threshold function from `obspy`, executed repeatedly within a loop over the incoming data.

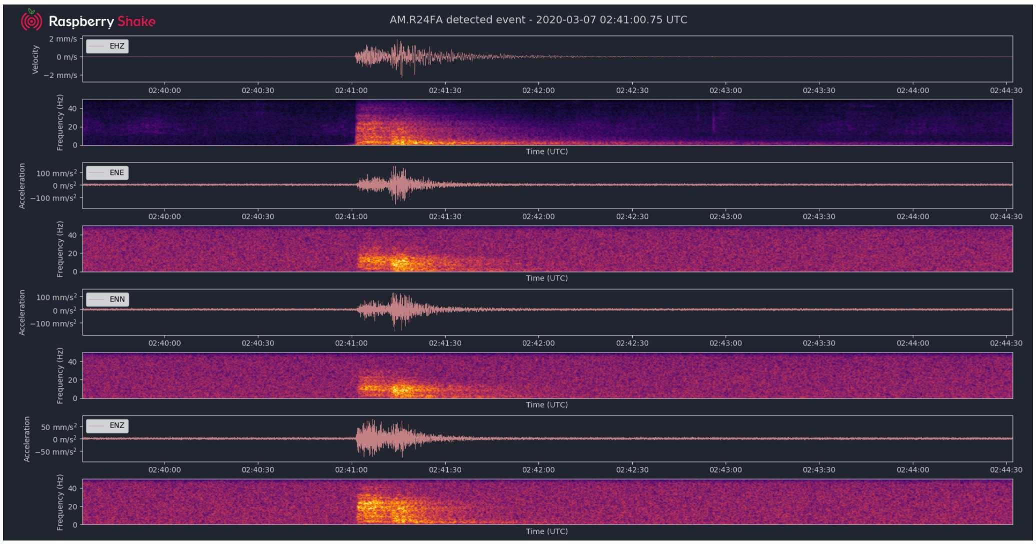

Figure 2: An earthquake trace plotted with a spectrogram on multiple data channels in `rsudp`. The spectrograms are a representation of the fraction of maximum frequency power of the signal on each channel over the duration of the plot. Note that the first channel is data recorded with a geophone (EHZ), and the next three are accelerometers (ENE, ENN, ENZ).

`rsudp` can be used by seismologists as a data analysis tool operating in real time, and as a way for students, citizen scientists, and other end-users to easily visualize and conceptualize live-streaming seismic data (Figure 2). Using the application's simple and straightforward framework, power-users can run their own custom code in the case of detected strong motion. The distribution already contains many useful data-processing modules, including: sound alerts, automated and instantaneous social media notifications, data-forwarding, real-time seismic amplitude (RSAM) forwarding, integrated logging, a miniSEED data archiver, and external script execution (for example, to control input/output pins or some other programmable action). The combination of speed, easy-to-interpret visualization, and ease of customization makes `rsudp` a valuable and instructive companion to the Raspberry Shake family of instruments for researchers, students, and amateur seismologists alike.

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