What On Earth Was That?!  
Sound Perception in Seismic Source Process Analysis

Introduction

Sounds created from seismic data have been used by only a few groups in seismological research and outreach. “Audification” - the process of turning seismic data into sound - has been used mostly in educational settings (Peng, 2012). However, sounds generated from seismic data evolve complex reactions and physical analogues for seismologists and non-seismologists alike, because of our innate abilities to associate sound with physical processes (Holtzman, 2012). This intuition may be of use even to experienced seismologists; the ability to combine spatial-temporal cues with audio and visual cues could prove to be an important analytic tool for modern seismology. The aim of this project is to use our hearing to further our understanding of source processes of earthquakes and other physical phenomena.

We have listened to a variety of natural seismic events to investigate their similarities and differences. Earthquakes and other seismic events occur primarily outside the range of human hearing, so we used a variety of techniques to isolate desired frequency ranges and shift them into audible ranges.

Methods

- Data from landslides near Blingham Canyon Mine in Utah; earthquake on Hayward fault near Berkeley, CA; and a aftershock and repeating earthquakes on San Andreas Fault near Parkfield, CA.
- Fourier analysis to determine frequency content of data.
- Butterworth filtering to isolate desired frequency ranges.
- Time compression/expansion to shift frequency ranges.
- Use MATLAB to create sound files.
- Pick seismometer stations based on seismometer quality and distance.
- Use REAPER audio production software to spatialize the sounds using multiple channels.
- Listen to the sounds from the different sources to generate criteria for comparison and draw conclusions.

Comparisons

Landslide vs. Earthquake

- Comparing a magnitude 4 earthquake (Oct., 2011) near Berkeley, CA, and a magnitude 4 aftershock (September, 2004) near Parkfield, CA, on the San Andreas Fault.
- Station proximity to the source led to some “clipping” of the sounds for the Parkfield aftershock.
- Both earthquakes had a wide range of frequencies represented in their impulse, however Parkfield was weighted to the lower frequencies.
- Berkeley had a more uniform distribution.
- Both earthquakes had different levels of attenuation, and doesn’t “swell” like the landslide.
- Parkfield’s coda was shorter, and the mobilizing frequencies faded out more quickly, letting the lower frequencies dominate sooner.
- Berkeley’s coda was longer in general, and higher frequencies were audible for more time.
- Comparison a magnitude 4 earthquake (Oct., 2011) near Berkeley, CA, on the Hayward Fault, and a landslide at the Blingham Canyon Mine in Utah.
- Frequency content:
  - Landslide has a smaller, lower frequency range.
  - Earthquake has a wider range, but is still concentrated in the same range as the landslide (centered around ~1 Hz).
- Duration, waveform, and coda:
  - Landslide happens over a relatively long time, and doesn’t build and attenuate in the same way as an earthquake, since the source itself overlaps the “coda” in the time.
  - Earthquake is more of an impulse, and has a better-defined attenuation, and doesn’t “swell” for the landslide.
- Rupture:
  - Landslide doesn’t involve a “rupture,” so “source” is more ambiguous.
  - Earthquake source has a relatively defined location and propagation.

Two Faults

- Rupture:
  - The Hayward Fault has a very long rupture, however the San Andreas Fault doesn’t.
- Duration:
  - Both faults have a large range of frequencies represented in their impulse, however Parkfield had a more uniform distribution.
- Frequency content:
  - Both faults have a wide range of frequencies represented in their impulse.
- Waveform, and coda:
  - Both faults had different levels of attenuation, and doesn’t “swell” like the landslide.
- Earthquake has a wider range, but is still concentrated in the same range as the landslide (centered around ~1 Hz).

Repeters

- “Repeating” earthquakes that occurred roughly every 2 years over a 25-year span along the San Andreas Fault in Parkfield, CA.
- Remarkably consistent magnitude, frequency content, duration, and other waveform characteristics.
- Sounds lead to the same conclusion - these earthquakes are virtually identical in a variety of features.
- Perception of motion across the array, but speed and direction of this “motion” were consistent between events.

Further Questions and Future Work

- Landslide vs. Earthquake:
  - Magnitudes of landslides are calculated based on surface waves, but due to the elongated nature of the source function, the magnitude does not compare well with earthquake magnitudes. How can we compare these more consistently?
  - Since the landslide represents a fundamentally different source process from an earthquake, and does not have a rupture, how can we continue to compare these two phenomena, and how should we go about considering the “source” for a landslide?
  - Two Faults:
    - Both the frequency content and the speed of attenuation differed between these two events. How are the differences in the properties of the sounds of these two faults related to their mechanical properties, and do they lead to a generalized way to differentiate the two?
    - What about the medium or source leads to the quicker attenuation of certain frequencies ranges on the San Andreas Fault as compared to the Hayward Fault?
- Repeating:
  - The properties of these repeating events are remarkably similar. How do other sets of repeating events on other faults compare, and how are the properties of these faults similar or different to the San Andreas Fault, and what can this tell us about the properties of these faults?
  - Despite being extremely consistent, these events still gave a perception of motion that could not be explained by the relatively short differences in wave arrival time for different stations. What factors in the source and medium lead specifically to this perception of motion - rupture propagation, different attenuation rates for certain frequency ranges at different locations, or something else?

References


Matthew Vaughan, Case Western Reserve University
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