***GEOL880.3*, 2022/23 Term 2**

Applications of Seismic Methods to Engineering

Project 1

Use Matlab to simulate seismic source location experiments shown in the Figure 1 below. The shape of the study area and source-receiver layouts are intended to simulate those of your planned experiment, and so make any changes if necessary.

The rectangular area in each of the cases in Figure 1 represents a block of unmined rock between two mining rooms (corridors). Because of the disbalance of stress resulting from mining, we expect microearthquakes to occur in some proximity of the edge of the block (pink stars). Set dimensions *d* and *w* to represent the proposed acquisition environment and change the numbers of sources and receivers and their placement if necessary.

The goal of the seismic study consists in locating these microearthquakes. The objectives of this class project are:

1) Simulate the waveforms from each source and recorded on each receiver;
2) Estimate the location uncertainties at 95% confidence.

The above will need to be done for several source locations and two configurations

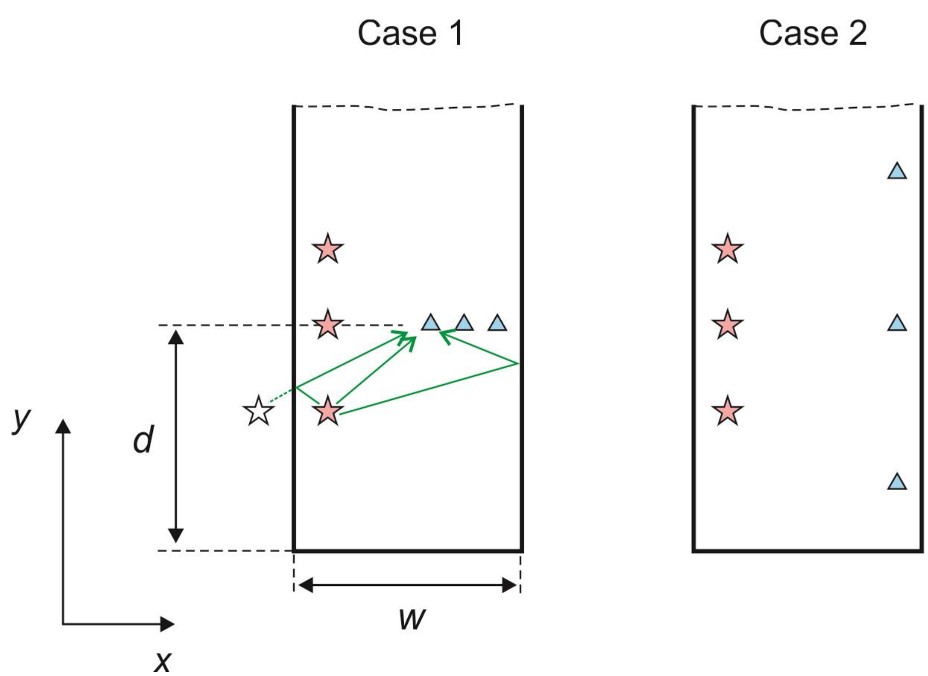

Figure 1. Two layouts of the seismic experiment. Pink stars are the sources, greenish triangles are receivers. White star is a mirror image of one of the sources illustrating how the reflected wave path and travel time can be easily modeled.

of receivers shown in Figure 1.

Methods

Use methods and Matlab subroutines from Lab 2 of GEOL483, Lab 4 of GEOL335, and add new code. Implement the following processing sequence:

In your Matlab program:

1) **Create a Matlab script** precomputing a source waveform in file `waveform.mat` by following Task 3 in Lab 4 from GEOL335 assignments. However, instead of function `wavelet_ft()`, use `wavelet_Brune()`, which should give a zero-phase waveform corresponding to the so-called Brune spectrum.

For ground displacement, this spectrum has the form (normalized to equal one at zero frequency)

$$S_u(f) = \frac{1}{1+(f/f_c)^2}, \tag{1a}$$

and for acceleration (normalized to equal one at infinite frequency),

$$S_a(f) = \frac{(f/f_c)^2}{1+(f/f_c)^2}, \tag{1b}$$

where f_c is called the corner frequency of the earthquake. This shape of spectrum is commonly used for earthquakes.

You will need to **look up the value of corner** frequency appropriate for microcracks in rock salt and use it as parameter of function `wavelet_Brune(fc)`.

Additionally, function `wavelet_Brune()` takes into account the attenuation of seismic waves. This is done by multiplying the wave amplitudes by frequency-dependent factor

$$A(f) = \exp(-\pi f t^*), \tag{2}$$

where the attenuation parameter t^* ("t-star") is determined by the travel time and average inverse Q-factor along the ray path:

$$t^* = \frac{t}{Q}. \qquad (2)$$

2) **Try looking up in the literature** or Internet the Q factor for potash and use it the call to `wavelet_Brune()`. I think it should be near Q = 50 (is this so?).

3) Zoom in the time-domain plot of the waveform and **determine the width of the primary peak** of the waveform between zero crossings.

   Note that the width of the pulse is principally controlled by wave attenuation. To see this, run `wavelet_Brune()` without parameter t^* or using a much higher Q.

   Note that in about middle of `wavelet_Brune.m` script, there is code for plotting the spectrum of the wavelet in figure 777. Enable this test plot by writing "`if true`" in this block and note how the spectrum changes when t^* is changed, and how this is related to the width of the pulse.

   With a realistic Q and source-receiver distance, <u>a half or quarter</u> of this width (time duration) will be the estimates of picking time uncertainty σ used below.

4) **Create a Matlab script** implementing the geometry of Case 1 in Figure 1. The script should produce two matrices containing the source coordinates and receiver coordinates. It should also produce plots similar to those in Figure 1.

   In the script, do not assume any fixed geometry or numbers of source or receivers. Make sure that the code can be easily modified by changing coordinates and adding or deleting sources and receivers.

5) Create a function taking arbitrary source and receiver coordinates (in 2-element arrays) and returning the travel times and estimated amplitudes for the direct wave and reflections from each side of the block of rock salt. The wave paths are illustrated by the green rays in Figure 1.

6) In the modeling script of step 3), use the above function to calculate travel times and amplitudes from all sources to all receivers. **Put the travel times in a matrix** (rows are the ray numbers (source-receiver pairs), columns are the wave modes (direct, reflection from wall #1, 2, or 3). **Create a similar matrix for amplitudes**.

7) Using the calculated matrices, the `wavelet_Brune()` function, and further suggestions from GEOL335 Lab 4, **create a seismic record section** of waveforms recorded <u>from the source farthest away from the receivers</u>. Use a constant Q value for all rays.

8) **Examine the obtained section**. Can all arrivals from the selected

microearthquake be differentiated at all receivers?

9) **Repeat steps 4) to 8) for a source nearest to the receivers**, or for any other sources which may be of interest.

10) **For one of the sources, perform location** error study as in lab project 2 of GEOL483. As travel-time picking variance σ, use the estimate obtained in step 3) above.

    Create plots of location uncertainties at 95% confidence level.

11) **Repeat steps 4) to 8) and 10) for receiver geometry shown in Case 2** (Figure 1).

12) **Investigate one of the cases** which seems more promising in terms of locating the microearthquakes and differentiating between the direct waves and reflections:

    a) Try changing the number of receivers and their spacings. Does the number improve the location ability?

    b) Add broadband random noise to the records modeled in step 6). The noise can be created by function `rand()`, with amplitude being a certain fraction of the maximum signal in the seismogram.

       Evaluate and describe how the noise affects the ability to discern the arrivals from different sides of the block and to read their arrival times.

Reading and Code Examples

GEOL335 materials:

http://seisweb.usask.ca//classes/GEOL335/2023/WWW/index.html

GEOL483 materials:

http://seisweb.usask.ca//classes/GEOL483/2023/WWW/index.html

Report

The student will be expected to prepare a written report with pasted-in illustrations.