Seismic Processing
Prac 1 - Building a Synthetic Record.

ERTH3021

October 6, 2015

This is the first of three pracs on seismic data processing. This prac is dedicated to building a synthetic 2D seismic dataset. The primary motivation for building a synthetic dataset for processing is to ensure we know what the answer is before we start, and thus can assess the effectiveness of our data processing.

The second prac will involve building the tools needed to process a seismic dataset. We will test these tools on the models generated today.

The third prac will use these tools to process a real seismic dataset.

1 Introduction

The core concept used to create this synthetic model is known as the convolutional model. The convolutional model states that a recorded signal is the convolution of a source wavelet with the earth's response, convolved with the recorder response, plus some additional noise, i.e.

$$Y(t) = S(t) * E(t) * R(t) + N(t)$$

where

- Y(t) is our recorded signal
- S(t) is the source wavelet
- E(t) is the earth's response
- R(t) is the recorder response
- N(t) is some noise
- * is the convolutional operator

We are going to break the earth's response $E(t)$ into 3 main components -

- A(t) - the direct wave
- B(t) - the refracted wave
- C(t) - the reflected wave

and we are going to ignore the recorder response for this prac. Thus our synthetic signal can be described as

$$Y(t) = [A(t) + B(t) + C(t)] * S(t) + N(t)$$

Each component described above will be addressed as a separate exercise.

This prac uses python as a teaching tool. The entire prac consists of several hundred lines of code. A significant proportion of this code has been supplied. This supplied code uses some advanced processing techniques, for example classes and decorators. The main reason for this is to reduce the amount of boilerplate code. Understanding this part of the code is not required for this prac.

The assessment of this prac will take the form of a brief report. This report should include a summary of the main components of the prac (suggested with an asterisk), as well as screen shots from each exercise. A brief paragraph and/or bullet points which shows understanding of the major concepts is sufficient.

Exercise 1 - Initial Setup

1. *Load and view earth model
2. Initialise parameter dictionary
3. Initialise data workspace
4. *Define survey geometry
5. Load initialisation values
6. *Write test signal
7. *View result.

Exercise 2: Direct Wave

The direct wave travels along the earth/air interface, and can thus be calculated from the velocity formula

$$v = \frac{s}{t}$$

where

- v = velocity
- s = displacement
- t = time

Spherical divergence is the idea that as a wave spreads out, the energy in the wave spreads out over the surface of the waveform. The amplitude of the wave is inversely proportional to the square of the distance traveled, i.e.

$$A = \frac{1}{distance^2}$$

1. *Create a function which calculates the direct travel time, given a velocity and distance
2. *Create a function which calculates the spherical divergence weighting, given a distance
3. Apply weights to traveltimes
4. Write valid results to workspace
5. Display Result
6. Apply AGC
7. *Display result with AGC

Exercise 3: Refracted Wave

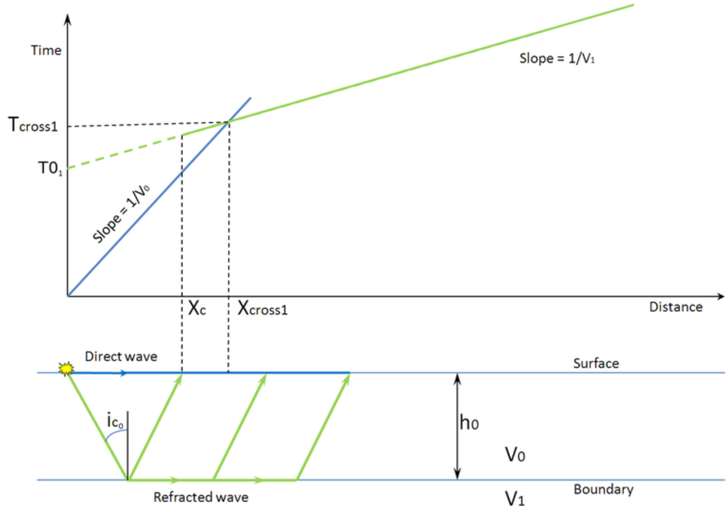

Figure 1: Calculating refraction travel-time, image from wikipedia

The formula to calculate the refracted travel time is

$$T = \frac{X}{V_1} + \frac{2z\cos i_c}{V_0}, \quad i_c = \sin^{-1}\frac{V_0}{V_1}$$

Where

- X = lateral distance
- V_0 = velocity of weathering layer
- V_1 = velocity of sub-weathering layer
- z = thickness of weathering layer
- i_c = critical angle

The exercise consists of the following steps:

1. *Create a function which calculates the refracted travel time
2. Apply spherical divergence to travel times
3. Write valid results to dataset
4. *Display result

Exercise 4: Reflected Wave

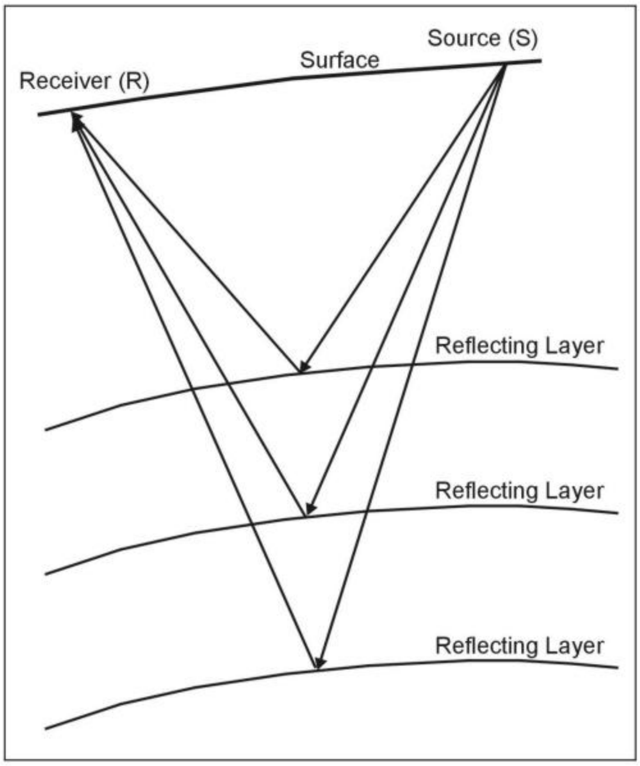

Figure 2: Calculating reflection travel-time, image from the U.S. EPA website

Calculating the reflection times in a homogeneous earth is relatively simple. Calculating the travel time in an inhomogeneous earth is less simple. Functions have been provided which will perform most of the hard lifting for this.

Calculating amplitudes can also be complex. A relatively accurate approximation might involve the Aki-Richards equations seen on the Crewes Zeoppritz Explorer. Instead, for this exercise, we will use the zero-offset reflection and transmission coefficients.

$$R_r = \frac{z_1 - z_0}{z_1 + z_0}$$
$$R_t = \frac{2 * z_0}{z_1 + z_0}$$

where

- z_0 = acoustic contrast in layer 0, i.e. $\rho_0 v_0$
- z_1 = acoustic contrast in layer 1, i.e. $\rho_1 v_1$

This exercise will include the following steps:

1. *Implement functions to calculate reflection and transmission coefficients
2. *Discuss geometry of calculations
3. Calculate reflection traveltimes (using supplied point extrapolation routine)
4. Calculate transmission amplitudes (using supplied point extrapolation routine)
5. Calculate reflection amplitudes
6. Write result to dataset
7. *Display Result

Exercise 5: Build Combined Shot-record

1. *Write function which combines exercises 2, 3 & 4.
2. *Convolve with wavelet
3. *Display result
4. *Add noise
5. *Display result

Exercise 6: Exploring Advanced Modelling Techinques

This exercise examines alternative modelling techniques, including finite difference modelling and bent-ray ray-tracing.