AESM1511

Assignment 2: Fourier Transformation and Filtering

Introduction

In the previous assignment, you got some feeling of the Fourier theory and its application by practicing the principle of superposition. Now you also covered the Fourier theory in the part Advanced Signal Analysis. So, it is time to do some practising with it. You are going to perform two-dimensional Fourier transformation from the time-space domain to the frequency-wavenumber domain.

Tasks and questions

1. As part of the practice, we are now going to learn how to read a binary file that was created originally using Seismic Unix. We are going to look at an elastic subsurface model consisting of three layers. Because the model is elastic, it is characterized by propagation velocities of P-waves, S-waves, and densities. Figure 1 shows the P-wave velocity model. From top to bottom, the velocities are: 1200 m/s, 1800 m/s, 3000 m/s for the P-waves; 500 m/s, 1000 m/s, 1800 m/s for the S-waves. (The densities are not important for our assignment.)

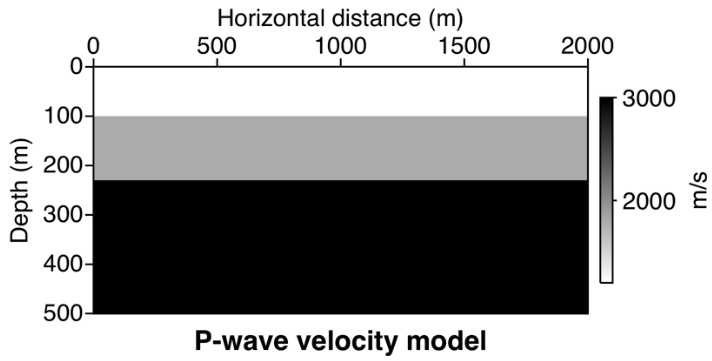

Figure 1: P-wave velocity model of the subsurface.

For this model, using a finite-difference elastic modelling code (Thorbecke and Draganov, 2011) we can obtain a response as in the binary file refl_3layers_fp50_dx0p5_500_rvz.bin. This response was modelled using a source placed at the surface at 500 m and characterized by a Ricker wavelet. The response of the subsurface to the source field was recorded by vertical particle-velocity receivers from 510 m to 1510 m spaced at 2.5 m. The number of traces is 401, the number of time samples is 1001, and the time sampling is 1 ms. Read the binary file. For this, define the file name as a parameter. Then, use something like the command sequence

```
fid=fopen(parameter,'r');
temp=fread(fid,401*1001,'float32',0,'ieee-le');
fclose(fid);
data_refl(:,:)=reshape(temp,1001,401);
```

Visualize the reflection data in a figure using imagesc. The figure should show the colour bar; use grey colour scale, plot the line axes with linewidth of 2, and print the title and the axes labels using fontsize 14. What we see in the figure is what is called a common-source gather, i.e., the response of the subsurface to the signal generated by one source as recorded at all receivers.

2. Now, we are going to transform the common-source gather from the time-space domain to the frequency-space domain. We do this using Fast Fourier Transform (FFT). The command for FFT in Matlab is, not surprisingly, fft(). Transform the data using the command sequence

   fft(data in time-space domain,[],?)*(time sampling).

   Read the help file for fft() and choose which dimension to use to transform the time to frequencies. We will discuss during the face-to-face session why the time sampling should be in the command sequence. Try plotting the transformed data using imagesc directly after the transform. Use the same parameters as in Task 1, but now with normal colour scale (i.e., plot in full colour). What happens when attempting to plot (give a short description of the observation) and why that happens (give a short explanation)?
   After solving this "problem", create a figure using imagesc (using the same parameters as in Task 1, but in full colour) using only the positive frequencies lower than or equal to 200 Hz. (If we visualize the data without the upper limit, we will notice that there is no information above 200 Hz, so this part of the spectrum is not needed.) Actually, discard the negative frequencies and the frequencies above 200. This speeds up calculations.
3. Looking at the frequency-space image, we will notice that the main energy in the frequency domain is concentrated up to a certain offset. Comparing the common-source gather in the time-space and frequency-space domain, to what events in the time-space domain do you think does that energy correspond? Give a short answer.
4. We will now try to filter out that energy. An easy way is to try to filter it in the frequency-space domain. For this, we can apply a so-called low-cut filter, i.e., mute frequencies lower than 60 Hz. Should this be done for all horizontal distances? Give a short answer.
   Filter the data by (1) setting the frequencies lower than 60 Hz to zero, (2) setting the frequencies from 60 Hz to 30 Hz to go linearly to zero, and (3) setting the frequencies from 60 Hz to 30 Hz to go to zero following a sinusoidal curve (quarter of a period). In cases (2) and (3), the frequencies lower than 30 Hz should be set to zero. Transform the data back to the time-space domain using ifft(). Use the command sequence

   2*real((number of frequencies)*ifft(data in frequency-space domain,[],?)*(frequency sampling)).

   Create a figure for each of the three filtering cases using imagesc showing the data (using the same parameters as in Task 1). What can be observed about the events – what events are preserved and what is their preservation quality? Which filter gave the clearest result? Give a short answer to both questions.
5. Now, we will transform the common-source gather from the frequency-space domain to the frequency-wavenumber domain, which means that we will see the

data after a two-dimensional transformation. Transform the data using the command sequence

fftshift(fft(data in frequency-space domain,[],?)*(space sampling),?).

Create a figure using imagesc showing the data (using the same parameters as in Task 2). What can be observed about the energy? Give a short answer.

6. Repeat Task 5, but now by taking every 2nd, 4th, and 8th trace. Visualize the three images and the image from Task 5 in one figure using subplots (using the same parameters as in Task 2). Comparing the four images, explain what happens to the main energy.
7. Make a flowchart of the complete program you have written.

Thorbecke, J.W., and Draganov, D., 2011, Finite-difference modeling experiments for seismic interferometry: Geophysics, Vol. 76 (6), H1-H18.

Submitting your results

Submit your complete solution before **18.00** on October 9, 2022 in Brightspace under Assignments at the top of the course's webpage. Submit the results in the form of a zip file containing an executable .m file (or files in applicable) and a file with the flowchart. The name of the zip file should be

AESM1511_2022_matlab_a2_surname_studentnumber.zip

or

AESM1511_2022_matlab_a2_surname1_surname2_surname3.zip if you are working in a group. Working in groups is encouraged. Nevertheless, working in groups of more than 3-4 people is not effective and discouraged.