Choice of geophone layout in a simple near-surface seismics setting

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1 Introduction

When running a near-surface seismic survey, the resulting recorded wave forms will consist of overlapping arrivals from air waves, direct waves, reflected waves, and refracted waves. Correctly identifying these waves and picking their onsets, in particular of the direct and refracted waves, is crucial for refraction and reflection seismics.

The waveforms recorded by the geophones always contain superimpositions of the different types of seismic waves which can make their identification difficult. The only parameter we can control is the layout of the geophones. See Fig. 1 for a sketch of the geometry.

In many settings we do have a basic idea of the depth of an interface and rough estimations for the seismic velocities of the direct subsurface and the underlying layer. In this activity we use this information to simulate arrival times and recorded waveforms. We then vary the geophone spacing (assuming a fixed number of available geophones and the shot at the center) to obtain an ideal setting to identify the arrival times of specific waves.

2 Required Matlab/Octave functions

All the Matlab/Octave functions needed for this activity can be downloaded from the Seism-O GitHub repository

`https://github.com/NSGeophysics/Seism-O`

You can directly download the entire repository using Git (`https://git-scm.com/`) by running in a command window

```
git clone https://github.com/NSGeophysics/Seism-O.git
```

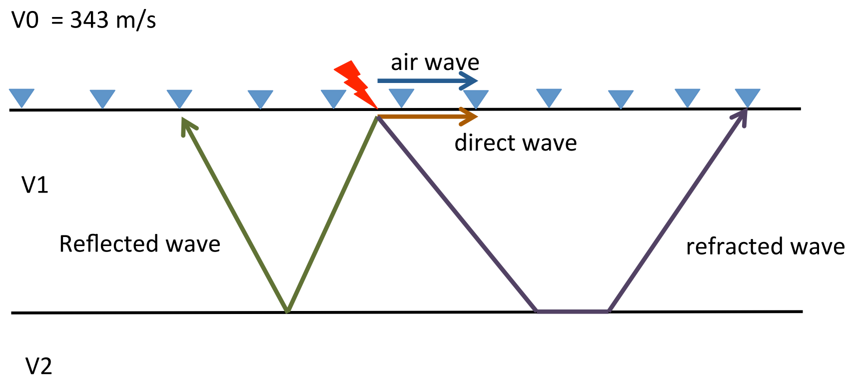

Figure 1: Air wave, direct wave, reflected wave, and refracted wave in a near-surface seismics setting. The flash represents the seismic source, the triangles are the geophones.

3 Simulation of arrival times

Let's assume that in this setting we have a horizontal interface at depth `h` = 2 m with shallow seismic velocity `V1` = 600 m/s and deeper seismic velocity `V2` = 1000 m/s. Let's start with setting the geophone offset (distance between geophones) to `offset` = 1 m.

After you start MATLAB/OCTAVE , switch to the folder in which you installed the Seism-O MATLAB/OCTAVE functions. In MATLAB/OCTAVE, run

```
>> [x1,t1]=showReflectedWave(V1,offset,h);
```

The resulting figure (Fig. 2) shows the arrival times of the reflected wave.

4 Simulation of recorded waveforms

To show how the corresponding recorded waveforms look like, run

```
>> figure
>> shotgather(x1,t1);
```

The resulting figure should look like Fig. 3.

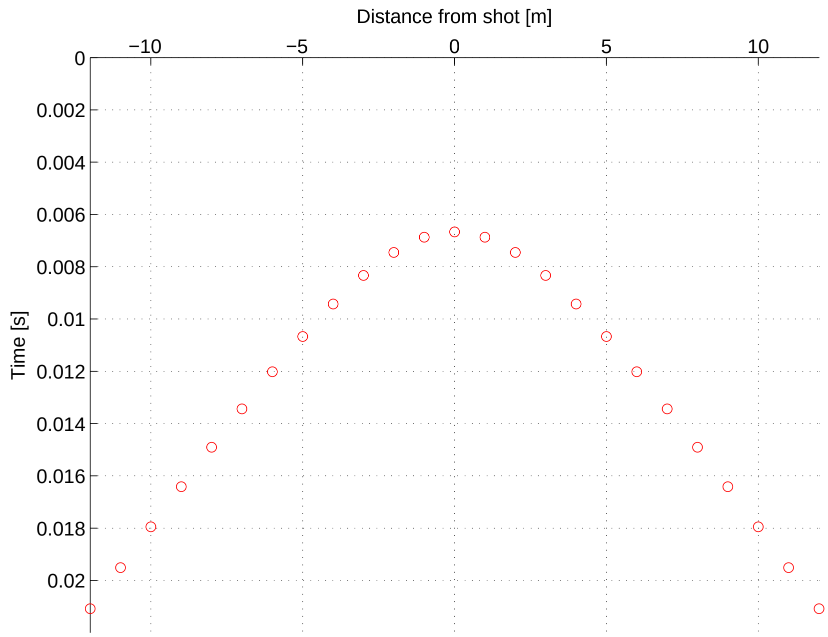

Figure 2: Arrival times of the reflected wave with wave velocity 600 m/s, reflector depth 2 m and geophone spacing 1 m.

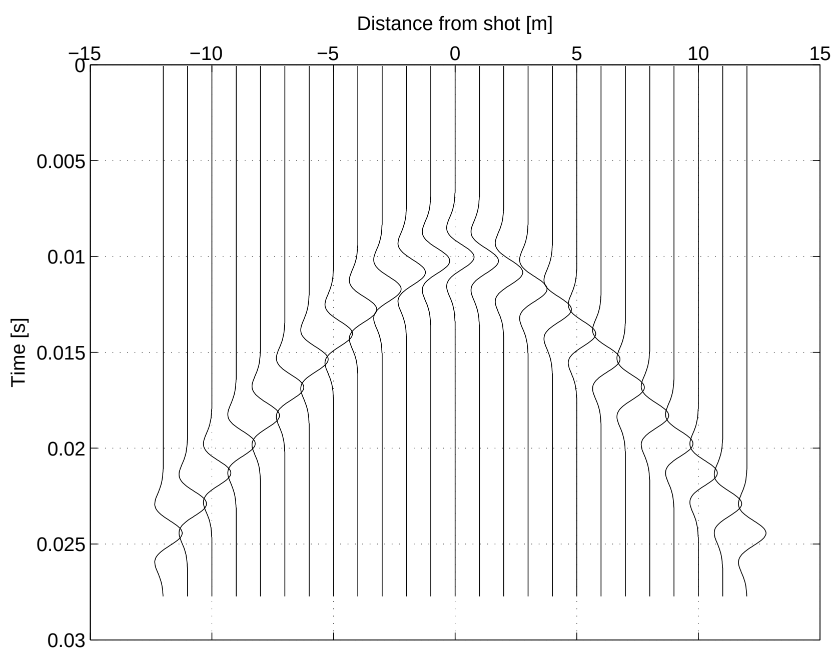

Figure 3: Recorded waveforms (shotgather) of the reflected wave with wave velocity 600 m/s, reflector depth 2 m and geophone spacing 1 m.

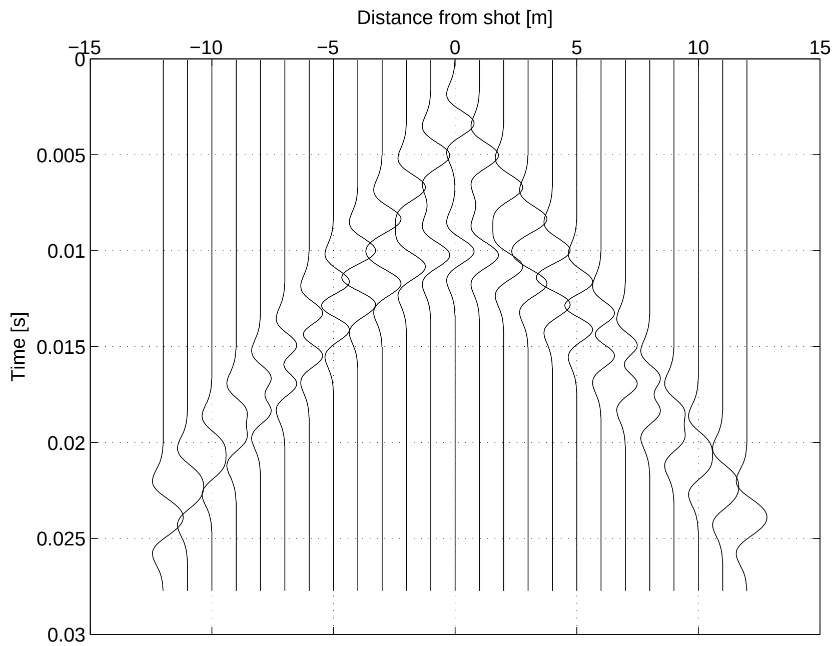

Figure 4: Recorded waveforms (shotgather) of the reflected wave and direct wave superimposed. Wave velocity is 600 m/s, reflector depth is 2 m and geophone spacing is 1 m.

5 Superimposed waveforms

Let's see how a direct wave plotted together with a reflected wave would look like. To see how the picked arrival times overlap, run

```
>> figure(1)
>> [x2,t2]=showDirectWave(V1,offset);
```

For geophones away from the source, the arrival times of the direct and the reflected wave will be close together. The identification gets more difficult when looking at the shot gather:

```
>> seis1=shotgather(x1,t1);
>> seis2=shotgather(x2,t2);
>> seis=addgather(seis1,seis2);
>> figure
>> plotgather(seis)
```

The result should look like Fig. 4.

Finally, the MATLAB/OCTAVE function `showAllWaves.m` superimposes the waveforms of the air wave, the direct wave, the reflected wave, and a refracted wave:

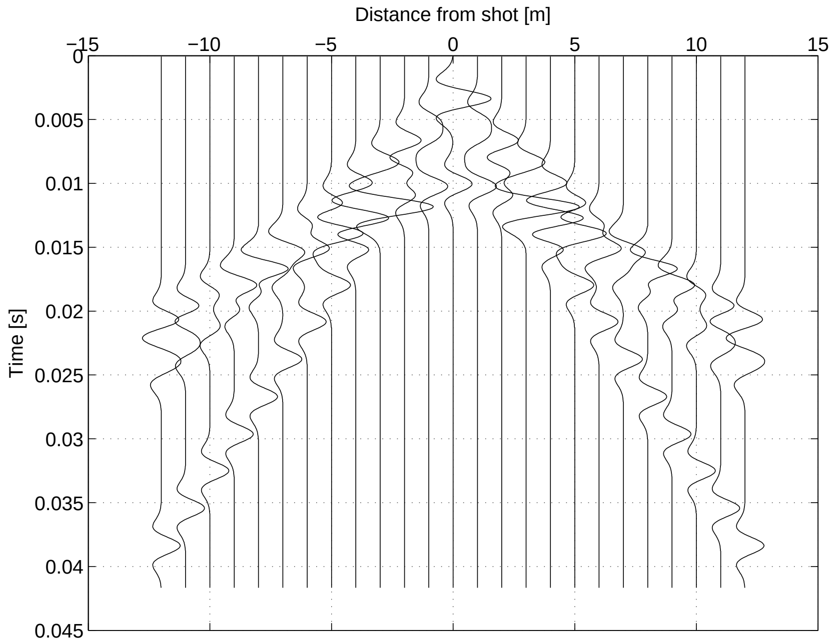

Figure 5: Recorded waveforms (shotgather) of the air wave, direct wave, reflected wave, and refracted wave superimposed. Shallow wave velocity is 600 m/s, deep wave velocity is 1000 m/s, reflector depth is 2 m and geophone spacing is 1 m. It is difficult to tell the refracted, reflected, and direct waves apart. The air wave stands out as the slowest wave and can at distances greater than 7 m be identified.

```
>> seis=showAllWaves(V1,offset,h,V2);
>> figure
>> plotgather(seis);
```

The resulting superimposed waveforms (Fig. 5) are difficult to discern.

6 Choosing the right geophone layout

Remember that the only parameter we can choose in a such a setting is the geophone layout (spacing, if we only have a fixed number of geophones).

Exercise: Play with the geophone spacing and find a value that allows us to easily identify the refracted wave.

Exercise: Choose a different setting, for example `V1` = 600 m/s, `V2` = 2000 m/s, `h` = 10 m. Find a suited geophone spacing value for this situation.

Explore the rest of the Seism-O package. For example, it allows to plot common depth point gathers and attempt a (simplified) normal move-out correction.